11th ASIAN - AUSTRALASIAN
CONFERENCE ON COMPOSITE MATERIALS

Cairns Convention Centre, Cairns, Australia
July 29 - August 1, 2018
From the Chair
Prof Hao Wang
University of Southern Queensland

WELCOME


ACCM-11 has developed as one of the largest composites conference bringing together industry and research in composites from all over the world, and includes new contemporary themes such as Additive Manufacturing and Cement Based Composites.

ACCM-11 will feature a 3-day program of a divergent range of composite research themes and will showcase plenary and keynote presentations by thematic leaders. ACCM-11 will also include diverse social events including a Welcome Dinner, Conference Banquet, and the ACCM-11 Awards Ceremony.

Cairns captivates its visitors as the gateway to The Great Barrier Reef and Wet Tropics Heritage Rainforest and is a popular tourist destination. We look forward to welcoming you at ACCM-11 in Cairns in Jul-Aug 2018.
PROGRAM COMMITTEE

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Prof Yu Chen, Beijing University of Technology
Prof Zhigang Chen, University of Southern Queensland
Prof Laifei Cheng, Northwestern Polytechnic University
Prof Raj Das, RMIT University
Dr Jayantha Epaarachchi, University of Southern Queensland
Prof Tay Tong Earn, National University of Singapore
Dr Jay Epaarachchi, University of Southern Queensland
Prof Junwei Gu, Northwestern Polytechnical University
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Prof Soon Hyung Hong, Korea Advanced Institute of Science and Technology
Prof Gengkai Hu, Beijing Institute of Technology
Dr Ning Hu, Chongqing University
Prof Guoliang Huang, University of Missouri
Dr Everson Kandare, RMIT University
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Prof Lingxue Kong, Deakin University
Prof Alan Lau, Swinburne University of Technology
Prof Jinsong Leng, Harbin Institute of Technology
Prof Yan Li, Tongji University
Prof Hezhou Liu, Shanghai Jiao Tong University
Dr Yuyan Liu, Harbin Institute of Technology
Prof Guoxing Lu, Swinburne University of Technology
Dr Jun Ma, University of South Australia
Dr Allan Manalo, University of Southern Queensland
Prof Ji Yeon Park, Korea Atomic Energy Institute
Prof Huaxin Peng, Zhejiang University
Prof Faxiang Qin, Zhejiang University
Prof Yiping Qiu, Donghua University
Prof Minzhi Rong, Sun Yat-sen University
Prof Peter Schubel, University of Southern Queensland
Prof Xun Shi, Shanghai Institute of Ceramics of the Chinese Academy of Sciences
Dr Inderdeep Singh, Indian Institute of Technology Delhi
Dr Pingan Song, University of Southern Queensland
Prof Russell Varley, Deakin University
Prof Jihui Wang, Wuhan University of Technology
Prof Xin Wang, University of science and technology china
Prof Xungai Wang, Deakin University
Prof Yuesheng Wang, Beijing Jiaotong University
Prof Lixin Wu, Fujian Institute of Research on the Structure of Matter
Prof Cheng Yan, Queensland University of Technology
Prof Chunhui Yang, Western Sydney University
Prof Guang Yang, Huazhong University of Science and Technology
Prof Jun Yang, University of Western Ontario
Prof Qingsheng Yang, Beijing University of Technology
Dr Sha Yin, Beihang University
Prof Tao Yu, University of Wollongong
Prof Zhongzhen Yu, Beijing University of Chemical Engineering
Dr Xuesen Zeng, University of Southern Queensland
Prof Chao Zhang, Northwestern Polytechnic University
Prof Mingqiu Zhang, Sun Yat-sen University
Prof Xuexi Zhang, Harbin Institute of Technology
Dr Zuhua Zhang, University of Southern Queensland
Dr Deju Zhu, Hunan University
Prof Jiahua Zhu, University of Akron
### ACCM-11/PROGRAM OVERVIEW

#### DAY 1
**Monday 30th July**
- **08:00** - Opening Ceremony
- **09:00-10:30** - Plenary Session 1
- **10:45-12:40** - Concurrent Sessions (115 minutes)
- **12:40-15:20** - Afternoon Tea
- **15:35-17:35** - Keynote Session
- **17:35-18:30** - Welcome Dinner

#### DAY 2
**Tuesday 31st July**
- **08:00** - Trade Exhibition
- **08:30-10:45** - Plenary Session 2
- **10:45-12:40** - Concurrent Sessions (115 minutes)
- **12:40-15:20** - Afternoon Tea
- **15:35-16:20** - Young Researcher Presentations
- **16:20-18:30** - Poster Session
- **18:30-21:30** - Conference Banquet

#### DAY 3
**Wednesday 1st August**
- **08:00** - Registration
- **08:30-10:30** - Keynote Session
- **10:45-12:40** - Concurrent Sessions (115 minutes)
- **12:40-15:35** - Lunch
- **15:35-16:50** - Journal Session
- **16:50-17:20** - Closing Ceremony
- **17:20-18:30** - Break
- **18:30-21:30** - Convener/Keynote Speaker Appreciation Dinner

#### Key Activities
- **Registration**: 08:00-10:30
- **Plenary Sessions**: 08:30-10:45, 10:45-12:40
- **Concurrent Sessions**: 10:45-12:40, 13:40-15:20
- **Lunch**: 12:40-15:35
- **Afternoon Tea**: 15:35-16:50
- **Closing Ceremony**: 16:50-17:20
- **Break**: 17:20-18:30
- **Convener/Keynote Speaker Appreciation Dinner**: 18:30-21:30

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**Register Today!**
- **29th July**: 08:00-18:30
- **1st August**: 08:00-17:00

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**Key Dates**
- **Opening Ceremony**: 08:00, Monday 30th July
- **Closing Ceremony**: 16:50, Tuesday 31st July
- **Keynote Session**: 15:35, Wednesday 1st August
- **Conference Banquet**: 18:30, Tuesday 31st July

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**Contact Information**
- For further details, please contact info@accm.org
- Website: www.accm.org

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**Accommodation Options**
- Hotel A
- Hotel B
- Hotel C

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**Sponsors**
- Sponsor 1
- Sponsor 2
- Sponsor 3

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**Agenda**
- Plenary Sessions
- Concurrent Sessions
- Keynote Presentations
- Breaks
- Closing Ceremony

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**Venue**
- Location A
- Location B
- Location C
### ACCM-11/PLENARY TALKS

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<tr>
<td>9:15-10:00</td>
<td>In-Process Monitoring Of Advanced Composites For Material Quality Assurance</td>
<td>Nobuo Takeda</td>
<td>University of Tokyo</td>
<td>Hall B</td>
<td>Yiu-Wing Mai</td>
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<tr>
<td>10:00-10:45</td>
<td>Metal Matrix Composite Reinforcement by Boron Nitride Nanotubes: Insight from Computations</td>
<td>Debra J. Bernhardt</td>
<td>The University of Queensland</td>
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<td>Woo Il Lee</td>
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<td><strong>Tuesday</strong></td>
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<td>8:30-9:15</td>
<td>Understanding and Improving the Notch Sensitivity of Composite Laminates</td>
<td>Michael Wisnom</td>
<td>University of Bristol</td>
<td>Hall B</td>
<td>Koichi Goda</td>
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<tr>
<td>9:15-10:00</td>
<td>Nanostructured fibres as anodes for energy storages</td>
<td>Limin Zhou</td>
<td>Hong Kong Polytechnic University</td>
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<td>Jang-Kyo Kim</td>
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<tr>
<td>10:00-10:45</td>
<td>3D Graphene Based Nanocomposites For Next Generation Energy Applications</td>
<td>Joong Hee Lee</td>
<td>Chonbuk National University</td>
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<td>Yuzhong Wang</td>
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### KEYNOTE TALKS

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<tr>
<td>15:35-16:05</td>
<td>Improving The Delamination Resistance Of Carbon Fiber/Epoxy Laminates With Hierarchical Short Carbon Fiber/Carbon Nanotube Interleaves</td>
<td>Yiu-wing Mai</td>
<td>University of Sydney</td>
<td>Meeting Room 5/8/7</td>
<td>Yuzhong Wang, Jae R Youn</td>
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<td>16:05-16:30</td>
<td>Carbon Fibers In Tribo-Composites: A Review</td>
<td>Klaus Friedrich</td>
<td>University of Detroit Mercy</td>
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<td>16:35-17:05</td>
<td>Rational Design Of Graphene/Polymer Composites With Exceptional Transport Properties</td>
<td>Jang Kyo Kim</td>
<td>Hong Kong University of Science and Technology</td>
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<td>17:05-17:35</td>
<td>High Performances of Plant Fiber Reinforced Composites: Design, Processing and Applications</td>
<td>Yan Li</td>
<td>Tongji University</td>
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<tr>
<td>15:35-16:05</td>
<td>Different Contribution of Fiber Bridging For Mode I and II Delamination in CFRP Laminates</td>
<td>Masaki Hojo</td>
<td>Kyoto University</td>
<td>Meeting Room 2</td>
<td>Zhong Zhang, Tong Eam Tay</td>
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<tr>
<td>16:05-16:35</td>
<td>3D Printing Of Polymer-Based MicroNano Functional Composites</td>
<td>Qi Wang</td>
<td>Sichuan University</td>
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<tr>
<td>16:35-17:05</td>
<td>Active Hybrid Composites For Adaptive Airframe Structures</td>
<td>Ulf Breuer</td>
<td>Technical University of Kaiserslautern</td>
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<td>17:05-17:35</td>
<td>Equivalent Modulus Of Composite Resin For Stress Simulation Of Dental Restoration</td>
<td>Nak-Sam Choi</td>
<td>Hanyang University</td>
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## ACCM-11/KEYNOTE LECTURES

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<tbody>
<tr>
<td>16:35-16:55</td>
<td>Utilising Carbon Nanotube Weave For Multifunctional Composite Aerocrafts</td>
<td>Brian Falcon</td>
<td>Queen’s University Belfast</td>
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<td>Xingai Wang Masahiko Hojo</td>
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<tr>
<td>16:05-16:25</td>
<td>3D Printed Carbon Fibre Composite Materials For Biomedical Applications</td>
<td>Jinlong Leng</td>
<td>Harbin Institute of Technology</td>
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<tr>
<td>16:25-17:05</td>
<td>Metal And Ceramic Matrix Composites For Nuclear And Fusion Applications</td>
<td>Ho Jin Ryu</td>
<td>Korea Advanced Institute of Science and Technology</td>
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<tr>
<td>17:05-17:35</td>
<td>Functionalization of Natural Fibre for Energy Storage Applications</td>
<td>Xiaowen Yuan</td>
<td>Mason University</td>
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### Wednesday 1 August

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<tr>
<td>8:30-9:00</td>
<td>Recent Advancement Of Nanocellulose Based Multifunctional Composites</td>
<td>Jiwon Kim</td>
<td>Inha University</td>
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<td>Qi Wang Michael Wisnom</td>
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<tr>
<td>9:00-9:30</td>
<td>Self-Healing Polymers And Polymer Composites Based On Microcapsules Strategy</td>
<td>Mingliu Zhang</td>
<td>Zhenghan University</td>
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<tr>
<td>9:30-10:00</td>
<td>Nano-scale Engineering Of Fibre Composites for Extrem</td>
<td>Chun Wang</td>
<td>University of New South Wales</td>
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<tr>
<td>10:00-10:30</td>
<td>Filling The Property Gap Of Two-Phase Composites</td>
<td>Huixin Peng</td>
<td>Zhejiang University</td>
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<tr>
<td>8:30-9:00</td>
<td>Mechanical And Interfacial Properties Of Glass Fiber /Poly(Dicyclohexyladipene) Composites At Different Thermal Conditions And Surface Treatments</td>
<td>Juang Min Park</td>
<td>Gyeongsang National University</td>
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<td>Jang-Kyo Kim Minggiu Zhang</td>
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<tr>
<td>9:00-9:30</td>
<td>Durable Superhydrophobic Polymer Nanocomposite Surfaces And Coatings</td>
<td>Zhong Zhang</td>
<td>HUST</td>
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<tr>
<td>9:30-10:00</td>
<td>Thermoelectric Materials</td>
<td>Lijun Chen</td>
<td>SICCAS</td>
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<tr>
<td>10:00-10:30</td>
<td>Rational Design Of Advanced Elastomer Nanocomposites Towards Extremely Energy-Saving Tires Based On Macromolecular Assembly Strategy</td>
<td>Liqun Zhang</td>
<td>Beijing University of Chemical Technology</td>
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<tr>
<td>8:30-9:00</td>
<td>Carbon Nanotubes Composite for Mechanical Energy Storage with High Energy Density and Power Density</td>
<td>Fei Wei</td>
<td>Tsinghua University</td>
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<td>Brian Falcon Yan Li</td>
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<tr>
<td>9:00-9:30</td>
<td>Composite Materials Applications to Industries in China</td>
<td>Jianxin Zhu</td>
<td>Shenzhen Institute</td>
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<tr>
<td>9:30-10:00</td>
<td>A Novel Biochar-Cement Composite For Concrete Structures</td>
<td>Piyang Mendis</td>
<td>University of Melbourne</td>
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<tr>
<td>10:00-10:30</td>
<td>Natural Fibre Reinforced Green Composites</td>
<td>Kochi Goda</td>
<td>Yamaguchi University</td>
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<tr>
<td>8:30-9:00</td>
<td>How to Flame-Retard Carbon Fiber-Reinforced Epoxy Resin Composites Efficiently</td>
<td>Yuzhong Wang</td>
<td>Sichuan University</td>
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<td>Chen G Kim Lin Ya</td>
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<td>9:00-9:30</td>
<td>Novel Strategy to Utilise Low-Cost Keratinous Fibres for High-Performing Flame Retardant</td>
<td>Debesh Bhattacharyya</td>
<td>University of Auckland</td>
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<td>9:30-10:00</td>
<td>A Novel Strategy for Enhancing the Flame Retardancy and Toxicity Suppression of Epoxy Resins</td>
<td>Yuan Hu</td>
<td>University of Science and Technology of China</td>
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<td>10:00-10:30</td>
<td>Not all Fire Retardants are Equal to a Fire Safety Engineer</td>
<td>Jonathan Barnett</td>
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<tr>
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<td>Composites Structure Design-2</td>
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<td>Cement based Composites-1</td>
<td>Composite Machining and Joining-1</td>
<td>Advanced Manufacturing (pultrusion, filament winding, automation)-1</td>
<td>Advanced Manufacturing (pultrusion, filament winding, automation)-2</td>
<td>Cement based Composites-2</td>
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ACCM-11 2018

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Metal Matrix Composite Reinforcement by Boron Nitride Nanotubes: Insight from Computations

Christoph Rohmann\textsuperscript{1,2}, Marlies Hankel\textsuperscript{1} and Debra J. Searles (Bernhardt)\textsuperscript{1,3,*}

\textsuperscript{1}Centre for Theoretical and Computational Molecular Science, Australia Institute for Bioengineering and Nanotechnology, The University of Queensland, Brisbane, Australia
\textsuperscript{2}Maryland Nanocenter, University of Maryland, College Park, Maryland 20783, United States
\textsuperscript{3}School of Chemistry and Molecular Biosciences, The University of Queensland, Australia

*Email: d.bernhardt@uq.edu.au

Abstract

Boron nitride nanotubes (BNNTs) have been proposed as a suitable reinforcement for metal matrix composites resulting in materials high mechanical strength, thermal & chemical stability and neutron radiation shielding properties. This makes them exciting materials for many applications including in aerospace. In this talk results from density functional theory calculations will be presented which examine the strength of interactions of metals with BNNTs to provide insight into their bonding.\textsuperscript{1-3} Calculations to study the effect of oxygen on the interactions will also be presented. Titanium and aluminium are considered due to their relatively low densities, and copper is considered because copper alloys are known to have desirable properties for use as a structural material. Results from calculations on metal atoms, tetra-atomic metal clusters and metal surfaces comprising Al, Ti and Cu will be presented, in addition to different crystal faces of an Al slab. Effects including the chirality of the nanotube, its diameter and the influence of vacancy defects and doping with carbon (producing boron/carbon nitride nanotubes, BCNNTs) will be presented.

Keywords: metal matrix composites, boron nitride, nanotubes, metal reinforcement

Fig 1. Dependence of the binding energy between BNNTs and metal atoms on the BNNT diameter.
Plenary

3D Graphene Based Nanocomposites for Next Generation Energy Applications
Joong Hee Lee*

Advanced Materials Institute of BIN Convergence Technology (BK21 Plus Global) & Dept. of BIN Convergence Technology, Chonbuk National University, Jeonju, Republic of Korea

*Email: jhl@chonbuk.ac.kr

Abstract

Great advance in the field of portable electronics, hybrid electric vehicles, portable power supplies and satellites have led to urgent and increasing demands in the field of high energy storage/conversion devices. In recent years, numerous research efforts have been made for the development of more efficient energy storage and conversion devices such as supercapacitors, batteries, and solar cells. Especially, supercapacitors and solar cells have great potential to meet the demands of both high energy density, power density and energy conversion efficiency in many advanced technologies. For the last half decade, graphene has attracted increasing attention due to its unique electrical, optical, optoelectronic, and mechanical properties, which have opened up huge numbers of opportunities for supercapacitor and solar cell applications. Comparing to two dimensional graphene, three-dimensional (3D) graphene hybrid nanostructure has gained wide acceptance in the research community because of its high specific surface area, excellent electrochemical properties, and unique structural morphology. This talk is mainly focused on the recent research developments in 3D graphene based supercapacitors and solar cells, including hetero atom doped 3D graphene, 3D graphene/carbon nanotubes architecture, 3D graphene/metal oxide composites, and 3D graphene/polymer composites. The challenges and prospects of 3D graphene based supercapacitors and solar cells are also discussed here.

Keywords: 3D graphene, Nanoarchitecture, Energy storage, Energy conversion
Understanding and Improving the Notch Sensitivity of Composite Laminates

Michael Wisnom*

Bristol Composites Institute (ACCIS), Advanced Composites Collaboration for Innovation and Science, University of Bristol

*Email: M.Wisnom@bristol.ac.uk

Abstract

Composite laminates with notches generally show a linear-elastic response, and the stress concentrations give rise to large reductions in static strength. The complex damage mechanisms at the notch, and especially longitudinal splitting, provide some load redistribution, giving rise to the well known hole size effect, whereby the notch sensitivity reduces for small holes.

In this presentation the mechanisms of damage are considered, and the way that these contribute to the notch sensitivity is discussed. It is shown that the notched strength is very dependent on the ply thickness, and can be improved by optimising this.

Pseudo-ductile thin-ply composites are a new development whereby ply fragmentation gives rise to a non-linear stress-strain response similar to that of a metal. It is shown how this provides an alternative way to redistribute stresses at notches, leading to reduced notch sensitivity.

Michael Wisnom is Professor of Aerospace Structures at the University of Bristol and Director of Bristol Composites Institute (ACCIS). He is a leading authority on the mechanics and failure of fibre reinforced composites, with over 400 refereed journal and conference publications. He is a fellow of the Royal Academy of Engineering, Editor in Chief of Composites Part A, and a past president of the International Committee on Composite Materials.
In-Process Monitoring of Advanced Composites for Material Quality Assurance

Nobuo Takeda*

*Email: takeda@smart.k.u-tokyo.ac.jp
Improving the Delamination Resistance of Carbon Fiber/Epoxy Laminates with Hierarchical Short Carbon Fiber/Carbon Nanotube Interleaves

HLZ Zhou¹,², XS Du², HY Liu², HM Zhou¹, Y Zhang¹, and Y-W Mai², *

¹State Key Laboratory of Materials Processing and Die & Mould Technology, Huazhong University of Science and Technology, Wuhan 430074, China.
²Centre for Advanced Materials Technology (CAMT), School of Aerospace, Mechanical and Mechatronic Engineering J07, The University of Sydney, Sydney, NSW 2006, Australia

*Email: yiu-wing.mai@sydney.edu.au

Abstract
Hierarchical short carbon fibers (SCFs) synthesized with carbon nanotubes (CNTs) were used as CNT-SCF interleaves to increase the delamination fracture energy GIC of carbon fiber/epoxy (CF/EP) composite laminates. Even at a relatively low CNT-SCF areal density, 1.0 mg/cm², GIC was increased to 1.17 kJ/m² from 0.52 kJ/m² of the non-interleaved control laminates. This is a significant 125% improvement in delamination resistance compared to those results obtained by other interleaving methods for CF/EP laminates. In addition, the toughening effects of SCFs in bulk epoxy and interleaved CF/EP laminates were investigated to underpin the influence of the hierarchical CNT-SCF structure. SEM examination showed synergistic toughening mechanisms in these CNT-SCF interleaved CF/EP laminates. Further details are given in our published work (H Zhou et al., Composites Science and Technology, 140 (2017) 46-53).
Carbon Fibers in Tribo-Composites: A Review

Klaus Friedrich\textsuperscript{1,*}, Li Chang\textsuperscript{2}

\textsuperscript{1}Institute for Composite Materials (IVW GmbH), Technical University Kaiserslautern, Germany
\textsuperscript{2}Centre for Advanced Materials Technology, School of Aerospace, Mechanical and Mechatronic Engineering, The University of Sydney, Sydney, NSW 2006, Australia

*Email: klaus.friedrich@ivw.uni-kl.de

Abstract

This contribution outlines a few of the topics of interest in the field of tribology of carbon fiber reinforced polymer composites, especially for achieving low friction and low wear performance against metal counterparts under different environmental conditions. The overview presents a survey of the findings of present and past workers. Particular emphasis is focused on recent advances in developing a new class of engineering materials with a higher degree of multifunctionality by the simultaneous combination of carbon fibers and other fillers such as ceramic nanoparticles or carbon nanotubes. An attempt is made for the design of a desirable wear resistant composite material for specified wear conditions by the use of artificial neural networks. Finally, a few remarks about high friction composites as well as metal-, glass-, and ceramic-matrix composites are made.

Keywords: Carbon Fiber, Epoxy, Polyetheretherketone, Tribology, Friction, Wear, Multifunctionality

![Diagram](image.png)

**Fig. 1** External loadings and resulting changes of a carbon fiber reinforced polymeric structural component. Emphasize was given here to sliding contact under velocity $v$ and nominal pressure $p$ against a metallic counterpart.
Rational Design of Graphene/Polymer Composites with Exceptional Transport Properties

Jang-Kyo Kim*

Department of Mechanical and Aerospace Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong.

*Email: mejkkim@ust.hk

Abstract

This talk presents the preparation of 2D and 3D graphene architectures and the application of their polymer composites for thermal and electrical conduction. 2D graphene oxide (GO) sheets are synthesized by chemical exfoliation of graphite. Two different types of interconnected 3D graphene are prepared, namely graphene foam (GF) is grown on a Ni foam template via chemical vapor deposition while graphene aerogel (GA) is prepared by rational assembly of GO sheets into graphene hydrogel followed by freeze-drying. The 3D interconnected graphene structure is aimed to eliminate the issue of uniform GO dispersion for composite fabrication. Notable multi-functional properties of the composites with different graphene architecture are discussed.

The self-aligned GO/epoxy nanocomposites show a very low percolation threshold of 0.12 vol% due to the uniformly dispersed, monolayer GO sheets with high aspect ratios over 30,000 [1]. The layered structure induces a unique anisotropy in electrical and mechanical properties due to the preferential formation of conductive/reinforcing networks along the alignment direction. The poly (vinylidene fluoride) (PVDF) composites reinforced with chlorinated GO (Cl-rGO) delivers an exceptional dielectric properties [2]. A remarkable dielectric constant of 364 was achieved with a moderate dielectric loss of 0.077 at 1 kHz, which are well compared with the corresponding properties of the neat PVDF polymer with a constant of 28 and a loss of 0.0029. The addition of thionyl chloride into GO dispersion induces synergistic modifications of the structure, chemistry, charge carrier density and electrical conductivity of GO.

Keywords: Graphene, Nanocomposites, Electrical conductivity, Thermal conductivity

![Fig. 1](image)

Fig. 1 (a) Schematic of preparing GF/PEDOT:PSS composites; (b,c) before and (d) after PEDOT:PSS coating on graphene foam surface.
High Performances of Plant Fiber Reinforced Composites: Design, Processing and Applications

Yan Li*

School of Aerospace Engineering and Applied Mechanics, Tongji University, Shanghai, China

*Email: liyan@tongji.edu.cn

Abstract

Plant fiber reinforced composites (PFRCs) have raised great attentions among materials scientists and engineers in the recent decades due to their light weight, environmental friendly, interesting mechanical and physical properties, et. al. Realizing high performances of PFRCs are the necessity for expanding their application potentials.

On the basis of the shear-lag model, a double interface model by considering the unique multi-scaled structures was proposed and successfully calculated the interfacial behaviors of PFRCs so that the multi-scaled interfaces could be designed. Improving the mechanical properties of PFRCs were attempted by hybridizing with glass and carbon fibers and by incorporating nanocellulose. Multi-scaled failure modes were obtained and the mechanical properties were remarkably improved.

The acoustic, heat and dielectric properties of PFRCs were also investigated theoretically and experimentally based on the above multi-scaled methodology [2-3]. It was found that both plant fibers and their composites had superior capability for noise reduction, heat isolation and electromagnetic transparency. The mechanisms were proposed and the multi-scaled and hollow lumen structures provided major contributions.

Demonstration parts were manufactured and applied in the national key projects. It can be concluded that the development of structure-function integrated PFRCs appears to be more important and feasible than that of mechanically “high-performance” biocomposites.
Different Contribution of Fiber Bridging For Mode I and II Delamination in CFRP Laminates

Masaki Hojo*, Takuma Inoue, Aya Mamishin, Yu Adachi, Narumichi Sato, Masaaki Nishikawa, Naoki Matsuda

Department of Mechanical Engineering and Science, Kyoto University

*Email: hojo_cm@me.kyoto-u.ac.jp

Abstract

Evaluation of interlaminar properties under static and fatigue loading is essential to ensure reliability in structural applications such as primary structures of aircraft. For CFRP laminates with toughened matrices, it is common that the mode I fracture toughness value increases with the crack extension due to fiber bridging. Under fatigue loading, the crack propagation rate decreases with the crack extension by keeping the energy release rate constant. On the other hand, rather constant fracture toughness values are often obtained under mode II fracture toughness tests except for the early stage of the tests. The fatigue crack propagation rates are not influenced by the crack extension. The difference in the fracture mechanisms between mode I and II static fracture was investigated from the view points of microscopic fracture mechanisms using high resolution X-ray computed tomography at the damaged zone near the crack tip. It is clear that the contribution of bridging fiber under mode I is much more than that under mode II. At the early stage the fracture toughness tests under mode II, quick increase of the toughness is observed for toughened laminates when the crack length is determined by the change in compliance. The cause of this early stage behavior will also be discussed.
3D Printing of Polymer-based Micro/Nano Functional Composites

Qi Wang¹,² *, Ning Chen¹,², Hesheng Xia¹,², Jie Zhang¹,³, and Canhui Lu¹,²

¹ State Key Laboratory of Polymer Materials Engineering (Sichuan University), Chengdu, China
² Polymer Research Institute of Sichuan University, Chengdu 610065, China
³ College of Polymer Science and Engineering of Sichuan University, Chengdu 610065, China

*Email: qiwang@scu.edu.cn

Abstract

3D printing of polymer materials is a non-traditional advanced manufacturing technology which developed rapidly in recent years. This paper pioneered to study the 3D printing of polymer-based functional composites. Polymer-based micro/nano functional composites suitable for selective laser sintering (SLS) and fused deposition modeling (FDM) processing were successfully prepared using organic/inorganic hybridization, solid state shear milling, ultrasonic irradiation, intermolecular complexation and other techniques, e.g. PA11/BaTiO3 piezoelectric powders, PU/CNTs conductive powders, PVA/PLA/HA biomedical filaments, PP/PE/CNTs thermal conductivity filaments, etc. The novel technique for large-scale production of spherical polymer-based composite powders was established and the SLS processing of polymer-based functional composite powders, such as PA11/BaTiO3, PU/CNTs was successfully realized. The rheological properties, crystallization properties, thermal properties, laser absorption of polymer-based functional powders and the evolution of multilayer structure of 3D printing parts were systematically studied. The new conical screw extruded 3D printer was invented. FDM processing of polymer-based functional filaments, such as PVA/PLA/HA, PP/PE/CNTs were realized, the effects of processability of filaments and the FDM processing parameter on structure and properties of 3D printing parts were studied. Finally, the functional parts with complex geometric structure which cannot be manufactured by conventional methods were fabricated by optimizing 3D printing process, such as PA11/BaTiO3 piezoelectric device, flexible PU/CNTs sensor, PVA based cartilage engineering scaffold and cooling fans with good thermal conductivity, which makes a breakthrough in manufacturing complicated shape products that can’t be processed by traditional processing method and the functional products that can’t be processed by current 3D printing.

Keywords: Polymer-based micro/nano functional composites, 3D printing, Selective laser sintering, Fused deposition modeling, Functional devices with complicated geometric shapes
Active Hybrid Composites for Adaptive Vortex Generators
Ulf Breuer*, Sebastian Nissle, Moritz Hübler, Max Kaiser, and Martin Gurka

Institut für Verbundwerkstoffe GmbH, Technical University of Kaiserslautern, Erwin-Schroedinger-Strasse 58, D 67663 Kaiserslautern, Germany
*Email: ulf.breuer@ivw.uni-kl.de

Abstract
A new system of adaptive vortex generators (VGs) based on active hybrid composites is presented, enabling an on-demand optimization of the airflow for high angles of attack. The generated vortices enhance the boundary layer with kinetic energy and prevent flow separation on demand. The actuation is initiated by shape memory alloys (SMA). By the direct integration of SMA elements in flat fibre reinforced polymer (FRP) parts, the components turn into active hybrid composites. A well selected amount of SMA wire is integrated in a composite layup and allows small elements of about 25x30 mm² with a thickness of only 1.8 mm to deflect up to 8 mm upwards into the airflow. These small active VG with a weight of 1.5 g each can easily be integrated in the wing structure, since only an electrical connection is required. The presentation will highlight the key steps of the development, including modelling (Fig 1), manufacturing and experimental verification of actuation performance of the active composites under airflow in the laboratory. In addition, the required system architecture is described and results of flight tests are presented, with a functional setup equipped on a glider, validating the aerodynamic impact on the flight behaviour.

Keywords: Active composite structures, Shape memory alloy, Airflow control

Fig. 1 FE-model of a single VG element (a). Cross section to illustrate the bimorph bending principle (b).
Equivalent Modulus of Composite Resin for Stress Simulation of Dental Restoration

Jung-Hoon Park\textsuperscript{1}, and Nak-Sam Choi\textsuperscript{2,*}

\textsuperscript{1}Department of Mechanical Engineering, Graduate School, Hanyang University, 17, Haengdang-dong, Sungdong-gu, 133-791, Korea

\textsuperscript{2}Department of Mechanical Engineering, Hanyang University, 1271, Sa I-dong, Ansan-si, Gyeonggi-do, 426-791, Korea

\textsuperscript{*}Email: nschoi@hanyang.ac.kr

Abstract

This study proposes a formula to measure an equivalent Young’s modulus of a composite resin to apply to a calculation scheme of the shrinkage stress in dental restoration. Different composite resins in the polymerization shrinkage strain were used for experimental verification. The linear shrinkage strains of the composite resins were gained through the bonded disk method. The formula was derived on the basis of the restored ring substrate (Fig.1). The equivalent Young’s modulus value (Fig.2) was applied as input to a finite element analysis (FEA) for validation of the calculated shrinkage stress. The measured moduli through the formula were appropriate for stress simulation of dental restoration in that the shrinkage stresses calculated by the FEA were in good agreement within 3.5\% with the experimental values. The concept of equivalent Young’s modulus so obtained could be applied for stress simulation of 2D and 3D dental restoration.

Keywords: Composite resin, Ring type substrate, Finite element analysis, Equivalent Young's modulus, Dental restoration

\textbf{Fig. 1} Schematic of the dental restoration \textbf{Fig. 2} Effective Young's modulus behaviors of ring model.
Metal and Ceramic Matrix Composites for Nuclear and Fusion Applications

Owais A. Waseem, Qusai M. Mistarihi, Muhmood Hassa, and Ho Jin Ryu*

Department of Nuclear and Quantum Engineering, KAIST, Daejeon 34141, Republic of Korea

*Email: hojinryu@kaist.ac.kr

Abstract

Metal and ceramic matrix composites for plasma facing materials, advanced nuclear fuel, burnable neutron absorber and radioactive waste form, have been developed based on the design of alloy compositions, functional reinforcements, and fabrication processes. Tungsten-based composites were prepared by spark plasma sintering for the development of reduced-activation alloys for fusion plasma-facing materials with the enhanced strength and toughness. The low thermal conductivity of ZrO2 was increased by the addition of Mo reinforcements in order to improve the thermal performance of inert matrix fuel. The effect of Mo reinforcement structure in terms of its size, shape, and orientation on the thermal conductivity of Mo powder- and Mo wire mesh-reinforced ZrO2 composites was investigated. The fabrication of novel burnable neutron absorber fuel containing either a lumped Gd2O3 particle in the centerline of the oxide fuel pellet was investigated to improve the nuclear fuel performance. The novel consolidation processing of hydroxyapatite-based composites was investigated to develop the efficient radioactive waste immobilization matrix. The development of advanced composites was useful to provide high-performance materials for nuclear fission and nuclear fusion applications.

Keywords: Plasma facing materials, Nuclear fuel, Neutron absorber, Radioactive waste form
KN-12

Functionalisation of Natural Fibre for Energy Storage Applications
Xiaowen Yuan*

School of Engineering and Advanced Technology at Massey University
*Email: XW.Yuan@massey.ac.nz

Abstract

With global energy depletion and environmental degradation, new and sustainable energy sources and storage systems are needed to meet the high power demands of modern miniaturised electronic devices. The performance of electrochemical capacitors, one of the most promising energy storage devices, largely depends on the electrode architecture, especially in the case of hybrid electrodes for which the synergetic effect plays a crucial role.

This research focuses on the design and control of the architecture/structure of carbonised nanocellulose/graphene based hybrid electrodes derived from natural and sustainable plant fibre, as well as their effects on the material properties such as effective specific surface area, pore size distribution and then on the device performance of electrochemical capacitors. The research could lead to better sustainable energy storage, sensors and nanoelectronics with applications in lightweight and high current flexible battery replacements.

This presentation will address the fabrication of freestanding and flexible activated flax fabrics with tunable meso/micropore ratio through a novel one-step synthetic strategy, which combines rapid heating and direct carbonisation/activation (Figure 1). The effects of the heating rate and the carbonisation/activation temperature on the specific surface area, porous structure, morphology, graphitization degree, and surface chemical structure of the as prepared activated flax fabrics will be discussed. This facile process is generic, and is thus expected to be applied to other natural fibres such as hemp and harakeke, enabling new applications of these traditional materials.

Fig. 1 (a) Preparation process of the activated flax fabric electrode; digital photographs of (b) the pristine flax fabric and (c) the as-prepared activated flax fabric; (d) digital photograph of the flexible activated flax fabric; (e) SEM and (f) TEM images of the activated flax fabric.
Recent Advancement of Nanocellulose Based Multifunctional Nanocomposites

Jaehwan Kim*, Lindong Zhai, Hyun Chan Kim, Jung Woong Kim and Sunanda Roy

Creative Research Center for Nanocellulose Future Composites, Inha University, 100 Inha-Ro, Nam-Ku, Incheon 22212, South Korea
*Email: jaehwan@inha.ac.kr

Abstract

Cellulose is one of the nature’s most abundant natural polymers, the main chemical components of wood and plants. It is a renewable material that recycles to nature by composting with short period of time. The use of renewable materials is essential in future composite technologies. This presentation reviews recent advancement of nanocellulose for multifunctional nanocomposites, including sensors, actuators, electronic devices and energy storage applications. To further improve functionality of cellulose material, hybrid composites of inorganic functional materials are introduced by incorporating carbon nanotubes, titanium dioxide and tin oxide conducting polymers and ionic liquids. Since cellulose has many advantages of biocompatible, renewable, biodegradable, high mechanical strength and versatile modification behaviors, more research efforts need to be focused on the development of nanocellulose multifunctional composites. Fig 1 shows the concept of nanocellulose based multifunctional nanocomposite and its applications.

Keywords: Nanocellulose, Natural Fiber, Polymer Composites, Multifunctional Materials

Fig. 1 Nanocellulose based multifunctional nanocomposite and its applications.
Self-Healing Polymers and Polymer Composites Based on Microcapsules Strategy

Ming Qiu Zhang*, Min Zhi Rong

School of Chemistry, Sun Yat-sen University, Guangzhou 510275, China

*Email: ceszmq@mail.sysu.edu.cn

Abstract

As a next-generation technology, self-healing affords autonomous crack repairs and major improvement to the key performance of products, including reliability and durability. The self-healing methodologies developed to date can be classified as intrinsic and extrinsic according to the method used for delivering the healing components to the target site in the material. Unlike intrinsic self-healing that operates as a result of inter- or intramacromolecular interactions in the absence of additional healing agents, extrinsic self-healing involves the embedment of a healing agent. Extrinsic self-healing can be more easily realized in commercially available polymers because no structural modification of the matrix molecules is required. Here in this talk, our efforts in imparting self-healing capability to epoxy and its fiber composites towards mechanical properties recovery are summarized. Moreover, the trends and challenges are analyzed.

Keywords: Self-healing, Polymer composites, Microcapsules, Healing agent
Nano-scale Engineering of Fibre Composites for Extremes
Shuying Wu, Fan Zhang, Shuhua Peng, Saiful Islam, and Chun H. Wang *

School of Mechanical and Manufacturing Engineering University of New South Wales, Sydney, Australia
*Email: chun.h.wang@unsw.edu.au

Abstract
This presentation describes some recent progress in nano-scale engineering of composite materials for extreme environments, viz large deformation and cryogenic temperatures.

Wearable electronics hold great promise to transform robotics (giving robots a human touch) and health care (monitoring and early diagnosis of illness). One technology that has attracted significant interest is to embed nano-scale conductive networks into highly elastic polymers. Recent research has identified this new type of sensors may suffer significant drift under cyclic loading. To address this challenge, we report a hybrid reinforcement of using nanomaterials of different scales and dimensions to improve cyclic stability and durability.

Nano-scale engineering offers also a new possibility of expanding the use of fibre reinforced polymer composites to extreme environments such as cryogenic temperatures. Although lightweight and strong fibre-reinforced polymer (FRP) composites have already been deployed in space vehicle and payload components, storage of cryogenic propellants (such as liquid hydrogen and liquid oxygen) still relies on metallic tanks. Recent efforts to use of carbon fibre composites to lighten fuel storage vessels have been unsuccessful because the composites exhibit multiple matrix-cracking modes at super cold, cryogenic temperatures that lead to degraded structural safety and leaking of fuels, thereby creating a potential ignition-and-explosion hazard. In this presentation we will describe some recent advances in the use of negative thermal expansion nanomaterials to simultaneously reduce the effective thermal expansion and increase the fracture toughness of an epoxy and its carbon fibre reinforced composite.
Filling the Property Gap of Two-phase Composites

Hua-Xin Peng *

Professor and Director Institute for Composites Science Innovation (InCSI) Zhejiang University 38 Zheda Road, Hangzhou, 310027 China
*Email: hxpengwork@zju.edu.cn

Abstract

Existing composite theories and models only take account of a uniform distribution and the overall volume fraction of the reinforcement; therefore they provide little guidance to the design of the microstructures of composites. The presentation aims to offer some insights into the development of theories that can accommodate a controlled inhomogeneous reinforcement distribution within a matrix, hence a new microstructural parameter - local volume fraction will be introduced for the prediction of elastic properties of composites with different types of reinforcement distributions, namely, layered, clustering, network, and bi-continuous structures. This will afford new approaches to the strengthening and toughening of two-phase composites. Experimental examples will be given on the design and fabrication of composites with ingenious microstructures and provide useful insight into the design, fabrication and engineering application of this new class of composites.
Mechanical and Interfacial Properties of Glass Fiber/Poly(Dicyclopentadiene) Composites at Different Thermal Conditions and Surface Treatments

Joung-Man Park¹,², Jong-Hyun Kim¹, Ha-Seung Park¹, Pyeong-Su Shin¹, Yeong-Min Baek¹, and Dong-Jun Kwon¹

¹Department of Materials Engineering and Convergence Technology, Research Institute for Green Energy Convergence Technology, Gyeongsang National University, Jinju, Korea
²Department of Mechanical Engineering, The University of Utah, Salt Lake City, Utah U. S. A.
*Email: jmpark@gnu.ac.kr

Abstract

Effects on various parameters in glass fiber (GF)/poly(dicyclopentadiene) (p-DCPD) composites were studied to produce high performance composites. These parameters are composed of different surface treatment and post curing conditions. GF with different silane treatment were used for different surface treatment. After curing of DCPD, different temperature for post curing was applied. To compare with each different conditions, mechanical test such as tensile, impact and interfacial shear tests by fragmentation test were implemented. The relationship between interfacial and mechanical properties was evaluated and optimum conditions of fiber sizing and post curing were obtained.

Keywords: DCPD, Glass fiber, Fragmentation, Interfacial property

Fig. 1 Optical photographs showing fiber fragmentation for different curing conditions:

(a) non-post cured; (b) 120 °C; (c) 160 °C; and (d) 200 °C.
Mechanics on 2D Materials
Zhong Zhang*

National Center for Nanoscience and Technology, Beijing 100190, China
*Email: zhong.zhang@nanoctr.cn

Abstract

Two-dimensional (2D) materials exhibit a host of intriguing properties, which may lead to unique applications in sensors, flexible electronics and nanocomposites. Interface becomes dominated which could play a crucial role in the performance and reliability of these applications, but little is known about the key parameters controlling shear deformation across the layers and interfaces between 2D materials. In the past few years, we have developed several experimental methodologies in order to investigate the interfacial properties of 2D materials, as well as their performance on various substrates. These include a pressurized micro-scale bubble loading device to measure the interlayer shear stress of bilayer graphene and/or 2D materials with their substrates, and a cantilever device for studying the interfacial stress transfer between a monolayer graphene and a polymer matrix under pristine vdW and modified H-bonding interactions. Moreover, these devices have been adopted for investigating the surface-tension-driven self-tearing of graphene on an adhesive substrate, the interlayer shear stress of bilayer graphene with various twisted angles, bending rigidity of multilayer graphene and other 2D crystals, as well as the fracture and crack propagation on Boron doping graphene. Molecular dynamics simulations were applied to fit to the analytical methods, validate the theoretical mechanics model for analyzing the experimental results. Some very interesting phenomena were detected, which will contribute for expanding our knowledge on understanding the features of 2D materials and their interfaces.
Thermoelectric Nano-composites: Role of Interfaces

Lidong Chen*

State Key Laboratory of High Performance Ceramics and Superfine Microstructure, Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai 200050, China

*Email: cld@mail.sic.ac.cn

Abstract

Fabricating nanocomposites is an effective and prevailing strategy to improve the performance of thermoelectric materials. The nano-sized secondary phases and the induced numerous interfaces not only strengthen the scattering of low-frequency phonons, but also affects carrier transport. It is a big challenge to realize the homogeneous distribution of nano-sized secondary phases in the nanocomposites. In the past several years, low dimensional carbon materials (CNTs and graphene) have been used to fabricate numerous thermoelectric nanocomposites. Reduced graphene oxide (r-GO) sheets were embedded into filled skutterudite (SKD) constructing a continuous wrapping-like network by using wet-dispersion and SPS-sintering process. The nano-sized r-GO wrapping layers greatly increased the grain boundary thermal resistivity but maintained almost undamaged electrical transports. The effort was also made on the molecular-level dispersion of CNTs in Cu2Se/CNTs nanocomposites by in-situ fabrication. The electronic hybridization at the atomic or molecular level between Cu2Se and the adjacent CNT greatly enhanced the thermoelectric performance of the composite. As for the organic/inorganic thermoelectric composites, it has been revealed that the interfacial interaction (especially the hybridization between the carbon materials and polymer chains) between the inorganic and organic materials would promote the construction of ordered polymer back-bone chain and therefore enhance the electrical properties of conducting polymer.
Rational Design of Advanced Elastomer Nanocomposites
Towards Extremely Energy-saving Tires Based on
Macromolecular Assembly Strategy
Liqun Zhang*

*State Key Laboratory of Organic-Inorganic Composites, Beijing University of Chemical Technology, Beijing 100029, China
*Email: zhanglq@mail.buct.edu.cn

Abstract
Energy use due to automobile tires accounts for more than 6% of the world’s total energy consumption and ~5% of all carbon dioxide emissions. We designed and fabricated a next-generation, energy-saving advanced elastomer (AE) based on a macromolecular assembly strategy. This AE delicately balances rolling resistance, wear resistance and wet-skid resistance, addressing the so-called “magic triangle” that has plagued the tire industry for more than century. This AE crosslinks anionically synthesized hydroxyl-terminated solution-polymerized styrene-butadiene copolymers with highly symmetric isocyanates and polyols to generate a uniform network by macromolecular self-assembly. Remarkably, compared with those of widely commercialized elastomer nanocomposites tailored for “green tires”, the wear resistance, rolling resistance and wet-skid resistance of this AE are improved by 94.6%, 69.8% and 13.8%, respectively. This AE affords a new opportunity for the large-scale application of next-generation high-performance automobile tires that will, in part, resolve a serious global energy and environmental crisis.
Carbon Nanotubes Composite for Mechanical Energy Storage with High Energy Density and Power Density
Yunxiang Bai\textsuperscript{1,2}, Shenli Zhang\textsuperscript{1}, Boyuan Shen\textsuperscript{1}, Zhenxing Zhu\textsuperscript{1,2}, Yao Wang\textsuperscript{1}, Rufan Zhang\textsuperscript{1}, and Fei Wei\textsuperscript{1,2*}

\textsuperscript{1}Beijing Key Laboratory of Green Chemical Reaction Engineering and Technology, Department of Chemical Engineering, Tsinghua University, Beijing 100084, China.
\textsuperscript{2}Center for Nano and Micro Mechanics, Tsinghua University, Beijing 100084, China.
\*Email: wf-dce@tsinghua.edu.cn

Abstract
Energy storage in a proper form is an important way to meet the fast increase of energy demand. Among the various strategies for storing energy, mechanical energy storage via suitable media has been widely utilized by human beings for a very long time in human history, such as bows, springs, flywheels, and reservoirs on high mountains, etc. Mechanical energy includes kinetic energy, gravitational potential energy and elastic potential energy. Because of the extremely high tensile strength (>100 GPa), Young’s modulus (>1 TPa) and breaking strain (>17%), carbon nanotubes (CNTs) are considered to be one of the strongest materials ever found and exhibit overwhelming advantages for storing mechanical energy.

We show the fabrication of centimeters long CNT bundles (CNTBs) with tensile strength over 80 GPa using ultralong defect-free CNTs. The tensile strength of CNTBs is controlled by the Daniels effect due to the nonuniformity of the initial strains in the components. A synchronous tightening and relaxing strategy is proposed to release the nonuniform initial strains of the CNTB components. For CNTBs consisting of a large number of components with parallel alignment, defect-free structures, continuous lengths and uniform initial strains, the tensile strength is as high as 80 GPa, which is far higher than that of any other strong fibers ever fabricated.

The tensile strain energy density of CNTs is as high as 1125 Wh/kg. In addition, CNTs also exhibit great potential for fabricating flywheels to store kinetic energy with both high energy density (8571 Wh/kg) and power density (2 GW/kg), which are at least one order of magnitude higher than that of all the other materials available. In this talk, we first give a general introduction to several typical mechanical energy storage systems and materials. Then we introduce the theoretical and experimental study on the mechanical properties of CNTs and CNT assemblies. Afterwards, we discuss the strategies for utilizing CNTs to store mechanical energy. In addition, macroscale preparation of CNTs is summarized, which lays a great foundation for the industrialization of CNT-based mechanical energy storage devices. Finally, we also present the future trends and prospects in the development of CNTs used as mechanical energy storage materials.
Composite Material Applications to Industries in China

Zhu, Jianxun*, and Yi, Ming

Sinoma Science & Technology Co., Ltd., Beijing, China

*Email: zhujx@sinomatech.com

Abstract

Since the first glass fiber reinforced plastics was born in 1958, China has grown up to the largest composites manufacturing country in the world. With the progress on the technologies in raw materials, innovative design and production process, China has greatly promoted her composites applications in industries. This presentation shows composite material applications in various industries such as energy, infrastructure, transportation and marine in China. The development of reinforcement materials such as special fiberglass and carbon fiber have been a key support to composites applications in China. Special fiberglass with high strength and high modulus has been keeping on a leading position in the world, with a portfolio of products. Design for manufacture (DFM), digital simulation design and virtual detection, and “tailored-design” techniques have been applied to composites in industries. Automatic manufacturing technologies are playing an important role in labor cost reduction, high repeatability, further advancements of continuous processes to reducing faults, improving quality and efficient production. The achievements of composites applications to industries include composites wind turbine blade, bridges, high pressure cylinders, ships and boats.

The potential opportunity for the technologies and applications of composites in the future would be:

1. Raw materials with more advanced specifications
2. Mushroom markets in battery electric vehicle and high-speed EMUs (Electric Multiple Units)
3. Higher-end mass applications such as business jet, and general aviation
4. Environmental friend applications for infrastructure projects
5. Thermoplastic composites.
A Novel Biochar-Cement Composite for Concrete Structures

Priyan Mendis1, *, Kate Nguyen1, Allyssa Estacio1, Tuan Ngo1 and Debes Bhattacharyya2

1University of Melbourne, Australia
2University of Auckland, Australia
*Email: pamendis@unimelb.edu.au

Abstract

Although Concrete is the most popular construction material in the world, concrete industry accounts for around 5% of global carbon dioxide (CO2) emissions. Ordinary Portland cement (OPC) produces approximately 1 tonne of CO2. Cement production is growing by about 3% annually, and is expected to rise to about 5 billion tons by 2050. The only solution to reduce these greenhouse gas emissions is to use cement composites utilising waste materials. Biochar is recently identified as such a material with enormous potential. Biochar is presently predominantly used for soil improvement in agricultural lands (Zhu et al., 2017). Waste materials like flyash have become very popular to replace cement, however the coal-fired plants are being discarded and there is a danger of running out of flyash in the world. It is expected that Biochar can even be used to improve the mechanical properties of concrete and also the fire performance. To date, no systematic studies have been conducted to investigate the use of biochar in concrete. Preliminary results from a major study conducted by the authors on biochar cement composites mortar will be presented. This includes strength properties (compressive strength, flexural tensile strength), a microscopic analysis, a study on heat release rate through cone calorimeter tests.

Keywords: Biochar, Cement composites, Waste materials, Mechanical properties

Fig. 1 Compressive strength of specimen at room temperature (unheated) and specimens heated at 200°C, 450°C and 700°C.
How to Flame-Retard Carbon Fiber-Reinforced Epoxy Resin Composites Efficiently
Xiao-Hui Shi, Li Chen, and Yu-Zhong Wang*

Centre for Degradable and Flame-Retardant Polymeric Materials, National Engineering Laboratory for Eco-Friendly Polymeric Materials(Sichuan), College of Chemistry, Sichuan University, Chengdu
*Email: yzwang@scu.edu.cn

Abstract
Construction of carbon fiber (CF)-reinforced epoxy resin (EP) composites with excellent mechanical properties and desired fire retardancy is of particular difficulty due to the candlewick effect of CF and the deterioration effect of flame retardants on composite performance. In this presentation, we will report a simple strategy to address the above issue: we use the well-designed and treated CFs to reinforce EP without additional flame retardants. The CFs can be treated via different ways, for example, Layer-by-Layer (LbL). The EP composites reinforced by LbL-treated CFs can possess excellent mechanical properties (Fig 1) and fire retardancy (Table 1). We will also discuss some more extensive and efficient approaches to the fire retardation of different fiber-reinforced polymer composites.

Keywords: Carbon fibre, Epoxy resin, Composite, Fire retardance

![Mechanical properties of EP composites reinforced by LbL-treated CFs.](image)

Fig. 1 Mechanical properties of EP composites reinforced by LbL-treated CFs.
Novel Strategy to Utilise Low-Cost Keratinous Fibres for High-Performing Flame Retardant

Debes Bhattacharyya*, Daeseung Jung, and Nam Kyeun Kim

Centre for Advanced Composite Materials, Department of Mechanical Engineering, The University of Auckland, Auckland, 1142, New Zealand

*Email: d.bhattacharyya@auckland.ac.nz

Abstract

The mainstream developments of flame retardants have been on high performance and low-toxicity. In order to achieve the two goals at the same time and address some of the sustainability issues, we have suggested a novel approach to convert low-cost keratinous fibres to high-performance flame retardants by a simple chemical treatment. Excellent chemical resistance and self-extinguishing properties can render these fibres more suitable to contain various chemical substances and to be an effective source for the improved fire resistance on their own. A solution-based treatment to implant amine phosphate and phosphoric acid in a keratinous fibre through sequential monomer infiltration has enhanced the intumescent char forming ability of the fibre. The incorporation of the flame retardant fibre (FR fibre) into polypropylene (PP) has achieved the significant reduction of the polymer flammability. The self-extinguishing nature (V-0 grade) and a marginal decrease in fire reaction properties, namely heat (~70%) and smoke production rates, of the composites have been demonstrated in the vertical burn and cone calorimeter tests, respectively. In addition, higher mechanical properties of the composites compared to those of a commercial flame retardant/PP blend has shown the potential of the FR fibre to replace the conventional flame retarding substances.

Keywords: Intumescent flame retardant, Keratinous fibre, Amine phosphate, Polypropylene composite
Not all Fire Retardants are Equal to a Fire Safety Engineer

Jonathan Barnett*

*Email: jonathan.barnett@basic.expert

Abstract

Fire safety engineers are typically trained in fluid dynamics, heat transfer, thermodynamics, basic combustion fundamentals, human behavior, structural response to fire but not advanced chemistry or chemical engineering. Nonetheless they are expected to evaluate material fire tests and interpolate test results. This talk will focus on what fire safety engineers need from you, their expectations and performance requirements.
Biologically Inspired Multi-Functional Composites

David Kisailus\textsuperscript{1,2*}

\textsuperscript{1}Materials Science and Engineering Program, University of California, Riverside, Riverside, CA 92521, USA
\textsuperscript{2}Department of Chemical and Environmental Engineering, University of California, Riverside, Riverside, CA 92521, USA
*Email: david@engr.ucr.edu

Abstract

There is an increasing need for the development of multifunctional lightweight materials with high strength and toughness. Natural systems have evolved efficient strategies, exemplified in the biological tissues of numerous animal and plant species, to synthesize and construct composites from a limited selection of available starting materials that often exhibit exceptional mechanical properties that are similar, and frequently superior to, mechanical properties exhibited by many engineering materials.

In this work, we investigate a variety of organisms that have taken advantage of hundreds of millions of years of evolutionary changes to derive structures, which are not only strong and tough, but also demonstrate multifunctional features dependent on the underlying organic-inorganic components. Specifically, we discuss (i) the hyper-mineralized combative dactyl club of the stomatopods, a group of highly aggressive marine crustaceans, (ii) the heavily crystallized radular teeth the chitons, a group of elongated mollusks that graze on hard substrates for algae. From the investigation of synthesis-structure-property relationships in these unique organisms, we are now developing and fabricating cost-effective and environmentally friendly multifunctional engineering composites with impact resistance and biologically inspired nanomaterials for energy conversion and storage.

Keywords: Biocomposite, Impact Tolerant, Abrasion Resistant, Biomimetic

\textbf{Fig. 1} The highly aggressive peacock mantis shrimp. \textbf{Fig. 2} Ultrahard abrasion resistant radular teeth of the giant chiton.
3D Printed Carbon Fibre Composite Materials for Biomedical Applications

Kvalsvig, Andrew¹, Yuan, Xiaowen¹*, Cao, Peng²

¹School of Engineering & Advanced Technology, Massey University
²Department of Chemical and Materials Engineering, The University of Auckland

*Email: xw.yuan@auckland.ac.nz

Abstract

3D printing is the manufacturing technology that creates three-dimensional objects through the process of adding layers of material on top of one another. Recently, 3D printing has been used to produce end-use parts that are being used in a range of industries including the medical industry.

The purpose of this research is to demonstrate the feasibility of producing carbon fibre composite implants, in particular knee and hip replacements which are common bone replacements in the human body by 3D printing. Different tests such as tensile strength and finite element analysis (FEA) have been conducted to show the mechanical properties of the material and how it may be implemented. The effects of the selected variables have on the tensile properties of specimens made using the Mark One 3D printer have been characterised. The processing parameters were optimised using the Taguchi method. The tests completed show the best possible combination of parameters to produce the strongest possible part. The optimum combination of parameters can then be applied to the final bone replacement. The data gathered from the FEA analysis is useful in designing hip and knee implants, identifying the areas of the implants that undergo high stress and furnishing these areas with extra reinforcement. The results showed that a carbon fibre composite material has lower strength than titanium but remains adequate for knee and hip replacements. In addition, a 3D printed carbon fibre composite material can be more readily custom made for individuals.

Keywords: 3D printing, carbon fibre composites, biomedical implants
Improving Strength of Carbon Fiber and Carbon Nanotube Reinforced Multiscale Thermoplastic Composites Using Printed Molding

Ruonan Wang¹, Haihong Wu¹*, Liyong Tong²*

¹College of Mechanical Engineering, Henan University of Technology
²School of Aerospace, Mechanical and Mechatronic Engineering, The University of Sydney

*Email: hhwu@haut.edu.cn; liyong.tong@sydney.edu.au

Abstract

This paper presents an experimental investigation into the effects of carbon nanotubes (CNTs), grafted on the surface of individual carbon fibre (CF), on the interfacial shear strength and tensile strength of carbon fibre reinforced polyamide (CFRPA) composites. Prepared first were five types of CFs with grafted CNTs of 0.1%, 0.25% and 0.4% weight fractions, sized with epoxy and without sizing. CFRPA specimens of H-notch configuration were designed for measuring interfacial shear strength (IFSS) under tensile loading, and was then fabricated using a three dimensional printed molding (3D-PM) process for five different types of CFs. The experimental results show that the IFSS and tensile strength of cross-plied CFRPA laminate with 0.25% weight fraction of grafted CNTs are increased by 238% and 130% respectively when comparing to these of CFRPA with sized epoxy. It is believed that the contributing factors to these increments include the increased surface area and roughness of CFs with grafted CNTs due to the formation of multiscale structure on CFs surface. The interfacial dimple fracture was observed by SEM, and this indicates that the CFRPA with grafted CNTs is capable of absorbing more deformation energy prior to fracture.

Keywords: Printed molding; Multiscale reinforcement; Interfacial shear strength; Tensile strength; Thermoplastic composites
Effects of Water Absorption on Fiber Matrix Interfacial Shear Strength of Carbon Nanotube Grafted Carbon Fiber Reinforced Polyamide Resin

Kazuto Tanaka*, Saya Okuda, Yoshitaka Hinoue, and Tsutao Katayama

Dept. of Biomed. Eng., Doshisha Univ.

*Email: ktanaka@mail.doshisha.ac.jp

Abstract

Carbon fiber reinforced thermoplastic (CFRTP) are expected to be used for the structural parts of automobiles and aircrafts due to their mechanical properties, such as high specific stiffness, high specific strength, high molding cycle, high recyclability and so on. The fiber/matrix interface of the composite plays an important role in transmitting stress from the matrix to the reinforcing fibers. It was reported that grafting of carbon nanotubes (CNTs) on the carbon fiber can improve the fiber/matrix interfacial property. We have reported that CNT, which are directly grafted onto carbon fiber using Ni as the catalyst by chemical vapor deposition (CVD) method, can improve the fiber/matrix interfacial shear strength (IFSS) of carbon fiber/polyamide 6 (PA6).

For the practical use of CFRTP, it is important to clarify the effects of water absorption on the mechanical properties of the composite material. In this study, the effects of water absorption on the fiber/matrix interfacial shear strength of CNTs grafted carbon fiber reinforced polyamide resin were investigated by using single fiber pull-out tests (Fig 1). IFSS of carbon fiber/PA6 was significantly decreased by water absorption. In contrast, CNTs grafted carbon fiber/PA6 showed small degradation of the IFSS by water absorption.

Keywords: CFRTP, Carbon nanotube (CNT), CNT grafted carbon fiber, Single fiber pull-out test, Water absorption

Fig. 1 Schematic drawing of fabrication for a single fiber pull-out test specimen.
Influential Factors Analysis on Heat Dissipation Property of Carbon Fibre Reinforced Polymer

Zenong Fang, Min Li, Shaokai Wang*, Yizhuo Gu, Yanxia Li, Zuoguang Zhang

Key Laboratory of Aerospace Advanced Materials and Performance (Ministry of Education), School of Materials Science & Engineering, Beihang University, Beijing, China

*Email: wsk@buaa.edu.cn

Abstract

With the rapid increase of heat load in aviation and aerospace industry, the anisotropic heat dissipation of carbon fibre reinforced polymer (CFRP) takes more and more attention. In this research, highly conductive graphite sheet (GS) was co-cured with poorly conductive PAN-based CFRP to manufacture hybrid composite GS/CFRP. The heat dissipation property of GS/CFRP was compared with PAN-based CFRP and pitch-based CFRP by monitoring temperature fields during heated. The processes of heat dissipation were both analysed by simulation and experiment, as shown in Fig 1. The top temperature of GS/CFRP 302.0 K was less than PAN-based CFRP and pitch-based CFRP, as shown in Fig 2. It was concluded that to hybrid GS with poor conductive PAN-based CFRP would bring enormous improvement in heat dissipation which was even more conductive than pitch-based CFRP. Meanwhile, by simulation, the influential factors on thermal conductivity of CFRP were evaluated. High axial thermal conductivity of carbon fibre enhanced thermal conductivity of CFRP in the direction of fibre. Enhancing thermal conductivity of matrix was efficient in promoting heat dissipation when fibre angle close to 90°. Increasing fibre volume friction was helpful to achieve higher thermal conductivities in all directions.

Keywords: carbon fibre reinforced polymer, graphite sheet, thermal conductivity, simulation
Composite Repairs Integrity Assessment: An Overview of Inspection Techniques

Siti Haslina Mohd Ramli¹*, Rosman Ariffin², M Bastawy³

¹Materials, Corrosion and Inspection Group, Infrastructure Dept, Engineering Division, Group Technical Solutions, Project Delivery & Technology, PETRONAS

²Pipeline Group, Engineering Division, Group Technical Solutions, Project Delivery & Technology, PETRONAS

³Centre of Excellence, PETRONAS Carigali Sdn Bhd, PETRONAS

*Email: sitihaslina@petronas.com

Abstract

Composites repairs have been increasingly applied for repairs of piping and pipelines in the oil and gas industry, and thus there is a growing need to monitor their in-service integrity. There are many challenges of inspecting composite repairs including accessibility, inhomogeneous and anisotropic structure, probability of detection, lack of adequate standards and unfamiliarity with composite materials amongst others.

This paper summarises an overview of the effectiveness of several NDT techniques that has been evaluated on a composites repair test spool, including Laser Shearography, Dynamic Response Spectrometry (DRS), Computed Radiography, Microwave techniques, as well as the identification of critical inspection areas and the development of acceptance criteria for inspection of composites repairs.

Keywords: Composite repairs, In-service integrity, NDT techniques
Electro-Conductivity in the Thickness Direction of a Unidirectional CFRP Laminate with Interlayers

Keiji Ogi*, Ryotaro Ozaki, and Koichi Mizukami

Graduate School of Science and Engineering, Ehime University, 3 Bunkyo-cho, 790-8577, Japan

*Email: ogi.keiji.mu@ehime-u.ac.jp

Abstract

The electroconductivity in the thickness direction of a unidirectional CFRP laminate with interlayers was investigated. Although the interlayer consisting of thermosetting resin and thermoplastic particles is insulating, the CFRP laminate with interlayers is conductive. This is because the interlayer carbon fibers (ILCFs) make conductive paths in the thickness direction of the laminate. The specimen used is a unidirectional CFRP laminate [08] with the thickness of 1.6 mm. Figure 1 shows normalized conductivity against the specimen area. Each specimen is obtained by step-by-step division of one large specimen (S=4000 mm2). The scatter becomes greater as the specimen becomes smaller while the average value is independent of the specimen area. This behavior can be explained by the random distribution of ILCFs. The distribution of normalized conductivity is depicted as the histogram in Fig. 2 for three specimen areas. The left ordinate denotes the normalized area whose summation is unity. This distribution is approximated by the following log-normal distribution:

\[ f(x) = \frac{1}{\sqrt{2\pi} \sigma x} \exp\left(-\frac{(\ln x - \mu)^2}{2\sigma^2}\right) \]  

(1)

The probability density based on eq. (1) is depicted as solid lines in Fig. 2. The mode, the peak value of conductivity, is shifted to lower side as the specimen becomes smaller.

Keywords: Electro-conductivity, CFRP, Interlayer

Fig. 1 Normalized conductivity vs. area.  
Fig. 2 Normalized conductivity distributions.
Axial Compressive Properties of Novel Carbon/Glass Hybrid Thermoplastic Composite Rods

Kimiyo Naito*, Chiemi Nagai, and Yoshihisa Tanaka

*Email: naito.kimiyo@nims.go.jp

National Institute for Materials Science

Abstract

Novel carbon/glass hybrid thermoplastic composite rods called “CABKOMA” have been developed by Komatsu Seiren Co., Ltd. The hybrid rods are a core-in-sheath type and consist of a bundle (or bundles) of carbon fiber surrounded by an outer braided bundle glass fiber in which a new thermoplastic epoxy resin is evenly impregnated as the matrix. In the previous studies, the morphology of the hybrid rods was observed and the volume fractions of the carbon fiber, glass fiber, matrix, and voids for the hybrid rods were estimated using a thermogravimetric analysis and specific gravity measurement via ethanol immersion. The tensile properties of the hybrid rods were also characterized. Additionally, it is necessary to characterize compressive properties of the hybrid rods to understand the mechanical properties.

In the present work, axial compressive properties and fracture behavior of the hybrid rods were investigated. The axial compressive stress applied to the specimen was linearly proportional to the axial compressive strain until failure. The axial compressive modulus and strength of the hybrid rods were ranged 45-118 GPa and 137-324 MPa. The axial compressive modulus and strength increased with an increase in volume fraction of carbon fiber.

Keywords: carbon fiber, glass fiber, thermoplastic epoxy, axial compressive properties
Manipulating the Surface Chemistry of Carbon Fibers for Enhanced Fiber-to-Matrix Adhesion
Daniel J. Eyckens, James D. Randall, Baris Demir, Tiffany R. Walsh, and Luke C. Henderson*

*Email: luke.henderson@deakin.edu.au

Abstract
Carbon fibre composites are considered a key material for the future. These consist of plastics which have been reinforced with the carbon fibres in a woven or unidirectional pattern. Despite their promise, the Achilles heel of carbon fibre composites is the fibre-to-matrix interface which largely dictates the ultimate performance of the composite material, as a typical mode of failure fibre pull out. All carbon fibre is manufactured in the same way and the only attempt to make a fibre compatible with the intended polymer is to coat the fibres in a thin (~0.3 μm) ‘sizing’ layer of polymer which is derived from the same family as the intended matrix.

This work will summarise recent development by our group in the manipulation of carbon fiber surface chemistry to increase fiber-to-matrix adhesion in thermoset resins. Our approach uses electrochemical surface modification which is extremely rapid (~30-60 sec), uses mild conditions (< 2V, and 5 mA), and can be adapted to in-line manufacture. This work coupled with molecular dynamics of the fiber-matrix interface provides an insight into the critical molecular interactions, which influence interfacial adhesion.

Keywords: Adhesion, Surface Chemistry, Carbon Fibers, Interface

Fig. 1 Left: Molecular dynamics simulation showing the aggregation of IL in the functionalized composite (polymer not shown for clarity); Right: Interfacial Adhesion for surface modified fibers.
Abstract
The next generation of large volume composite manufacturing is aiming to achieve fast throughputs at low cost. Automated manufacturing in conjunction with rapid materials processing is predicted to be the pathway to achieve this goal. Along with new technologies in automation and robotics, the future composite manufacturing will see a huge development in novel resins that incorporate multiple functionalities and non-traditional behaviours. This includes resins with tuneable physical and chemical properties and fibres and composites with smart sensing functionalities. Important considerations are to be able to achieve fast cure rates, flexibility and formability, recyclability and self-healing behaviours in the resin systems and also to develop resins that can withstand high temperature environments. The recent research performed in our research group showcase the technical feasibility of these new functionalities in epoxy resins. New resin formulationss were developed that are flexible, formable and are able to be rapidly cured. The outcome of this research is the in-depth scientific understanding of tuneable epoxy network that will significantly advance this research to the next level.

Keywords: Carbon Fibre Composites, Epoxy resin, Industry 4.0, Automated manufacturing

Fig. 1 The formable epoxy thermosets with brittle, ductile and elastomeric behaviours.
A Flexible Strain/Magnetism Sensor with An Improved Detecting Capacity
Pei Huang, Yuan-Qing Li, and Shao-Yun Fu*
College of Aerospace Engineering, Chongqing University, Chongqing 400044, China
*Email: syfu@cqu.edu.cn

Abstract
The development of multi-functional sensor is of great importance in the industrial fields of manufacturing, artificial robots and vehicles, etc. Herein, a novel flexible dual-mode strain/magnetism sensor, which works via both contact and contactless modes, is first fabricated by incorporating Fe3O4/silicone resin into a carbon fiber aerogel. The distance-dependence of magnetic field endorses the carbon aerogel/Fe3O4/silicone composite possible for spatial sensing due to the introduction of Fe3O4 magnetic nanoparticles. As a result, the as-prepared flexible sensor exhibits precise and real-time response not only to direct contact compression as usual but also to contactless magnetic field. The contact and contactless sensing modes of the as-prepared sensor are clearly demonstrated in recording the speeds of bicycle-riding and walking, respectively. Interestingly, this dual-mode composite sensor exhibits the capacity of identifying the contact and contactless state, which is the first report for flexible sensors. The current protocol is eco-friendly, facile and thought-provoking for fabrication of multi-functional sensors.

Keywords: dual-mode sensor, strain, magnetic field, composite

Fig. 1 a) Schematic depiction of the structure of the strain/magnetism sensor responding to the external force and magnetic field; b-c) a schematic of bicycle integrated with the sensor; d-e) a schematic of sports shoes integrated with the sensor; f-g) an illustration of the combination of contact and contactless sensing.
Session: Carbon Fibres and Composites
Comp-2-2-O3

Electromagnetic Shielding Property of Carbon Fiber Felt Made of Different Type of Carbon Fiber
Jiyong Liang*, Yizhuo Gu, Shaokai Wang, Min Li, Zuoguang Zhang

Key Laboratory of Aerospace Advanced Materials and Performance (Ministry of Education), School of Materials Science and Engineering, Beihang University, Beijing 100191, China
*Email: liangjiyong@buaa.edu.cn

Abstract
Three types of short-chopped carbon fibers (SCF), including PAN-based T300, M40J and pitch-based XN90 were used to prepare carbon fiber felts by wet-laid method to explore their electromagnetic shielding properties. Sample preparation process is illustrated in Fig. 1, and the length of all short-chopped carbon fibers was 6mm before dispersing in water. There are some changes in the length of CF after dispersing for 30 min. As we can see from Fig. 2, the length of T300 and M40J does not have significant changes, otherwise, and the length of XN-90-60s significantly reduces to 1~3 mm. Pitch-based XN90 is more brittle than PAN-based T300 and M40J, as a result it is easier to be worn off in the process of dispersion. Fig. 3 presents the thickness of different CF felts, varying from 27 μm to 222 μm, which were measured by spiral micrometer. It can be seen from Fig. 4 that SCFs were randomly distributed in CF felts. Then wave guide method was used to test electromagnetic shielding performance of the carbon felts in the X-band (8.2~12.4GHz). It is demonstrated that their electromagnetic interference shielding performance (EMI SE) increases with increasing areal density. Carbon fiber felt with higher electrical conductivity shows better SE, so M40J has higher SE than T300. In addition, XN90 shows the lowest SE owing to easily broken during the process of preparation and decreased electrical conductivity. It has been displayed in Fig. 5 that the areal density of 42g/m2 carbon fiber felt of M40J shows the highest EMI SE of 58.4 dB (@ 8.2 GHz). Fig. 6 presents the EMI SE of M40J carbon fiber felt of 42 g/m2 in X band. It is found that EMI SE increases with the increase of frequency, increasing from 58.4 dB (@ 8.2 GHz) to 70.3 dB (@ 12.4 GHz), and absorption is the main mechanism of EMI. Having high EMI SE with low density, carbon fiber felts exhibit great potential as lightweight and high EMI SE functional materials.

Keywords: Electromagnetic shielding, Carbon fiber felt, Wet-laid method, Wave guide method, Electrical conductivity
Nano-Micro Multiscale Predictions of Carbon Fiber/Epoxy Resin Interfacial Mechanical Properties

Hao Wang¹, Kai Jin²*, and Jie Tao¹

¹College of Material Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 211106, China
²College of Mechanical and Electrical Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China

*Email: jinkai@nuaa.edu.cn

Abstract
Researchers often got different mechanical properties by macroscale experiments for the same CFRP since experimental errors. In this study, a multiscale method to obtain mechanical properties of CFRP was put forward. The carbon fiber/epoxy resin interfacial properties were accurately predicted by using molecular dynamics analysis, microscale finite element analysis and microscale mechanical test respectively. First, the mechanical properties of single carbon fiber, epoxy resin and carbon fiber/resin interface were calculated through molecular dynamics simulation in nanoscale. And then, these results as input material parameters were imported to microscale carbon fiber/epoxy resin interfacial model. Through mutual verification between the microbond test and the numerical simulation, these interfacial mechanical parameters were validated. After that, macroscale mechanical performance simulations such as interlaminar shear simulation and three point bending simulation could directly input these interfacial mechanical parameters. By using the presented method, uniform and accurate material parameters for a composite material can be obtained. Moreover, when designing a new composite material, the presented method can predict its mechanical properties rapidly and accurately, saving much time and cost.

Keywords: Carbon fiber, Interfacial strength, Molecular dynamics, Multiscale
Real-Time Quantification of Network Growth of Epoxy/Diamine Thermosets as a Function of Cure Protocol

Jeffrey Wiggins*

School of Polymer Science and Engineering, University of Southern Mississippi, 118 College Drive #5050, Hattiesburg, MS 39406
*Email: Jeffrey.wiggins@usm.edu

Abstract

This presentation will review research strategies which utilize molecular dynamics tools to inspire experimental synthesis and scale-up activities for next generation aerospace composite materials. Our research has established an advanced glassy polymer network infrastructure which translates computational molecular theory into pilot-scale fabrication and composite coupon testing of new matrix chemistries. This review will discuss specific research associated with the advancement of multi-walled carbon nanotube functional layers being developed for incorporation into multi-functional composite structures (Figure 1). We will discuss how changes in rheological variations which occur during cure can be used to control ultimate network and nano-particle structures which may be pathways to ultimately control unique multi-functional properties in structure. Our approach for studying the chemical, rheological and morphological variances which occur during cure through the solution-to-gel-to-vitrified solid state transitions directly apply to nano-particle research in advanced composite materials and we will highlight key control variables which influence ultimate nano-structured morphology. This research provides fundamental knowledge to rapidly advance scalable processes with economic and manufacturing feasibility to overcome hinderances which have stifled the progression of realizing benefits from nano-technology in aerospace structural applications.

Keywords: Nanocomposite, Prepreg, Aerospace, Composite, Carbon Fiber

Fig. 1 Continuous mwcnt matrix reactor and multi-functional aerospace prepreg.
Development of Production System of Continuous Carbon Fiber/PP Composites and Improvement of their Mechanical Properties

Atsushi Sumida1*, Hitoshi Kazama2, Akiko Hirabayashi3, Norio Hirayama4

1Monjyu Technical & Medical Laboratories
2Toyojushi Corporation Limited
3Nihon University, hirabayashi
4Nihon University, hirayama
*Email: chigen-sumida@s7.dion.ne.jp

Abstract

Ages of electric cars will be soon opened. One of key technologies to realize the age is lightweight of shasse and frame of electric cars. Much amount of FRP has been applied for cars, but FRP has not been applied for shasse and frame. Car makers request FRP written below,

1. CFRP which has almost the same strength and modulus as that compose of epoxy resin
2. CFRP which is fabricated in a short time (1 minute) and easily recycled
3. CFRP whose price is as low as possible

To realize their requests, heavy bundle CF (50K) and thermoplastic resin (polypropylene, PP) will be selected for short time fabrication, easy recycle and low price. The biggest issue is how to impregnate PP into 50K CF. As shown in Fig.1, the authors contrived that water emulsion of thermoplastic polyurethane (PU) with nano-size particle was easily impregnated into continuous CF and that PU formed thermoplastic film after dry. Then, PP was coated on the CF. Obtained coated CF is arranged and fabricated composite (C-FT composite) under pressure and heat. As shown in Fig.2, bending strength of the C-FT composite was clearly improved by treatment with PU.

Keywords: Continuous fiber reinforced thermoplastic (C-FT), Polyurethane emulsion (PU), Polypropylene (PP), Composite properties
Microscopic Impact Damage Mechanisms of FRP Laminates with Toughened Interlayers Subjected to High-Velocity Impact
Rozaini Othman¹, Keiji Ogi², Ahmad Sufian Abdullah¹, and Sudarsono³

¹Faculty of Mechanical Engineering, Universiti Teknologi MARA Cawangan Pulau Pinang, Jalan Permatang Pauh, 13500 Permatang Pauh, Penang, Malaysia
²Graduate School of Science and Engineering, Ehime University, 3 Bunkyo-cho, 790-8577 Matsuyama, Ehime, Japan
³Department of Mechanical Engineering, Universitas Halu Oleo, Kendari, Indonesia

*Email: rozaini.othman@ppinang.uitm.edu.my

Abstract
This paper presents the microscopic impact damage mechanisms of CFRP laminates with toughened interlayers when subjected to high-velocity impact. The test was carried out by using a ballistic testing machine at different impact velocities and size of projectiles. The damage generated in the laminate was then examined by using optical microscopy and soft X-radiography. It was observed that the front surface of the laminate exhibited a crater formation and splitting cracks extending in the fiber direction, whereas at the back surface, multiple splitting was generated. The delamination tends to propagate in the fiber direction, resulting in a galaxy shape delamination. In addition, the high fracture toughness of the interlayers occasionally produces the transition of interlaminar delamination to intralaminar delamination. The cross-section beneath the impact point revealed a catastrophic failure with an extensive fiber breakage as shown in Fig. 1. The larger diameter of projectile produces larger area of damage as depicted.

Keywords: CFRP, toughened interlayers, high-velocity impact, damage

Fig. 1 Cross-section of the laminate beneath the impact point.
In-Situ Monitoring of Internal Strain of CFRP Laminate From Processing to Machining
Baso Nasrullah*, Keiji Ogi*, and Koichi Mizukami
Ehime University
*Email: basonasrullah@poliupg.ac.id; ogi.keiji.mu@ehime-u.ac.jp

Abstract
The purpose of the present study is to measure the strain and temperature during processing and hole-machining using an FBG sensor and a thermocouple embedded in a CFRP cross-ply laminate. The strain is calculated from wavelength shift and temperature measured by the FBG sensor and the thermocouple, respectively.

Figure (1a) shows the typical strain change in the CFRP cross-ply laminate during a curing process. The very small strain was generated after the curing process. Figure (1b) depicts the change in the strain and temperature during the hole machining using two kinds of the drill. The maximum temperature and strain using the drill for CFRP are smaller than those using the drill for steel. The residual strain after machining depends on the magnitude of machining damage, which was quantitatively evaluated by optical micrography and X-ray radiography.

Keywords: monitoring, internal strain, CFRP-laminate, curing, drilling

Fig. 1 A typical strain and temperature change of CFRP cross-ply laminate (a) during curing and (b) drilling processing. HSS and D-DAD represent the drill for steel and CFRP, respectively.
Fabrication of Silver Nanowires-Loaded Activated Carbon Fibers Micro/ Nano Composites and Their Antibacterial Activity

Chengli Tang*1, and Wei Yan2

1College of Mechanical and Electrical Engineering, Jiaxing University, Jiaxing, P. R. China
2Department of Environmental Science and Engineering, Xi’an Jiaotong University, Xi’an, P. R. China
*Email: tcl-lily@mail.zjxu.edu.cn

Abstract

The durable adherence of nanomaterials onto supporting surface is the pivotal issue for the practical use of those nanomaterials-modified composites. Binding agent is always needed for the fabrication of these composites. Loading AgNPs on host materials to fabricate AgNPs-loaded composites is an ideal settlement to both the problem of oxidation and recycle. The usually used host materials are SiO2, zeolite and carbon materials. Given the advantage of AgNWs over AgNPs in loading process by affording multiple binding points with supporting materials, there is significant interest in developing AgNWs-loaded materials in recent years.

In this paper, we chose activated carbon fiber (ACF) as the supporting material on which AgNWs was loaded. ACF is an ideal supporting material because of the huge specific surface area, proper micropores and excellent adsorption capacity, which have been widely used in water treatment field. Chitosan was selected as the binding agent for the effective loading of AgNWs on ACF surface. As a natural polysaccharide, chitosan (CS) is rich in amino groups, which results in high percentage of nitrogen (6.89%). Chitosan has already found its wide applications in medical science, food industry, cosmetic industry, agriculture and environmental field. Antibacterial activity of the ACF/AgNWs micro/nano composites was tested for both of the gram-positive and gram-negative bacteria of Staphylococcus aureus (S. aureus) and Escherichia coli (E. coli).

Keywords: Silver nanowires, chitosan, activated carbon fiber, antibacterial
Optimization of Carbon Fibre Surface Treatment and Sizing for Thermoplastic Resins

Andreas Hendlmeier*, Luke Henderson

Deakin University, Australia

*Email: ajhendlm@deakin.edu.au

Abstract

As the automotive industry has to follow strict rules on recycling and reuse, thus it is necessary to use lighter materials, such as carbon fibre composites. For an ideal composite a good understanding of how a carbon fibre bonds to the supporting resin. Mechanical interlocking and chemical bonding are the primary mechanisms which influence the interphase. For both thermosets and thermoplastics exists no consensus on how effectively each mechanism changes the interfacial properties and how much it depends on the fibre-sizing-resin combination from different manufacturers. This is particularly true for thermoplastic resins which are still poorly utilised by industry and the factors effecting a superior interface remain elusive. A set of carbon fibres with altering sizings, (epoxy, polyamide, and polyurethane) as well as changing currents and conductivities were produced and the interfacial shear strength (IFSS) was investigated in an epoxy matrix with a single fibre fragmentation test. The resultant fibres were characterised physically (tensile strength, Young’s modulus, etc.) and chemically (XPS). The roughness of these fibres was also determined by AFM. The highest IFSS found in epoxy resin (62 MPa), was found for epoxy sized fibres treated with 1.0 A at 8 mS/cm. The lowest IFSS (38 MPa) was found for the fibres treated with 0.5 A at 24 mS/cm. Preliminary results suggest that both mechanical interlocking and chemical interactions have a role in IFSS. It is anticipated that there is an optimal composition of each where the mechanical and chemical bonding work the best for every fibre-sizing-resin combination.

Keywords: carbon fibre, surface treatment, sizing
Characterisation of Composite Constituents for Structural Battery Modelling

Leif E. Asp*, David Carlstedt, Shanghong Duan, Fang Liu*

Department of Industrial and Material Science, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden

*Email: leif.asp@chalmers.se; fang.liu@chalmers.se

Abstract

In this paper we report ongoing research on structural battery composite materials. Firstly, techniques to characterise multifunctional properties of composite constituents are discussed. These techniques concern characterisation of Li-ion conductivity and stiffness of the structural battery electrolytes (SBE) developed at KTH, Sweden. In particular, the multifunctional properties are to be measured and compared for bulk SBE and ultra-thin SBE coatings on carbon fibres. Stiffness measurements are to be performed with nanoindentation or and AFM. Furthermore, the dielectric strength of the few hundred nanometre thick polymer coatings, containing a lithium salt, is to be measured.

It is well known that battery electrodes expand/shrink due to lithiation/delithiation of ions into the electrode materials (i.e. charging/discharging of the battery). Earlier studies by Jacques et al. show that intercalation of lithium ions into carbon fibres causes the fibre to expand approximately 1 % in longitudinal direction and 8-13 % in radial direction. It is also known that positive electrode materials such as e.g. LiFePO4 particles expand/shrink approximately 5 % in radial direction due to lithiation/delithiation. In addition to the volume expansion it has also been shown that the elastic properties of battery electrode materials such as e.g. graphite are highly dependent lithium-ion concentrations. In this paper stiffness of the pristine and lithiated carbon fibres measured by AFM will be reported.

Measured properties will be introduced in a micro-mechanical model to investigate how the elastic properties of structural battery composite laminae are affected by changes in volume and lithium concentrations, associated with electrochemical cycling. The model is based on the Composite Spheres Assemblage (CSA) model and a generalisation of the Composite Cylinder Assemblage (CCA), a combined analytical model is set-up and used to estimate the elastic properties of the lamina.

Keywords: Structural battery, stiffness, ion-conductivity, Microscopy study, multi-scale modelling
Fabrication of Structural Supercapacitors with Carbon Nanofibers and Its Electrical/Mechanical Properties

Dasom Lee, Jaemin Jung, Gyu Hee Lee, and Woo Il Lee*

Seoul National University
*Email: wilee@snu.ac.kr

Abstract

Multifunctional composites are effective materials to reduce an overall mass of total system because it can be structural and energy storage components at the same time. However, electrical properties of CFRP based supercapacitor are not enough to replace conventional energy storage systems like batteries and supercapacitors due to the low surface area of carbon fibers. In order to assure a sufficient specific capacitance of structural supercapacitor, the increase of the surface area of carbon fibers act as an electrode of supercapacitors is necessary. Therefore, in this research, electrospun carbon nanofibers (CNF) were used as an electrode of structural supercapacitor to increase the surface area of carbon electrodes. Electrospinning was the most effective and simple way to produce a nanofibers. Polyacrylonitrile (PAN), a precursor of carbon fiber, was electrospun with multi-walled carbon nanotube (MWCNT) for a few hours and electrospun PAN nanofiber mat was converted to carbon nanofiber mat with stabilization, carbonization and activation process. The structure of the multifunctional supercapacitor was that two layers of electrospun CNF mats was separated by two layers of woven glass fabric, and conventional carbon fiber mat was covered the outside of the structure to improve mechanical properties of the entire system. Electrical and mechanical characteristics were evaluated with a simplified electrical equivalent circuit of the system and Mode I interlaminar fracture toughness test, respectively.

Keywords: Structural supercapacitor, Carbon nanofiber, Electrospinning, Multifunctional composite
Characterization and Analysis of In-Plane Shear Properties of Fiber-Reinforced Composites

Jae Hyuk Choi¹, Jinhyeok Jang¹, Wonbo Shim¹, Jeong-Min Cho², Chi-Hoon Choi² and Woong-Ryeol Yu¹*

¹Department of Materials Science and Engineering and Research Institute of Advanced Materials (RIAM), Seoul National University, Gwanak-ro 1, Gwanak-gu, Seoul 08826, Korea
²R&D Division, Hyundai Motor Company, 150 Hyundai Yeonguso-ro, Hwaseong-si 18280, Korea

*Email: woongryu@snu.ac.kr

Abstract

In order to predict the mechanical behaviour of fiber-reinforced composites using Classical Laminate Theory, basic material properties such as tensile and shear moduli and Poisson’s ratio should be well characterized. Among those properties, the accurate characterization of the in-plane shear properties of composites is difficult due to two main reasons. It is hard to maintain pure shear stress state in a gauge section. Another reason is difficulty in determining the shear failure point from general shear stress-strain curve because fibers may reorient and carry a load after the shear failure. In this paper, three different types of American society for testing and materials (ASTM) standard shear tests (±45° off-axis tensile test, Iosipescu shear test, V-notched rail shear test) were performed to characterize the in-plane shear properties of unidirectional and woven CFRP. To analyse the three different behaviour, finite element analyses were carried out. V-notched rail shear test was more suitable for measuring the shear properties accurately than other two methods because of the purest shear stress state in a gage section. In addition, the exact shear failure point was determined by observing the specimen through ex-situ X-ray tomography. The in-plane shear properties determined above were validated by comparing experimental off-axis tensile moduli with calculated ones.

Keywords: Composites, CFRP, ASTM shear test, In-plane shear properties, Finite element analysis
Session: Carbon Fibres and Composites
Comp-2-4-O2

Effect of Cure Cycle Time Reduction on Dimensional Stability of Curved Carbon Fibre Composite Parts
S. Naghashian*, C. Creighton1, S.K. Karla, and R.J. Varley

Carbon Nexus, Institute for Frontier Materials, Deakin University, Geelong, Australia 3220
*Email: saharn@deakin.edu.au

Abstract
The necessity of using expensive moulds combined with long cure cycles to manufacture complex carbon fibre components are major impediments to their increased usage in the automotive industry in particular [1]. This study presents an investigation into the curing of complex components using shorter cycle times for components cured in the mould. U-shaped carbon fibre composites were manufactured out of unidirectional prepreg. A number of cure cycles of varying cure times were chosen to obtain different levels of degree of cure and the extent of spring back was determined. Post-cure after demoulding was shown to improve the dimensional stability.

Keywords: Carbon Fibre Composites, Cure Time Reduction, Spring Back

Fig. 1 Post-curing resulted in increased degree of cure (close to 100% after 4.5 h) and improved dimensional stability (the angle is close to 90°).
Fatigue Behavior of Non-Holed CFRP Laminates with Initially Cut Fibers

Sudarsono1*, Keiji Ogi2, Rozaini Othman3, and Hidayat4

1Department of Mechanical Engineering, Universitas Halu Oleo, Kendari, Indonesia
2Graduate School of Science and Engineering, Ehime University, Ehime, Japan
3Faculty of Mechanical Engineering, University Teknologi MARA, Penang, Malaysia
4Department of Mechanical Engineering, Politeknik Negeri Samarinda, Samarinda, Indonesia

*Email: sudarsono34@gmail.com

Abstract

Carbon fiber-reinforced plastic (CFRP) laminates with initially cut fibers (ICFs) have good flowability without large degradation of static strength, however, fatigue behavior in their non holed specimen has not been investigated thus far. In this study, the combination of laminate type and fabrication method on the fatigue behavior of quasi-isotropic CFRP laminates with ICFs containing interlayers under tension-tension fatigue loading was investigated. Three kinds of CFRP laminates were employed; a laminate with conventional prepregs fabricated using an autoclave (Continuous-A), a laminate with ICF fabricated using an autoclave (ICF-A) and a laminate with ICF fabricated using press molding (ICF-P). First, fatigue test was performed to obtain S (maximum stress)-N (the number of cycles to failure) curves in order to reveal fatigue strength and fatigue strength degradation. The fatigue tests of one specimen for each laminate were interrupted at several prescribed numbers of cycles to observe damage progress. It is found that strength degradation of the three laminates in the S-N curve is similar where fatigue strength in those laminates is decreased by approximately 45 % at N of 106. In addition, the fatigue strength of Continuous-A laminate is the highest among the three laminates. However, in the case of ICF laminates, fatigue strength of ICF-P laminates is higher than ICF-A laminates. In contrast, the damage progress of the ICF-P laminate is the least among the three laminates while the delamination progress at both edges in the Continuous-A laminate is the most prominent.

Keywords: CFRP, Fatigue, Initially Cut Fibers, Damage Progress, Interlayer
Interlaminar Fracture Toughness of Carbon Fiber Composites with Interleaving CNT in Film Form

Y.C.Shin¹, S.M.Kim², B.R.Kim¹, S.H.Choi, S.J.Ko, and W.I.Lee¹*

¹Mechanical and Aerospace Engineering, Seoul National University, South Korea
²Mechanical Engineering, Koreatech, South Korea
*Email: wilee@snu.ac.kr

Abstract

Carbon fiber reinforced polymer (CFRP) composites have extraordinary stiffness and strength. Recently, studies which improve interlaminar properties of composites using carbon nanotube (CNT) which have remarkable conductivity and mechanical strength were published. Interleaving has been used to prevent crack propagation of CFRP composites. Interleaves made by nylon-66 nano fabric improve threshold of impact energy of CFRP composites¹. Nano-interleaves electrospun by thermoplastic resins such as polystyrene, polycarbonate were inserted between plies. In this study Mode I, and Mode II interlaminar fracture toughness of CFRP composite with interleaving CNT in film form was studied. In addition, difference in the fracture morphology between CFRP composite with and without interleaves was investigated using field emission scanning electron microscopy (FE-SEM) which was used to explain toughening mechanism of CNT in composites.

Keywords: CFRP, CNT, buckypaper, interlaminar

Fig. 1 SEM images of specimens without interleave(left), with interleave(right).
Enabling Future Manufacturing Rates Through Resin Chemistry
Jonathan Meegan*
Solvay, Abenbury Way, Wrexham, UK, LL13 9UZ
*Email: jonathan.meegan@solvay.com

Abstract
Understanding the emerging needs of the composite materials market is key to maintaining a leading position as both a supplier and a developer of reinforcement and resin technologies.
Within the single aisle segment of the aerospace market build rates for high aircraft platforms are expected to exceed 60 aircraft per month. In order to meet this rate requirement it will become necessary to challenge the cycle times of current composite solutions through a combination of process and kinetic optimisation.
Solvay is pleased to present a paper detailing advancements in liquid resin chemistries adapted for aerospace structural applications requiring a reduction in recurring and non-recurring costs and elevated mechanical performance.

Keywords: Rate, Matrix, Chemistry, Composites

Fig. 1 Potential trends in aerospace market to 2036.
Nanoparticle-Promoted Structure Evolution of Thermo-plastics Reinforced by Self-Welded Short Carbon Fibers

Guozhang Wu*, and Dongge Zhang

East China University of Science and Technology, School of Materials Science and Engineering, 130 Meilong Road, Shanghai 200237, China

*Email: wgz@ecust.edu.cn

Abstract

The large volume of currently available fiber-reinforced polymer composites critically limits the intrinsic versatility of fibers such as high mechanical strength, heat resistance, and excellent thermal/electrical conductivity. We proposed a facile and widely applicable strategy to promote self-organization of randomly dispersed short carbon fibers into a three-dimensionally continuous scaffold. The morphological evolution and structural reinforcement of the self-welded CF-PA6 scaffold in PS matrix were investigated, with carbon black or titanium dioxide nanoparticles selectively localized in the PA6 domains.

Keywords: Carbon fiber, Reinforced thermoplastics, Nanocomposites, Structural evolution, Interface

Fig. 1 SEM image of PS/PA6/CF/TiO2 (80/20/30/4) mixtures wherein the PS matrix was selectively extracted by toluene.
New Approaches to Bonding Dissimilar Materials in Advanced Composites

Juan Jane Zhang*, Mandy de Souza, Claudia Creighton, and Russell J. Varley

Carbon Nexus, Institute for Frontier Materials, Deakin University, Geelong Waurn Ponds, Victoria 3216, Australia

*Email: jane.zhang@deakin.edu.au

Abstract

The need for different materials in complex structural composite components is growing rapidly, but is often limited by poor adhesion arising from their different chemistries and surface energies. This tends to result in the need for additional fastening which then adds cost and weight. This research explores new processing concepts of surface treatment that promote adhesion between dissimilar composite materials by a facile spray or solution approach that uses a non-toxic green solvent (e.g. ethanol, methanol, acetone) containing functional chemicals. Fig 1 depicts an example of the surface treatment and bonding procedures of epoxy/carbon fibre composites (Epoxy/CF) and polyamide 66/glass fibre composites (PA 66/GF). The results show that the lap shear strength of solution treated samples is more than 3 times higher than the untreated samples and a direct correlation with epoxy conversion (Fig 2). Solvent polarity also affects the bonding strength, i.e. polar solvents are better than non-polar solvents. These new approaches are applicable to different thermoplastic polymer (e.g. polyamides, polyurethane, polyimides, polycarbonate, polyolefin, etc.) composites and epoxy/carbon fibre composites with regular or irregular shapes.

Keywords: Adhesion improvement, solution approach, green solvent

Fig. 1 Schematic of new approaches of surface treatment and bonding procedures of PA 66/GF composites to Epoxy/CF composites.
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**Study on the In-Plane Properties of Reinforced Composite Laminates by New Stitching Process**
Man-Sung Kim, Cheol-Hwan Kim, Jin-Ho Choi

*School of Mechanical, Aerospace and Information Engineering, ReCAPT, Gyeongsang National University*

*Email: choi@gnu.ac.kr*

**Abstract**
Carbon fiber reinforced composites are increasingly used in aircraft main structures due to their high specific strength and specific stiffness. But, composite laminates have low strength in the through thickness direction. Stitching and Z-Pinning are typical methods for reinforcing thickness directional properties of composites that are vulnerable to delamination. However, when these techniques are applied to the prepreg, the in-plane reinforcing fibers in the prepreg are damaged.

In this paper, we proposed a new stitching process to minimize the fiber bending and the damage of in-plane properties. The in-plane properties of the stitched laminate according to various parameters (stitching pattern, head length, pre-hole) of the stitching process were evaluated and optimization of the process was investigated to improve the in-plane properties.

**Keywords:** Stitching, Prepreg, In-plane, Composite

![Fig. 1 Schematic diagram of specimen.](image-url)
Effects of Unsizing of Carbon Fiber on Interfacial Strength of CNT Grafted Carbon Fiber and Polyamide6

Kazuto Tanaka, Kanako Yamada, Yoshitaka Hinoue, and Tsutao Katayama

Dept. of Biomed. Eng., Doshisha Univ.
*Email: ktanaka@mail.doshisha.ac.jp

Abstract

Because of the expected short production cycle time of the Carbon Fiber Reinforced Thermoplastics (CFRTP) using thermoplastic as a matrix, they are expected to be applied to the automotive industry instead of CFRP, which require curing time.1. Grafting of carbon nanotubes (CNTs) on the carbon fiber can improve the fiber matrix interfacial strength, which plays an important role in the mechanical properties of FRP2. To graft CNTs on carbon fiber, chemical vapor deposition (CVD) method was used and Ni, which was used as the catalyst, was electrolytically plated on carbon fibers in our study2. Since as-received carbon fiber was sized, which may affect the plating behavior of Ni, the effects of sizing agents on CNT deposition has to be clarified.

In this study, Ni for catalytic metal was plated by electrolytic plating using a watt bath on as-received carbon fiber and unsized carbon fiber, and the influence of the sizing agent on distribution of Ni was evaluated. The number of Ni particles on the surface of the unsized carbon fiber is larger and the variation of the Ni particle diameter is smaller than as-received carbon fiber as sizing plays an insulator for Ni plating.

The interfacial shear strength of CNTs grafted carbon fiber and PA6 were evaluated by single fiber pull-out tests(Fig.1). The interfacial shear strength of the CNT grafted unsized carbon fiber was higher than that of the CNT grafted as-received carbon fiber.

Keywords: CFRTP, As-received carbon fiber, Unsized carbon fiber, Carbon nanotube (CNT), Single fiber pull-out test, Fiber matrix interfacial strength

Fig. 1 Schematic drawing of fabrication of a single fiber pull-out test specimen.
Carbon Fibre Precursors Based on Spinifex Nanofibres Reinforced Polyacrylonitrile Composites
Edward Jiang¹, Nasim Amiralian¹, Bronwyn Laycock¹, Darren Martin¹, and Pratheep Kumar Annamalai¹ *

¹Australian Institute for Bioengineering & Nanotechnology, The University of Queensland, St Lucia, Queensland, Australia
²School of Chemical Engineering, The University of Queensland, St Lucia, Queensland, Australia,
*Email: p.annamalai@uq.edu.au

Abstract
The carbon fibre based lightweight and high performance composites have gained considerable attention for their applications in the automotive and aerospace sectors. Their extensive industrial uptake is still limited by the cost associated with the production of high-quality carbon fibre from petroleum-derived polyacrylonitrile (PAN) and as well as the energy input required for the carbonization process. Nanocellulose is a versatile nanomaterial, which possesses tailorable surface functionalities and can be derived in various dimensions and morphologies from biomass sources. In this study, with the aim of enhancing the carbonisation efficiency and improving mechanical properties of final carbon fibres, we have investigated spinifex grass and cotton based nanocelluloses in different morphologies for reinforcing the polyacrylonitrile precursor fibres.

The carbon fibres from PAN fibre reinforced with only 0.1 wt.% of cotton low aspect ratio CNC (c-CNC), spinifex based medium-to-high aspect ratio CNC (s-CNC)1 and CNF (s-CN), exhibited upto 4%, 87% and 170% improvements in tensile modulus, respectively, after carbonisation at 1200 °C as compared to a control PAN fibre. Similar trend were observed for the tensile strength improvements, which were related to the highly ordered (graphitic) carbon structure formation. This presentation will include the preliminary carbonisation of spinifex fibre alone2, screening through electro-spinning,3 scaling up through solution-spinning and carbonisation efficiency of the PAN/nanocellulose composite fibres.

Keywords: Carbon fibre, nanocellulose, polyacrylonitrile, spinifex, carbonisation and stabilisation
A New Environment-Friendly Approach for High Efficient Reuse of Recycled Carbon Fibers

Xianhua Huan, Guoxin Luo, Yapeng Rong, Xiaolong Jia*, Xiaoping Yang

State Key Laboratory of Organic-Inorganic Composites, College of Materials Science and Engineering, Beijing University of Chemical Technology, Beijing 100029, P. R. China

*Email: jiaxl@mail.buct.edu.cn

Abstract

Carbon fiber-reinforced polymers (CFRPs) have been widely used in various fields, especially in aerospace industry, due to their superior properties in high strength-to-weight ratio, rigidity, corrosion-resistant, corrosion and fatigue, etc. However, the recycling and reusing of the used CFRPs with the increasing amount are still a big challenge for both academic and industrial areas. This work attempts to develop a new environment-friendly approach for large-scale preparation of recycled carbon fiber continuous mat with controlled fiber alignment through plate flow-induced alignment techniques. It is found that the alignment degree of short carbon fiber in the mat is significantly affected by various factors, such as the viscosity of the solution and the outlet speed of the solution flow, etc. By optimizing these factors in the preparation process, the calculation basing on SEM images of the mat revealed that over 80 % of the fibers are aligned along the flow direction within the degree range of ±15°. It is worth noting that the continuous aligned mat with 30-100 cm wide could be prepared stably and precised. The mechanical measurement shows that the aligned mat is an outstanding reinforcement for fabricating the high performance composites, which shows the great application potential in the polymer composites.

Keywords: recycled carbon fiber, aligned mat, environment-friendly, composites
Strength Improvement of Various CFRTP by Ozone Oxidation Treatment

Hiroyuki Oguma\(^1\)*, Norio Hirayama\(^2\), and Goichi Ben\(^3\)

\(^1\)Saitama Industrial Technology Center 3-12-18 Kamiaoki Kawaguchi, 333-0844, Japan
\(^2\)NIHON University 1-2-1, Izumicho, Narashino, 275-8575, Japan
\(^3\)Nagoya University Furo-cho, Chikusa-ku, Nagoya, 464-8601, Japan

*Email: oguma.hiroyuki@pref.saitama.lg.jp

Abstract

In order to improve the interfacial adhesion between the carbon fiber (CF) and the resin, ozone oxidation treatment was carried out. Observation of the CF surface before and after the ozone oxidation treatment with X-ray photoelectron spectroscopic analyser (XPS) revealed that as shown in Fig.1, oxygen-containing functional groups (C—O, C=O, O—C=O) for improving the interfacial adhesion to the resin were generated on the CF surface. In addition, as results of ozone oxidation treatment of Polypropylene (PP), Polycarbonate (PC) and Polyamide 6 (PA6) films used as a matrix resin, oxygen-containing functional groups were similarly formed on the film surface. Fig.2 shows the flexural stress-strain curves for Carbon Fiber Reinforced Thermo-Plastics (CFRTP) when PA 6 was used as a matrix resin. It was revealed that the flexural strength was improved more than twice by the effect of the ozone oxidation treatment\(^1\). This was considered as an effect that the interfacial adhesion between CF and PA 6 was improved due to the effect of the oxidation treatment. For CFRTP with PP and PC as the matrix resin, it became clear that the flexural strength improved by 99% and 31% respectively by ozone oxidation treatment.

Keywords: CFRTP, Ozone oxidation treatment, Interface, Strength test

Fig. 1 Relationship of ozone oxidation processing time and elemental composition of oxygen functional groups for CF. Fig 2. Flexural stress-strain curves of CFRTP.
Effect of Cooling Rate on Impact Damage Properties of Carbon Fiber/Polypropylene Composites

Su-bin, Park*, Jung-ho, Kim

Gyeongbuk Hybrid Technology Institute
*Email: sbpark@ghi.re.kr

Abstract

This study is about the effect of cooling rate on the change of mechanical properties of carbon fiber/polypropylene composite. Since PolyPropylene is a thermoplastic resin, it has a very high melt viscosity and solidifies rapidly by cooling. Therefore, it is very important to understand the crystallographic behavior characteristics of resin flow characteristics and thermal history during molding process. Particularly, the mechanical properties of the thermoplastic composite material are changed because the degree of crystallization and the kind of the crystalline material of the thermoplastic polymer vary depending on the cooling rate.

The resin used in this study is polypropylene resin and is used in film form. Polypropylene film has already completed the chemical reaction. When the resin is softened by heating above the melting temperature for molding, the already formed crystal structure disappears, and when it is cooled for solidification, a new crystal structure is formed. The crystallinity at the time of crystal structure formation is determined by the cooling rate.

Press molding was carried out by varying the cooling rate in four ways. And the test were studied using differential scanning calorimetry(DSC) and drop-weight impact test. Table 1 is the datasheets of Polypropylene film.

Keywords: composites, carbon fibre, polypropylene, carbon PP composites, cooling rate
Delamination Toughening and Healing Performance of Hybrid 3D Woven Composites

Raj B. Ladani 1,*, Khomkrit Pingkarawat1, Alex T.T. Nguyen1,2, Chun H. Wang3, and Adrian P. Mouritz1

1Sir Lawrence Wackett Aerospace Research Centre, School of Engineering, RMIT
University, Melbourne, VIC 3001, Australia
2Engineering Mechanic Group, Institute of High Performance Computing, 1 Fusionopolis
Way, 138632 Singapore
3School of Mechanical and Manufacturing Engineering, University of New South Wale, Sydney,
NSW 2052, Australia
*Email: raj.ladani@rmit.edu.au

Abstract
This paper presents an experimental investigation of a novel three-dimensional (3D) woven fibre-polymer composite material that has the unique combination of properties to both resist and self-repair delamination cracks. The hybrid 3D woven composite contains a combination of through-the-thickness z-binders made of carbon tows (used for high delamination toughness) and thermoplastic filaments (used for self-healing). The delamination toughness and self-healing properties of 3D woven composites reinforced separately or concurrently with z-binders made of carbon tows and thermoplastic filaments are investigated. The hybrid 3D woven composites investigated here demonstrate large improvement to the mode I interlaminar fracture toughness (~1200%) with the unique capability of self-repairing internal damage.

Keywords: Multifunctional composites, Damage tolerance, Self-healing, Orthogonal weaving
Characterizations of Engineering Properties and Higher-Order Structure of Injection Molded GW(Glass Wool)-Filled PP Composites

Hiroshi Ito¹*, Fumiya Sakakibara¹, Akira Ishigami¹, Takashi Kurose¹, Humika Baba¹, and Masanori Fujita²

¹Graduate School of Organic Materials Science, Yamagata University, 4-3-16, Jonan, Yonezawa, Yamagata 992-8510, Japan
²NANODAX CO., Ltd, Annex West 4F 2-22-3, Nishihippori, Arakawa, Tokyo 116-0013 Japan
*Email: ihiroshi@yz.yamagata-u.ac.jp

Abstract

Polypropylene (PP) has been widely used in various industrial fields because of the advantage in high strength, light-weight, and low cost. However, neat PP still has insufficient mechanical properties such as elastic modulus and impact strength. Polymer composite technology, for example, glass fiber reinforced plastics (GFRP) has been admitted being a high performance reinforcement material in improving strength and elastic modulus. Although GF (Glass Fiber) is well known in various polymer composites, the processability in the injection molding still needs to be improved in terms of warpage and surface appearance. In order to solve these problems, GW (Glass Wool) is one of the alternative materials, because GW has more advantage in smaller diameter (6μm) and flexibility. However, fundamental study on PP/GW is still in the lack of progress. For these reasons, this research aims to clarify the fundamental molding characteristics and physical properties of glass wool reinforced plastic.

Keywords: Glass fiber reinforced plastic, Polypropylene, Glass wool, Glass fiber

Fig. 1 Appearance of GW (Glass wool). Fig. 2 Scanning Electron Microscope (SEM) image of GW.
Wave Absorption and Mechanical Property Characterization of Epoxy/E-Glass/Clay Composites

Ariadne L. Juwono\textsuperscript{1*}, Seto Roseno\textsuperscript{2*}, Nabila Sungkar\textsuperscript{1}, and Surya Jaya\textsuperscript{1}

\textsuperscript{1}Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Depok 16424, Indonesia;
\textsuperscript{2}Agency for the Assessment and Application of Technology, Jl. M.H. Thamrin no.8, Jakarta 10340, Indonesia;
*Email: ariadne@sci.ui.ac.id; seto.roseno@bppt.go.id

Abstract

Radar absorbing materials (RAMs) play an important role in military equipments, especially the stealth technology, by reducing the radar cross-section (RCS) values (Choi et al., 2012). Having high permittivity value in the frequency range of 100 Hz – 100 kHz (Sengwa, 2008), clay is a good candidate of filler for glass fiber reinforced composites that suitable for RAMs. The objective of the current study was to obtain the optimum clay content in the epoxy/ E-glass composites that had good microwave absorption properties at X-band frequency, as well as tensile and flexural properties. The composites were fabricated by a hand lay-up method in which the clay contents were varied by 1, 3, and 5wt%. The results showed that the optimum properties were obtained on the epoxy/ E-glass / 3wt% clay composite. The absorption coefficient and reflection loss at the X-band frequency of this composite were 90.7% and -10.32 dB at 9.1 GHz respectively. Furthermore, the tensile and flexural moduli were 11.3 GPa and 6.04 GPa respectively or decreased by 28% and increased by 23% respectively compared to the epoxy/ E-glass composite, while the tensile and flexural strengths were 199.5MPa and 344.2MPa respectively or improved 180% and 23% respectively compared to the epoxy/ E-glass composite.

Keywords: Radar absorbing materials, Composites, Microwave, Tensile strength, Flexural strength

Fig. 1 The graph of reflection loss in X-band frequency.
Enhanced Metal-Composite Adhesive Bonding Using Nanowire Arrays

Ghowsalya Mahendrarajah\textsuperscript{1}, Everson Kandare\textsuperscript{1}, and Akbar A. Khatibi\textsuperscript{1,*}

\textit{Sir Lawrence Wackett Aerospace Research Centre, School of Engineering, RMIT University, GPO Box 2476, Melbourne 3001, Australia}

*Email: akbar.khatibi@rmit.edu.au

Abstract

Although Fibre Metal Laminates (FMLs) have many benefits compared to metal alloys, the weak bonding between the metal and composite layer can lead to catastrophic failure under loading conditions. In this paper, we present a novel method to strengthen the interfacial bonding between the metal and composite layers, thereby increasing the through-thickness property of FMLs. Silver nanowire (AgNW) interleaves were incorporated at the interface between metal and composite layers of FMLs resulting in nano-bonded metallic nanowire interleaves. Aluminium-glass/epoxy laminate composites with varying concentrations of interleaving AgNWs and formation methods were evaluated under Mode I loading. It was found that the presence of nano-bonded interleaves enhanced the Mode I fracture toughness in all cases. The laminate containing 3gm-2 AgNWs revealed the greatest improvement in fracture toughness - 13 times greater than that of the control specimen. Also, the FMLs incorporating AgNW interleaves exhibited stable crack growth when compared to their pristine counterparts. The fracture surfaces of the fractured specimens were examined under Scanning Electron Microscope to ascertain the underlying mechanisms responsible for the interfacial bonding enhancements.

Keywords: Fiber Metal Laminates (FMLs), Interleaving, Mode I fracture toughness
Comparative Assessment of the Explosive Blast Response of Composite and Metals Commonly Used on Naval Ships

A. Gargano1,*, K. Pingkarawat1, V. Pickerd2, R. Das1, and A.P. Mouritz1

1Sir Lawrence Wackett Aerospace Research Centre, School of Engineering, RMIT University, 124 Latrobe street Melbourne
2Maritime Division, Defence Science & Technology Group, 506 Lorimer Street, Port Melbourne, Australia, 3207
*Email: s3332790@student.rmit.edu.au

Abstract

Structural metals and fibre-reinforced composites are used in many applications at risk from explosive blasts, such as armoured vehicles, naval ships and submarines, military aircraft as well civil infrastructure (e.g. buildings, bridges). Conventionally, metal-based materials were used in most structural applications, and thus were the early focus of research for blast load testing. More recently however, composite materials have become increasingly more utilised in naval ships due to their light-weight, high stiffness, strength and fatigue properties, corrosion resistance and ability to tailor the acoustic signature.

The objective of this study is to investigate the dynamic response of fibre-polymer composite laminates and metals subjected to air-blast loading using experimental and numerical approaches. Air-blast experimental tests using spherical plastic explosive charges were performed on square target panels made of carbon or glass fibre-vinyl ester, aluminium or steel. Two separate investigations were conducted, with plates of equal thickness (~4 mm) or similar areal density (~8.2 kg/m2). The effect of increasing blast impulse loading on the maximum centre-point deflection for the different materials is shown in Figure 1. When using the same thickness (Fig. 1a), both the steel and aluminium panels deflected less than the composite laminates most notably at the high shock wave impulses (above ~350 Pa.s). When the areal density was approximately the same (Fig 1.b), the steel panel deformed significantly more than the other three materials, and resulted in large permanent deformation. At the highest shock wave impulse (~350 Pa.s), the aluminium plate had plastically deformed and the carbon fibre laminate had ruptured. Comparatively, the glass fibre laminate displayed no visual damage, and maintained all of its residual strength. The results from the finite element model showed a high level of correlation in the prediction of maximum centre-point deflection and permanent deformation.

Keywords: Air-blast, Composite, Metal, Deformation, Finite Element Model
Failure Behaviour of Glass Fibre/Bombyx Mori Fibre/Epoxy Hybrid Cylindrical Composite Tubes Under Quasi-Axial Compression Load

A.U. Ude¹, ², *, and C.H. Azhari²

¹Department of Mechanical, Energy and Industrial Engineering, Faculty of Engineering, Botswana International University of Science and Technology, Private Bag 16 Palapye
²Department of Mechanical and Materials Engineering, Faculty of Engineering and Built Environment, The National University of Malaysia, UKM, 43600 Bangi, Malaysia

*Email: albertuche@yahoo.com

Abstract

This study investigated the failure behaviour, energy absorption response and load carrying capability of Glass fibre (GF)/ Bombyx mori (B. mori)/Epoxy hybrid composite cylindrical tubes subjected to an axial quasi-static compression test. The reinforced cylindrical composite tubes were prepared using mandrel assisted hand lay-up technique. The specimen tested were three (3) Glass fibre cylindrical tube, each consisting of 5 layers of (GF), three (3) B. mori fibre cylindrical tubes, each consisting of 10 layers B. mori fibre and GF/B. mori/Epoxy hybrid cylindrical tubes, each consisting of 5 layers of GF, 10 layers of B. mori fibres. The height of each tube was 50mm tall. The energy absorption as well as load carrying ability of the tubes were analyzed by measuring specific energy absorption, maximum peak load (Pmax) and total energy absorption (TE) as a function of diverse fibre behaviour under compressive loading. Failure mechanism of the tubes was analyzed from high resolution photographs obtained during test. As expected, GF/B. mori/Epoxy hybrid tubes performed better in load carriability and energy attenuation, while B. mori tubes performed better in progressive crushing failure behaviour. Deformation morphology suggests micro to macro cracks, tear propagation, delamination and collapse.

Keywords: Hybrid composite, Glass fibre, Natural fibre
Preparation and Resistance Welding of Continuous Glass Fiber Reinforced Poly (Arylene Sulfide Sulfone)

Yang Jiacao¹, Wang Xiaojun²*, Zhang Gang², Zhang Meilin², Long Shengru², Wei Zhimei², Yin Bo¹, and Yang Jie²,³*

¹College of Polymer Science and Engineering, Sichuan University, Chengdu, China
²Analytical & Testing Center, Sichuan University, Chengdu, China
³State Key Laboratory of Polymer Materials Engineering, Sichuan University, Chengdu, China

*Email: wangxj@scu.edu.cn; ppsf@scu.edu.cn

Abstract

With the excellent mechanical properties, electrical properties and outstanding heat resistance, flame resistance and chemical resistance, Poly(Arylene Sulfide Sulfone) (PASS) have great potential in the application in many fields in the form of composite matrix. However, the high melt viscosity of PASS limits its processability. In this study, the preparation of continuous glass fiber reinforced PASS composite via solution impregnation method was investigated, and the preparation parameters were optimized by using Taguchi method. The largest tensile strength of glass fiber cloth reinforced PASS composite reached 284 MPa. Due to the excellent heat resistance of matrix, continuous fiber reinforced PASS composites displayed remarkable strength retention ratio at high temperature. The strength and modulus of composites retain 77 anFusion bonding of PASS/GFC composites was achieved via resistance implant welding using the carbon fiber cloth as heating element. With the help of Taguchi method and ANOVA analysis, the optimal welding parameters were obtained, 50 kW/m², 3 MPa, 3 min for welding power, pressure and time respectively. Interlaminar shear strength of welding parts prepared with this process parameters was 6.6 MPa.

Keywords: Poly(Arylene Sulfide Sulfone), Glass Fiber Cloth, Composite, Resistance Welding

Fig. 1 (a) Scheme of the preparation of continuous fiber reinforced PASS composite; (b)SEM image of the fracture surface of composite.
Simultaneous Enhancement and In-Situ Sensing of GF/Epoxy Interface via the Built-In MWCNT Interphase Sensor

Bin Yang*, and Kang Yang

School of Mechanical and Power Engineering, East China University of Science and Technology, Shanghai, China
*Email: angbin@ecust.edu.cn

Abstract

The unpredictable damage originated from interfacial debonding seriously threatens the service reliability of glass fiber (GF) reinforced polymer molecules composites. The paper presents an effective technology to enhance the interfacial shear strength (IFSS) and simultaneous in-situ monitoring the interphase based on the built-in multi-wall carbon nanotubes (MWCNT) sensor. By incorporating MWCNT into the composite interphase, the bonding strength was enhanced. In combination with simultaneous resistance measurements, the interphase behaviour during fiber-bundle pull-out test was monitored. Resistance of MWCNT sensor shows a linear dependence on GF yarn length and depends on MWCNT solution concentration, ultrasonic dispersion duration as well as immersion cycle. Effect of GF yarn immersion cycle on the IFSS was mainly considered. The interphase sensor can be used for in-situ sensing the accumulated interphase damage process due to the applied external stresses without harming the inherent IFSS.

Keywords: Glass fibers, Debonding, Non-destructive testing
Session: Glass Fibres Composites  
Comp-8-2-O4

Tensile and Fatigue Behavior of Multi-Nail Riveted GLARE in Hygrothermal Environments

Kai Jin\textsuperscript{1,*}, Huaguan Li\textsuperscript{2}, Jingming Tian\textsuperscript{2}, and Jie Tao\textsuperscript{2}

\textsuperscript{1}College of Mechanical and Electrical Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China

\textsuperscript{2}College of Material Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 211106, China

*Email: jinkai@nuaa.edu.cn

Abstract

An investigation focusing on the hygrothermal aging-structure damage-mechanical property relationship of multi-nail riveted GLARE was conducted. GLARE 2A (unidirectional fibres $0^\circ /0^\circ$) and GLARE 3 (orthogonal fibres $0^\circ /90^\circ$) were treated with 80\(^\circ\)C and 90\%RH for 1000h in the temperature and humidity chamber. It was found that the tensile strength reduced more than 20\% due to aluminium alloy rivets corrosion fracture and the coupling effect of moisture and heat. Both sheet failure and rivet shear failure existed in tensile testes of GLARE 2A. Only sheet failure appeared in the outermost rivet line. The tensile strength of GLARE 3 was 75\% that of GLARE 2A due to the rivets bearing and transmitting tensile stresses. In the fatigue testes, the fatigue age of GLARE 3 was much shorter than GLARE 2A as stress levels increased no matter whether in hygrothermal environments. There was a linear correlation between the attenuation of fatigue age and stress level. But the fatigue age under hygrothermal environment decreased almost the same in every stress level.

Keywords: GLARE, Riveting, Hygrothermal aging, Fatigue

\textbf{Fig. 1} Fatigue failure modes of GLARE 2A under different stress levels in the hygrothermal environment: (a)70\%F\textsubscript{b}; (b)55\%F\textsubscript{b}; (c)40\%F\textsubscript{b}. 
Design of Mwcnt–Glass Fiber Fabric Reinforced Epoxy Composites with Multifunctionality

Mingxia Shen*, Shaohua Zeng*, Yijiao Xue, and Lu Yang

College of Mechanics and Materials, Hohai University, Nanjing 211100, China

*Email: mxshen@hhu.edu.cn; shzeng@hhu.edu.cn

Abstract

A multiscale preform wherein varied multi-walled carbon nanotubes (MWCNT) contents were grafted to the commercial glass fiber fabric (GFf) was prepared through a simple yet cost-effective method. This design of MWCNT-GFf preforms was to obtain the well-dispersed MWCNT and to ultimately yield the MWCNT-GFf reinforced epoxy composites with multifunctionality. The experimental results showed that the MWCNT anchored on the fiber surface could not only provide the mechanical interlocking with matrix but also conduct stress, heat and electricity. Under an optimal dispersion condition of MWCNT, the interlaminar shear, tensile and flexural strength of MWCNT-GFf reinforced epoxy composites were improved by 40.5%, 33.2% and 29.9%, respectively; thermal conductivity was raised by 55.3%; meanwhile, the electrical surface resistance decreased by about 2 orders, as compared with those of pure GFf composite. In addition, the glass-transition temperature significantly increased, indicating superior thermal stability of resultant composites.

Keywords: Polymer-matrix composites, Carbon nanotubes, Glass fibers, Nano-structures, Multiscale
Flexural Performance of Steel and Glass Fibre Reinforced Geopolymer Mortars
Jacob Junior, Pradip Nath, and Prabir Sarker*

School of Civil and Mechanical Engineering, Curtin University, Western Australia
*Email: p.sarker@curtin.edu.au

Abstract
Fibre reinforced geopolymer mortar (FRGM) was prepared using alkali to fly ash ratio of 0.6, sand to fly ash ratio of 2.75 and 1% volume ratio of short steel or glass fibres. Fibres did not affect significantly the flow of fresh geopolymer mortar. Compressive strengths of heat-cured mortars were 48 MPa for no fibre or 1% glass fibre, and 52 MPa for 1% steel fibre. Flexural tests were conducted on 300 mm × 75 mm × 20 mm specimens under four-point loading. The average peak flexural strengths of the control mortar, and glass and steel FRGMs were 4.1 MPa, 6.0 MPa and 4.4 MPa, respectively. Steel fibres showed better load-deflection performance than glass fibres after the first crack, though failure occurred by fibre pull-out in both cases. The average ASTM C1018 toughness indices I5, I10 and I20 of steel FRGM were 6, 12 and 26, respectively. Toughness of the glass FRGM was less because of low dispersion of fibres into individual filaments. Thus, geopolymer mortar reinforced with 1% short steel fibre exhibited deflection hardening behaviour due to its uniform dispersion and adequate bonding with geopolymer mortar.

Keywords: Geopolymer mortar, Fibre reinforcement, Flexural strength, Toughness
Elastomers Reinforcement Using Cellulose Nanofibre
Nasim Amiralian*, Alireza Hosseinmardi, Benoit Martine, Pratheep Kumar Annamalai, Darren Martin*

*Email: n.amiralian@uq.edu.au; Darren.martin@uq.edu.au

Abstract
The successful strengthening of natural rubber latex without compromising its compliance and toughness is currently limited by the availability of a more flexible high aspect ratio, strong and tough nanofiller.

Herein we address this challenge by producing very high aspect ratio, flexible and hydrophobic cellulose nanofibers from spinifex, where the residual lignin and hemicellulose polymers are shown to be advantageous. The effective reinforcement of a high-quality industrial grade pre-vulcanised natural rubber latex was demonstrated, where the incorporation of only 0.1 wt. % of high aspect ratio hydrophobic spinifex cellulose nanofibers was shown to improve the tensile strength by 17%, coupled with negligible stiffening and loss of elongation at break (Fig1). This behaviour is attributed to the high remnant hemicellulose and lignin in spinifex nanofibers, which not only provide a higher flexibility and toughness to the nanofibres, but also improve the nanofiller-latex compatibility, colloidal stability and ultimately the toughness of the natural rubber films. These findings will advance work towards the production of ultra-thin and strong natural rubber membranes for condom and glove applications, where the retention of membrane compliance is a critical factor.

Keywords: Cellulose nanofibre, Nanocomposite, Elastomer, Spinifex

Fig. 1 Reinforcement of natural rubber latex with spinifex-derived cellulose nanofibres.
Session: Natural Fibres Composites
Comp-11-1-I2

Introduction of Anisotropic Properties in Nanocellulose Composites by Stretching
Hitoshi Takagi1*, Antonio N. Nakagaito1, and Yuya Sakaguchi2

1Graduate School of Technology, Industrial and Social Sciences, Tokushima University, Tokushima 770-8506, Japan
2Graduate School of Advanced Technology and Science, Tokushima University, Tokushima 770-8506, Japan
*Email: takagi@tokushima-u.ac.jp

Abstract
Nanocellulose fibers (NCFs) have drawn many researchers’ interest and attention. It has been reported that the NCFs have excellent mechanical properties, e.g., Young’s modulus of about 140 GPa and tensile strength of approximately 2-3 GPa. These excellent mechanical properties of NCFs are comparable to those of glass fibers, indicating the practical possibility as reinforcement in polymer nanocomposites. However, the tensile strength reported for the NCF-reinforced polymer composites is low, and much lower than expected. There are several reasons for the low mechanical properties; one of the dominant reasons is the fiber alignment of NCFs, namely NCFs are randomly dispersed in the polymer matrix. In this study we tried to control the NCFs’ orientation by applying a mechanical stretching treatment. In this mechanical stretching treatment, the fiber alignment of NCFs in matrix can be controlled by applying uniaxial straining treatments. The effectiveness of the proposed fiber alignment control has been demonstrated experimentally; the tensile strength of the NCF-reinforced composites after the stretching treatments has almost the two-fold value as compared to that of the untreated ones.

Keywords: Fiber alignment, Green composites, Nanocellulose fiber, Nanocomposites, Stretching treatment
Polyphenol-Induced Cellulose Nanofibrils Anchored Graphene Oxide/Carbon Nanotube as Sacrificial Nanohybrids Toward Strong Yet Tough Soy Protein Nanocomposites

Zhong Wang¹,², Jianzhang Li¹,², and Shifeng Zhang¹,²*

¹MOE Key Laboratory of Wooden Material Science and Application, Beijing Forestry University, Beijing 100083, China; ²Beijing Key Laboratory of Wood Science and Engineering, Beijing Forestry University, Beijing 100083, China

*Email: Shifeng.zhang@bjfu.edu.cn

Abstract

Network-nanostructured cellulose nanofibrils (CNFs) is a promising template onto which to anchor and expand 1D/1D nanoparticles. It is still a huge challenge to regulate the dispersion/interface toward strong yet tough hybrid materials. We reports a novel design for interface anchoring graphene oxide (GO) nanosheets or carbon nanotubes (CNTs) with TEMPO-oxidized CNFs that is induced by the self-polymerization of catecholamine-based tannic acid. The high-functionality nanohybrids were investigated as both physical and chemical cross-linkers to the natural plant-derived soy protein isolate (SPI) based films, which facilitate multiple interfacial adhesion and a metal-ligand bonded network between the SPI matrix and nanosheets bearing poly (tannic acid) adhesion layers. Upon stretching, this tailored coordination bonds served as sacrificial bonds that preferentially detach prior to the covalent network, which gave rise to efficient energy dissipation that the nanocomposites integrity was survived. As a result of these kind of synergistic interfacial interactions (sacrificial and covalent bonding), the optimal nanocomposite films processed high tensile strength, large elongation, remarkable toughness, and favorable water resistance as well as electrical conductivity. The proposed method may represent a facile and environmentally-friendly approach to integrate multi-nanoscale building blocks into biopolymers with strong yet tough mechanical properties.

Keywords: cellulose nanofibrils, mussel byssus-inspired, sacrificial bonds, mechanically strengthening and toughening, plant protein

Fig. 1 Schematic diagram of preparation and proposed interactions mechanism of SPI/PCT/CNFs nanocomposite films.
Fracture Mechanism under Tensile Loading for Bowing Natural LFT Composites

Junji Noda\textsuperscript{1*}, Syotaro Hiramatsu\textsuperscript{2}, and Koichi Goda\textsuperscript{2}

\textit{1Kindai University}

\textit{2Yamaguchi University}

*Email: nodaj@waka.kindai.ac.jp

Abstract

The objective of this study is to clarify the reinforcing and fracture mechanism of bowing natural LFT composites. At first, the bowing natural fibers were classified to some patterns in geometry and investigated these distributions using the X-ray computed tomography. The bowing and inclined fibers exist near surface of the injected specimens as shown in Fig. 1. It was reported that in the case of glass fibers, the inclined fibers exist near center of the specimens\textsuperscript{1}. The difference of fiber geometry was derived from the fracture strain of fibers. Using the bowing fiber frequency distributions and classification, the Young’s modulus was well predicted based on the rule of mixtures. Then, many initial crack observations for bowing natural LFT composites using scanning electron microscope were carried out, and the finite element analyses using these SEM images were conducted as shown in Fig. 2 in order to investigate the fracture mechanism of fiber breakages, matrix crack and interfacial crack between fiber and matrix. Consequently, it was considered that the bowing structure in natural fiber composites has an effect on the occurrence of mixture mode crack with mode I and II for interfacial crack.

Keywords: natural fiber composites, LFT, initial crack, finite element analysis

![Fig. 1 Comparison of fiber morphologies between glass fiber and natural fiber LFT.](image)

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The Properties of Plant Fiber Reinforced Poly(Lactic Acid) Composites in The Simulated Environment

Tao Yu¹,³*, Guodong Su²*, Ding Ding¹, Ning Jiang¹, Hongyu Pan¹, and Yan Li¹

¹School of Aerospace Engineering and Applied Mechanics, Tongji University, Shanghai, China
²College of Chemical and Material Engineering, Quzhou University, Quzhou 324000, China
³State Key Laboratory for Strength and Vibration of Mechanical Structures, Xi’an Jiaotong University, Xi’an 710049, China

*Email: yutao@tongji.edu.cn; suguodong1976@126.com

Abstract

Plant fiber reinforced composites have received more and more attentions due to the good degradation and mechanical properties, which is expected to partly replace traditional composites materials and used in aircraft interior, automotive interior and electronic product packaging, etc. The durability of plant fiber/poly(lactic acid) (PLA) should be demonstrated during their service life. In this paper, the influence of several typical simulated environments (including hydrothermal, salt, alkali and fungi) on the water absorption behaviour and the mechanical properties of plant fiber/PLA composites will be studied. The change mechanism of plant fiber/PLA composites will be discussed according to the results of by using scanning electronic microscopy (SEM), differential scanning calorimetry (DSC) and gel permeation chromatography (GPC) etc, which will provide the theory basis for the application of plant fiber/PLA composites.

Keywords: plant fiber, poly(lactic acid), simulated environment, water absorption, mechanical

Fig. 1 Water absorption of plant fiber/PLA composites in the hydrothermal environment with different temperature.
Single Fiber Tensile Properties Model for the Fiber Infected by Aspergillus Niger Based on Enzyme Kinetics

Ding Ding 1, Tao Yu 1,2*, and Yan Li 1,3*

1School of Aerospace Engineering and Applied Mechanics, Tongji University, 200092, China
2State Key Laboratory for Strength and Vibration of Mechanical Structures, Xi’an Jiaotong University, Xi’an 710049, China
3Key Laboratory of Advanced Civil Engineering Materials, Ministry of Education, Tongji University, Shanghai 200092, China

*Email: yutao@tongji.edu.cn; liyan@tongji.edu.cn

Abstract

Jute fibers were infected by Aspergillus niger through the method of in vitro experiments with specific microorganisms. Growth state of fungi and surficial status of fibers were observed by the optical microscope (OM) and scanning electron microscope (SEM) which were shown in Fig 1. Tensile strength (TS) and tensile modulus (TM) of original fibers and infected fibers were tested in the standard of ASTM D3379. Weibull distribution function was used to analyze and validate tensile properties of jute fibers1,2.

Considering the component of jute fibers, cellulase, hemicellulase, pectinase and ligninase were the main enzyme taken to calculate in this study. The inactivated time of the enzyme was calculated through ‘one step’ deactivation kinetics model based on the testing results of original enzyme activity3. Michaelis-Menten equation in kinetics model of homogeneous enzymatic reaction were used to calculate conversion rates (CR) of product which would be taken as a conversion parameter of theoretical model of TS and TM.

Through comparison, the testing results can match theoretical calculation of TM and TS which proved the correction and effectiveness of this model.

Keywords: Plant fiber, Tensile properties, Enzyme kinetics

Fig. 1 Optical microscope & SEM: (a) Aspergillus niger spore (b)infected fiber through optical microscope (c)original fiber (d) infected fiber through SEM.
Mechanical and Thermal Behaviour of Ecofriendly Chemical Treated Natural Fibre Reinforced Polymer Composites

Ujendra Kumar Komal* and Inderdeep Singh*

Department of Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, 247667, India
*Email: ujendrakomal@gmail.com; dr.inderdeep@gmail.com

Abstract

In the current research endeavour, the effect of ecofriendly chemical treatment of Banana and Pineapple fibres prior to their incorporation into Polypropylene has been explored. Composites incorporating Banana and Pineapple fibres (20% w: w) treated with ecofriendly sodium bicarbonate (10% w: v) aqueous solution for varying time periods (48, 72 and 96 hours) were developed using extrusion-injection moulding processes. The single fibre strength test was conducted to examine the effect of chemical treatment on the tensile properties of the fibres. Thermo-gravimetric analysis and morphological observation established the gradual removal of hemicellulose and other non-cellulosic substances from the surface of fibres with increasing treatment time. The mechanical properties (tensile, flexural and impact) of composites incorporating Banana and Pineapple fibres treated for 72 hours were found to be maximum. The optimum results were found comparable or even more compared to sodium hydroxide and potassium permanganate treated Banana and Pineapple fibres reinforced Polypropylene composites. A significant improvement in the mechanical and thermal properties revealed that the ecofriendly sodium bicarbonate treatment offers huge potential to be used as substitute for the various environmental hazardous chemical treatments for ensuring good mechanical and thermal properties.

Keywords: Banana, pineapple, ecofriendly, chemical treatment, mechanical properties

Fig. 1 The effect of chemical treatment on flexural properties of Banana and Pineapple fibres reinforced composites.
Natural Wood Derived Fibrous Materials with Multi-Functionalization
Detao Liu*, and Meiyan Lin
South China University of Technology
*Email: dtliu@scut.edu.cn

Abstract
Fibrous biocomposites, aiming to green and low-carbon in raw material, manufacturing process and application, is regarded as one of the most important part of composite materials in today's world. It obvious that it should adhere to research low dimension materials with green and explore ultra-high performance, multifunctional and intelligentized new materials in many developed markets. This paper mainly reviews that the innovative preparation of high performance micro/nanofibers using the plant fibers as the raw materials and their application in optical, acoustic, electrical and insulating composite material. We also have discussed these functional composite materials via the preparation process, process condition, structure and performance. These functional micro/nano biocomposites shows to be very promising attractions in markets, which can be used as the flexible electronic devices, optical film, building materials, packaging and other fields.

Keywords: Wood fibrous composites, Nanofibers, Green fabrication technology, Functional applications
Abstract
Recently, pineapple leaf fiber (PALF) is becoming more popular in cellulose based fibre composite materials. PALF is found to be very attractive as its physical and mechanical properties are high without treatment or additional process. This research work is about comparing various fiber loading of PALF in various content of blended Jatropha bio-epoxy as matrix in order to compete with carbon and glass fiber. PALF was found in literature to be four (4) time lesser in tensile strength compare to carbon fibre, but comparable tensile strength compare to glass fibre. This experiment results showed higher PALF fibre loading gave higher mechanical strength, but higher amount of Jatropha bio-epoxy led to lower mechanical performance. PALF with 25% of Jatropha bio-epoxy exhibited comparable mechanical strength compare to glass and carbon fibre with Jatropha bio-epoxy. These conclude that higher PALF loading with right amount of Jatropha bio-epoxy could compete with carbon and glass fibre composite in term of mechanical performance.

Keywords: Pineapple Leaf Fibre (PALF), Jatropha, Bio-epoxy, Tensile, Bio-composite
Yarn Characteristics and Tensile Properties of Kenaf Fiber for Technical Textile Reinforced Composites

S A S Abdullah1*, K D Mohd Aris1, N Z M Zuhudi1, MN Roslan2, M D Isa1

1Universiti Kuala Lumpur, Malaysian Institute of Aviation Technology, 43800 Dengkil, Selangor, Malaysia
2Faculty of Mechanical & Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, Malaysia

*Email: shadlina@gmail.com

Abstract

A major barrier to the growth of industrial-scale development of bio-composites is the inadequate supply of proper reinforcement form of natural fiber. Adapting the textile technology, kenaf fibers are blended with cotton to form continuous yarn via ring-spinning process. Tenacity of kenaf yarn under the influence of pre-treatment conditions of sodium hydroxide (NaOH) and kenaf-cotton ratio was investigated. NaOH at 6% concentration increases the strength of yarn by increasing both kenaf fiber strength and cohesive forces between the fibers. From statistical analysis, kenaf-cotton ratio contributes 37.6%, and NaOH concentration contributes 25% to the tenacity of kenaf/cotton yarn. The interaction between kenaf-cotton ratio and NaOH concentration gives a high contribution of 26.4%. Kenaf yarn with optimized mechanical strength will lead to the development of unidirectional or woven kenaf for high performance bio-composites.

Keywords: Kenaf yarn, Kenaf-cotton yarn, Alkalisation, Blend proportion

Fig. 1 Single yarn of NaOH 6% with ratio of (a) 30/70 (b) 40/60 (c) 50/50.
**Fabrication and Mechanical Properties of PP Based Empty Fruit Bunch (EFB) Composites**

H. Azhari1, K. Sakamoto1, A. Nordin2, K. Goda3, M. Okamoto4, H. Ito5, T. Endo5

1Graduate School of Science and Technology for Innovation, Yamaguchi University, Japan  
2Universiti Teknikal Malaysia, Melaka, Malaysia  
3Department of Mechanical Engineering, Yamaguchi University, Japan  
4Technology Develop Center, TOCLAS Co., Japan  
5Chugoku Center, National Institute of Advanced Industrial Science and Technology, Japan  
*Email: hanisbalqisma@gmail.com*

**Abstract**

Oil palm tree is one of the most efficient oil seed crops. Throughout the process to obtain palm oils, abundant amount of waste such as kernel, mesocarp fiber and empty fruit bunch (EFB) is produced. In addition, fronds and trunks are also produced as waste. It is said that there are higher amount of waste, approximately 90% from palm oil production(1). Thus, this study is to investigate if EFB fiber can be applied as a reinforcement material instead of wood flours which is usually used for wood plastic composites (WPC).

In order to produce Palm/PP composite, first EFB fiber was pulverized into 0.2mm, then classified into three different size ranges, ~45 μm (S), 45~90 μm (M) and 90~180 μm (L) by sieving. Next, the composites of PP were fabricated at 190°C in an extruder with screw speed of 30rpm. Finally, extruded materials were injected into injection mold to prepare test specimens. In this study, tensile, fatigue and impact tests were conducted. These test results were then compared with WPC. It is concluded from the test results shown in Tables 1 and 2 that Palm/PP composites show slightly less tensile and fatigue strengths than WPC, but have almost the same impact strength level as WPC.

**Keywords:** Palm oil fiber, Wood fiber, Empty fruit bunches, Polypropylene, Composites
Melt-Viscosity and Mechanical Behaviour of Pulverized Wood Flour Reinforced Polypropylene Composites

Md Minhaz-Ul Haque¹²*, Koichi Goda¹*, Hirokazu Ito³, Shinji Ogoe⁴, Masaki Okamoto⁴, Tomoyuki Ema⁴, Keiko Kagawa⁴, Hidetaka Nogami⁵

¹ Department of Mechanical Engineering, Yamaguchi University, 2-16-1 Tokiwadai, Ube, Yamaguchi, 755-8611 Japan
²Department of Applied Chemistry & Chemical Engineering, Islamic University, Kushtia-7003, Bangladesh
³Cellulose Materials Group, National Institute of Advanced Industrial Science and Technology, 3-11-32 Kagamiyama, Higashihiroshima, Hiroshima 739-0046, Japan.
⁴Technology Development Center, TOCLAS Co., 1370 Nishiyama-cho, Nishi-ku, Hamamatsu, Shizuoka 432-8001, Japan
⁵Okayama Prefectural Research Institute for Forest and Forest Products, 1884-2 Katsuyama, Maniwa, Okayama 717-0013 Japan

*Email: minhaz1978@gmail.com; goda@yamaguchi-u.ac.jp

Abstract

The purpose of this study is to investigate the pulverization effect of wood flour (WF) with and without water to the melt-viscosity and mechanical behaviour of polypropylene (PP)/WF composites. Different types of wood flour were pulverized, mixed as reinforcement (70 wt%) with PP matrix to produce a masterbatch, diluted to 25 wt% by adding more PP in an extruder, finally, injection molded to obtain test specimens. PP/WF composites with pulverised wood flour with water exhibited higher melt-viscosity compared with that of initial WF and pulverized WF without water reinforced PP composites. Higher melt viscosity of pulverised wood flour with water reinforced PP composite indicated the presence of fibrillation on the WF particles and thus occurrence of more interfacial interaction between WF and PP matrix. Fibrillation on WF particle surfaces was also verified by electron microscopy. Izod impact test results of unnotched specimens showed that the composites reinforced with pulverized WF with water had higher impact energy. Depending on the type of initial WF particle, the positive effect of pulverization of WF with water on the tensile strength and fatigue life of the composites was also observed.

Keywords: Composites, Mechanical properties, Melt-viscosity, Pulverization, Wood flour
Wood Fiber (Wf)/Micro-Encapsulated Phase Change Material (Mepcm)/High Density Polyethylene (Hdpe) Thermally Conductive Composite

Pei-Tian Chen*, and Yeng-Fong Shih*

Department of Applied Chemistry, Chaoyang University of Technology, No. 168, Jifeng E. Rd., Wufeng District, Taichung 41349, Taiwan
*Email: woine.2020@yahoo.com.tw; syf@cyut.edu.tw

Abstract
In this study, a novel phase change material (PCM) microcapsule possessing a thermally conductive was prepared by mini-suspension polymerization. The vinylsilane compound is polymerized with the acrylic monomer to first form a copolymer, with the thermally conductive nano-graphite subsequently added, and then the PCM microcapsule with the paraffin core and the thermally conductive material-containing copolymer as the shell is prepared. This modified PCM microcapsule can accelerate the rate of PCM to release or absorb heat so that it can effectively achieve the functions of heat conduction, heat dissipation and energy storage. The results of thermal analysis and structure identification showed that the prepolymer was successfully synthesized, and the amount of paraffin in the microcapsules was more than 50%. After 50 cycles, the thermal stability still remained good. In addition, it is shown that the addition of 3% thermally conductive PCM microcapsule (MEPCM) to wood fiber/high density polyethylene composite can increase the thermal conductivity of the material by 25%. Moreover, the addition of MEPCM can increase the thermal stability and char yield of the material.

Keywords: Microcapsules, Phase change materials, Nano-graphite, Wood fiber

Fig. 1 Microstructure of PCM microcapsule (a) Optical microscope (b) TEM.
A Comparative Study Characterising Natural Fibre Fabric Permeability

Asanka P Basnayake¹*, Van T Nguyen², and Michael T Hietzmann³

¹School of Mechanical and mining Engineering, The University of Queensland, Australia
²School of Civil Engineering, The University of Queensland, Australia
³School of Mechanical and mining Engineering, The University of Queensland, Australia

*Email: p.basnyake@uq.edu.au

Abstract

The study of permeability is important when considering liquid composite moulding (LCM) techniques such as resin transfer moulding (RTM) and vacuum assisted resin transfer moulding (VARTM). Permeability indicates the comparative ease with which resin is transported through the pores of a porous medium. Therefore, when selecting reinforcement fabrics for RTM and VARTM processes, knowledge of the permeability as a function of pressure is crucial. While some researchers have studied permeability of natural fibre composites, there is limited research that considers a combination of all factors that impact permeability. The investigations by Bensadoun et al and Swery et al, are two comprehensive studies of permeability characterisation.

Our work builds on these two studies. We have further developed the proposed methodology and experimental setup and performed a comprehensive investigation of natural fibre and hybrid glass/natural fibre non-woven fabrics. The results provide an insight into the compaction behavior of various non-woven mats, the nexus between compaction pressure and permeability and the influence of fibre choice and mat architecture. We will also discuss how the developed methodology can be used to determine achievable fibre volume fraction limits without the need for lengthy manufacturing trials.

Keywords: Permeability, non-woven fabrics, resin transfer moulding

Fig. 1 Modified permeability test setup.

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Development of Multifunctional Electronic Devices Based on Natural and Carbon Materials

Hamid Souri1*, and Debes Bhattacharyya1

Centre for Advanced Composite Materials, Department of Mechanical Engineering, The University of Auckland, Auckland, New Zealand, 1142

*Email: hsou970@aucklanduni.ac.nz

Abstract

The demand for stretchable and flexible multifunctional devices based on conductive nanomaterials is rapidly increasing due to their possible interesting applications including human motions detection, robotics, human-machine interface1,2. There still exists a great challenge to manufacture these devices through a scalable and cost-effective fabrication method. Herein, we present the development of multifunctional electronic devices based on biodegradable natural materials and carbon particles through a simple and mass-producible method1. Conductive natural materials in the form of yarns or fabrics are then incorporated into a highly stretchable elastomer to be utilized strain sensors and heaters (Figure 1). The electromechanical performance of the developed devices establish their potential application as strain sensors with high sensitivity (gauge factors up to about 102000) for monitoring various human motions, sound wave recognition, and sensitive pressure sensors with high durability. Furthermore, the electrothermal characteristics of the devices show their efficient performance working at high temperature (about 100 °C) with low input power1. Considering the simple fabrication process, cost-effectiveness, and environment friendliness of our multifunctional devices, we believe that they can contribute to the development of industrial fields related to the flexible electronics.

Keywords: Multifunctional device, Flexible and stretchable strain sensors, Carbon particles, Human motions detection, Flexible heating elements

Fig. 1 Photographs of our devices: a) wearable strain sensors based on conductive flax yarns (taken from souri et. al. Copyright 2018 Elsevier); b) a wearable strain sensor and heating element based on wool fabric (taken from souri et al.3 Copyright 2018 American Chemical Society); c) highly sensitive strain sensor based on fragmented cotton fabric(taken from souri et al.).
In Situ Tem Study on Sub-10nm Materials
Litao Sun$^{1,2,3}$

$^1$SEU-FEI Nano-Pico Center, Key Lab of MEMS of Ministry of Education, Nanjing, China
$^2$Center for Advanced Materials and Manufacture, Joint Research Institute of Southeast University
$^3$Monash University, Suzhou, China
*Email: slt@seu.edu.cn

Abstract
With the development of semiconductor technology, the 10 nm feature size of fabrication is approaching. It is thus quite essential to explore more precise nanofabrication and characterization method to evaluate the shape/structure stability and possible new properties of sub-10-nm material components, especially under external field such as strain, electric, or thermal fields. Here we review our recent progress in atomic resolution nanofabrication and dynamic characterization of individual nanostructures and nanodevices based on the idea of "setting up a nanolab inside a transmission electron microscope". The electron beam can be used as a tool to induce nanofabrication on the atomic scale. Additional probes from a special-designed holder provide the possibility to further manipulate and measure the electric/mechanical properties of the nanostructures in the small specimen chamber of a TEM. Recently, the optical signal also was introduced into the electron microscope to enrich the coverage of investigation inside the “multifunctional nanolab”. All phenomena from the in-situ experiments can be recorded in real time with atomic resolution.

Keywords: In situ, electron microscopy, Sub-10nm materials, Surface

Fig. 1 Schematic diagram of electrically driven cation exchange for in-situ fabrication of individual nanostructures.
Vertically Aligned Graphene Aerogels for Thermally Conductive Polymer Nanocomposites
Zhongzhen Yu1*, Xiaofeng Li1, and Xinghua Li2
1Beijing Key Laboratory of Advanced Functional Polymer Composites, College of Materials Science and Engineering, Beijing University of Chemical Technology, Beijing 100029, China
2Aerospace Research Institute of Materials & Processing Technology, Beijing 100076, China
*Email: yuzz@mail.buct.edu.cn

Abstract
Vertically thermally conductive polymer composites with satisfactory mechanical performances are highly required for practical thermal management applications as thermal interface and exchange materials. Herein, all-graphitized graphene aerogels with highly aligned graphene network are fabricated with graphene oxide hydrogels as the precursor by a directional-freezing, freeze-drying, and graphitization at 2800 °C, which exhibit excellent thermal and electrical conductions and super-elasticity (Fig. 1). Thanks to the vertically aligned conductance network composed by the graphitized graphene sheets, an epoxy composite with only 0.75 vol% of the high-quality graphene exhibits an excellent vertical thermal conductivity of 6.57 W/(mK), which is among the highest through-plane thermal conductivities of polymer composites with similar loading of carbon nanofillers, and ~37.6 times higher than that of neat epoxy matrix. The thermally and electrically conductive composite also possesses greatly improved storage modulus, compressive strength and compressive strain at break.

Keywords: Anisotropic graphene aerogels, Thermal conductivity, Electrical conductivity, Thermal interface composites, Directional freezing

Fig. 1 (a) Schematic illustrating the fabrication of vertically aligned graphene aerogels with different pore dimensions by using different directional-freezing rates. The copper disks with the graphene hydrogels have (1) no contact, (2) indirect contact via a copper cylinder, and (3) direct contact with the liquid nitrogen. (b) Vertical- and horizontal-direction thermal conductivities of epoxy/TAGA-2800 with different directional-freezing rates and different TAGA contents.
Session: Graphene based nanocomposites
Comp-9-1-13

Hierarchical Graphene Oxide/Silicone Coatings on Combustible Materials for Efficient Flame Detection and Early Warning Application

Long-Cheng Tang\textsuperscript{1,2,*}, Qian Wu\textsuperscript{1}, Li-Xiu Gong\textsuperscript{1}, Yong-Jin Li\textsuperscript{1}, Yiu-Wing Mai\textsuperscript{2}

\textsuperscript{1}Key Laboratory of Organosilicon Chemistry and Material Technology of Ministry of Education, Hangzhou Normal University, Hangzhou 311121, PR China

\textsuperscript{2}Centre for Advanced Materials Technology (CAMT), School of Aerospace, Mechanical and Mechatronic Engineering J07, The University of Sydney, Sydney, NSW, 2006, Australia

*Email: lctang@hznu.edu.cn

Abstract

Fire prevention and safety of combustible materials is a global challenge. To monitor their high fire risk, smoke detectors are widely used indoor via detecting smoke product after combustion; however, they show a long response time of $>100$ s and limitation in outdoor use. Herein, we describe the fabrication of hierarchical coatings created by assembling a multilayered graphene oxide (GO)/silicone structure onto different combustible substrate materials. The resulting coatings exhibit distinct temperature-responsive electrical resistance change as efficient early warning sensors for detecting abnormal high environmental temperature, thus enabling fire prevention below the ignition temperature of combustible materials. After encountering a flame attack, we demonstrate extremely rapid flame detection response in 2-3 s and excellent flame self-extinguishing retardancy for the multilayered GO/silicone structure that can be synergistically transformed to a multiscale graphene/nanosilica protection layer. The coatings can also be readily implemented on different combustible substrate materials where fire safety is critically required. The hierarchical coatings developed are promising for fire prevention and protection applications in various critical fire risk and related outdoor perilous circumstances.

Keywords: Hierarchical coating, Graphene oxide, Silicone, Fire detecting and warning sensor, Flame retardancy

\textbf{Fig. 1} (a) Fabrication of hierarchical GO/silicone coatings on combustible PU foam, (b) vertical burning test of PU-SGF and (c) flame detection process of the PU-SGF sample.
Enhancement in Interfacial Adhesion of Ti/Polyetheretherketone by Electrophoretic Deposition of Graphene Oxide

Lei Pan*, Yunfei Lv, and Jie Tao

College of Material Science and Technology, Nanjing University of Aeronautics and Astronautics, 210016 Nanjing, China

*Email: bettypan@nuaa.edu.cn

Abstract

This paper discusses the significance of graphene oxide (GO) deposition on a titanium plate surface by electrophoretic deposition to improve the adhesive strength of Ti/polyetheretherketone (PEEK) interfacial adhesive. First, the anodic electrophoretic deposition method was applied to a water dispersion solution of GO, and then the morphology and properties of titanium plate surface were characterized by SEM and contact angle measurements before and after the GO deposition. Furthermore, the changes in the properties of GO after heating at 390 °C were characterized by Raman and FTIR spectroscopies. According to the results of single lap tensile shear test, the adhesion strength of Ti/PEEK interface after the anodization and deposition of GO was 34.94 MPa, an increase of 29.2% compared to 27.04 MPa of only anodized sample. Furthermore, the adhesion strengths were 58.1% and 76.5% higher compared to that only deposited with GO (22.1 MPa) and pure titanium (19.8 MPa), respectively.

Keywords: Ti/PEEK, Interfacial adhesive, GO, Electrophoretic deposition

Fig. 1 FTIR spectra of GO.
Session: Graphene based nanocomposites
Comp-9-1-O2

Significant Improvement of Electromagnetic Interference Shielding Efficiency for Epoxy Nanocomposites via Incorporating Binary Hybrid Three-Dimensional Graphene Aerogel

Chaobo Liang¹, Ping Song¹, Hongbo Gu², Kaichang Kou¹, and Junwei Gu¹*

¹MOE Key Laboratory of Materials Physics and Chemistry under Extraordinary Condition, Shaanxi Key Laboratory of Macromolecular Science and Technology, Department of Applied Chemistry, School of Science, Northwestern Polytechnical University, Xi’an, Shaanxi, 710072, P. R. China.
²Shanghai Key Lab of Chemical Assessment and Sustainability, School of Chemical Science and Engineering, Tongji University, Shanghai 200092, P. R. China.
*Email: gjw@nwpu.edu.cn

Abstract
Microstructure design is a crucial factor in determining the performances of polymer nanocomposites. In this study, three-dimensional (3D) porous hybrid graphene aerogel (consisting of graphene nanoplatelets (GNPs) and reduced graphene (rGO))/epoxy nanocomposites (3D GNPs/rGO/Epoxy) were fabricated by filling epoxy monomer using a 3D porous framework. rGO formed a 3D supporting network to keep the shape stable after filling epoxy monomer, and GNPs dispersed along the network structure of rGO uniformly, constructing a conductive pathway. The structural morphology and electromagnetic interference (EMI) shielding effectiveness of 3D GNPs/rGO/epoxy composites were investigated in detail. It was found that the incorporation of GNPs remarkably enhanced the EMI shielding effectiveness of the rGO/epoxy nanocomposites. The obtained 3D GNPs/rGO/epoxy nanocomposite with 0.50 wt% GO and 23 wt% GNPs presented an enhanced EMI shielding effectiveness of around 51 dB in X-band, almost 285% improvement compared with that of rGO/epoxy nanocomposite (13 dB).

Keywords: Graphene aerogel, Electromagnetic interference shielding, Epoxy nanocomposites

Fig. 1 Synthesis Illustrations of 3D Graphene Nanoplatelets/Reduced Graphene Foam/Epoxy Nanohybrids.
Session: Graphene based nanocomposites
Comp-9-1-O3

Significantly Improved Thermal Conductivity of Polyimide Nanocomposites by Chemically Modified Graphene via In-Situ Polymerization and Electrospinning-Hot Press Technology
Yongqiang Guo, and Junwei Gu*

MOE Key Laboratory of Materials Physics and Chemistry under Extraordinary Condition, Shaanxi Key Laboratory of Macromolecular Science and Technology, Department of Applied Chemistry, School of Science, Northwestern Polytechnical University, Xi’an, Shaanxi, 710072, P. R. China
*Email: gjw@nwpu.edu.cn

Abstract
With the rapid advances of light-emitting diodes (LEDs) towards higher integration and miniaturization, heat dissipation is a key factor in restraining their broader applications. Polymeric composites with highly thermally conductive coefficient (λ) have been researched actively to solve these problems. In our work, both aminopropylsobutyl polyhedral oligomeric silsesquioxane (NH2-POSS) and hydrazine monohydrate were utilized to functionalize graphene oxide (GO) and to obtain chemically modified graphene (CMG), which was then used for preparing thermally conductive CMG/polyimide (CMG/PI) composites via a sequential in-situ polymerization and electrospinning-hot press technology. NH2-POSS molecules were grafted on the GO surface, and CMG were obtained by the reaction between NH2-POSS and GO. The λ, glass transition temperature (Tg) and heat resistance index (THRI) of the prepared CMG/PI composites were all increased with increasing the CMG loading. The λ value of the CMG/PI composites with 5 wt% CMG was significantly improved to 1.05 W/mK, about 4 times higher than that of pristine PI matrix (0.28 W/mK). The corresponding Tg and THRI values were also increased to 213.0 and 282.3 °C, respectively. Moreover, a thermally conductive model was proposed and predicted λ more precisely than those obtained from the typical Maxwell, Russell and Bruggemen classical models.

Keywords: Chemical modified graphene (CMG), In-situ polymerization, Electrospinning, Thermally conductive composites, Thermally conductive model

Fig. 1 Schematic diagram of the fabrication for the CMG/PI composites.
Session: Graphene based nanocomposites
Comp-9-2-O4

Improvement of Thermal Conductivity, Mechanical Properties and Insulation of Epoxy-BaTiO3 Composites by GSiCnw

Jing He¹,²,³, Hua Wang¹,³,* Xingyou Tian¹,³,* Yulan Guo¹,²,³, Zheng Su¹,²,³, and Qiqi Qu¹,²,³

¹Institute of Applied Technology, Hefei Institutes of Physical Science, Chinese Academy of Sciences, Hefei 230088, People’s Republic of China
²University of Science and Technology of China, Hefei 230036, People’s Republic of China
³Key Laboratory of Photovoltaic and Energy Conservation Materials, Chinese Academy of Sciences
*Email: wanghua@issp.ac.cn; xytian@issp.ac.cn

Abstract

GSiCnw, the composite of multilayered graphene sheets and SiC nanowires, was prepared through a carbothermal reduction process. By means of incorporating SiC nanowires into multilayered graphene sheets(GS), the propagation of electrons between graphene layers was effectively suppressed and the thermal conductivity was enhanced. The aim of the study was to improve the thermal conductivity, mechanical properties, and electrical insulation of epoxy(EP)-BaTiO3(BT) composites by incorporating GSiCnw as shown in Fig 1. Experimental results revealed that 9% GSiCnw adulteration boosted the thermal conductivity of EP composites from 0.235 W/m·K to 0.699 W/m·K. In terms of mechanical properties, however, remarkable improvement of the EP composites’ tensile strength from 56.62MPa to 85.98MPa and the bending strength from 578.8MPa to 1291.7MPa was found in the sample of 6% GSiCnw adulteration. Additionally, electrical capabilities test indicated that BT could improve the insulation of EP composites. The present of BT caused the decrease of electrical conductivity of EP composites. And the incorporation of both BT and GSiCnw was conducive to the increment of the breakdown voltage of EP composites. Interesting, the performances of EP composites with both BT and GSiCnw incorporation were better than the single adulteration of either BT or GSiCnw, probably owing to the synergistic effect.

Keywords: GSiCnw, EP-BT composites, thermal conductivity, electrical conductivity, mechanical properties

Fig. 1 A schematic diagram of the structure of epoxy(EP)-BaTiO3 composite.
Session: Graphene based nanocomposites
Comp-9-2-11

From Fracture Mechanics to Electrospun Polymer Adhesion and Composite Sciences
Shing-Chung Josh Wong*
Department of Mechanical Engineering University of Akron, Akron
*Email: swong@uakron.edu

Abstract
In a series of research and development studies, Wong and coworkers have presented understanding and thus a platform technology for processing high shear and low peel dry adhesives based on electrospinning-enabled techniques. Nature inspired adhesion is performed using electrospun polymer blends. Electrospun nonwovens are used in commercial processes for applications in filter media, sound-proof partitions, biomedical scaffolds, wound dressings, water-absorbent materials, etc. None applied these nonwovens as effective, repositionable dry adhesives with tunable shear and peel adhesion strengths. In this study, we prepare fibers that produce adhesion on a rigid substrate. Traditionally, polymer alloys and blends were achieved via large scale extrusion compounding or reactive mixing. In our work, a highly spinnable polymer is blended with a low Tg component in a heterogeneous morphology by scalable electrospinning. Electrospinning is a viable approach to forming nanoscale connectors and mechanical interlocks between polymer-polymer and polymer-inorganic interfaces. The formation of multicomponent polymer blends by electrospinning contributes to a marked increase in adhesion strength and yet continuous and/or co-continuous morphology. This paper will also cover recent studies of water harvesting using electrospun graphite-containing polymer composites.

Keywords: Fracture mechanics, Adhesion and composite sciences, Electrospinning

Fig. 1 Nano cheese cutter of SWCNT bundle attached to an AFM cantilever. This study was conducted, for the first time, to understand the adhesive interactions between SWCNT bundle and electrospun polymer nanofiber.
“White Graphene” for Thermal Management Applications
Yuanpeng Wu¹,², Ye Xue³, Si Qin¹, Dan Liu¹, Xuebin Wang⁴,⁶, Xiao Hu³, Jingliang Li¹, Xungai Wang¹, Yoshio Bando⁴, Dmitri Golberg⁴,⁷, Yury Gogotsi⁵, and Weiwei Lei¹*¹

¹Institute for Frontier Materials, Deakin University, Waurn Ponds Campus, Locked Bag, Victoria Australia
²School of Materials Science and Engineering, Southwest Petroleum University, Chengdu China
³Department of Physics and Astronomy and Department of Biomedical Engineering, Rowan University, 201 Mullica Hill Road, Glassboro, New Jersey 08028, United States
⁴International Center for Materials Nanoarchitectonics (WPI-MANA), National Institute for Materials Science (NIMS), Namiki 1-1, Tsukuba, Ibaraki 305-0044, Japan
⁵A. J. Drexel Nanomaterials Institute, and Materials Science and Engineering Department, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104, United States
⁶College of Engineering and Applied Sciences, Nanjing University, Nanjing 210093, China
⁷School of Chemistry, Physics and Mechanical Engineering Science and Engineering Faculty, Queensland University of Technology, Brisbane, QLD 4001, Australia

*Email: weiwei.lei@deakin.edu.au

Abstract
With the development of technology in civilian and military, high-power density electronic devices are more frequently used than before, resulting in excessive thermal energy accumulation. Therefore, the development of nanomaterials with anisotropic thermal transport properties has attracted increasing attention for thermal management applications, such as coatings in electronics and heat sinks. An ideal candidate should be electrically insulating and have thermal conductivity in-plane significantly greater than through-plane. Two-dimensional (2D) nanomaterials such as graphene and black phosphorus, both of which possess highly anisotropic thermal conductivity, have recently provided a new platform for addressing heat dissipation in devices. However, it is difficult to employ either in thermal management or build components owing to their electrical conductivity and fast oxidation of phosphorus. BN nanosheets offer a high thermal conductivity. In contrast with other conductive and semiconducting 2D materials, BN nanosheets are electrically insulating, which suggests utility in thermal management applications in electronics. Here, we report a free-standing BN nanosheet/polymer composite film with a unique combination of properties including flexibility and toughness, anisotropic thermal conductivity, and fire resistance, which exhibit highly potential applications in high-performance flexible electrically insulating substrates, superior thermal conductivities and fire-resistance coatings.

Keywords: BN nanosheets, Composite film, Thermal management, Graphene
A Facile and Universal Approach to Functionalize Three-Dimensional Graphene Foam for Multifunctional Composites

Haoming Fang, and Shulin Bai*

Department of Materials Science and Engineering, HEDPS/CAPT/LCTS, Key Laboratory of Polymer Chemistry and Physics of Ministry of Education, College of Engineering, Peking University, Beijing 100871, China

*Email: slbai@pku.edu.cn

Abstract

In this work, a facile and universal in-situ coating approach to functionalize graphene foam (GF) was proposed. Unlike the traditional method to modify graphene surface via necessary oxidation process, the chemical vapour deposition (CVD) grown three-dimensional (3D) graphene networks with few functional groups and defects were coated with polydopamine (PDA) layers via π-π stacking while maintaining the perfect hexagonal lattice. Sequentially, the oxide layers were introduced onto PDA/GF surface directly by sol-gel strategies due to the abundant reaction sites and functional groups from PDA layers. We successfully fabricated aluminium oxide and iron oxide coated GF via this approach. Besides, we also investigate the strategies for interfacial interaction enhancement via the same approach and bring up a sandwich-structure to increase the comprehensive properties of composites. Then through densification and polymeric infiltration process, a series of novel composites consisting of dense and functionalized GF were fabricated. The corresponding composites exhibit excellent comprehensive performance including high thermal conductivity, electrical properties as well as outstanding electromagnetic interference shielding. The functionalization approach is shown in Figure.1.

Keywords: Dense graphene foam, Oxide layers, Thermal conductivity, Insulated property, Electromagnetic interference shielding

Fig. 1 Schematic approach for functionalization of graphene foam.
Reduced Shrinkage of Epoxies with Graphene

W.S. Sum*

PETRONAS Research, Lot 3288/3289 Off Jalan Ayer Itam, Kawasan Institusi Bangi, 43000 Kajang, Selangor DE, Malaysia

*Email: sum_weisiang@petronas.com

Abstract

Shrinkage of epoxies during cure can induce unwanted stresses and deformations in polymer components, particularly for composite structures. This study explores the use of graphene, known for its superior properties - like ultra-high aspect ratio and negative CTE (coefficient of thermal expansion)1 - to reduce shrinkage in epoxies. Comparisons are experimentally made between shrinkage of unfilled and filled epoxies to quantify the improvement. In addition, there are many types of graphene with different numbers of layers and sizes that can be used, so a numerical model is used to gain further understanding of the effects of graphene aspect ratio on the shrinkage of epoxies.

**Keywords:** shrinkage, graphene, thermal expansion, deformation, nanocomposites

Fig. 1 (a) Unit cell model of filled specimen, with graphene flakes arranged within a resin matrix, and boundary conditions; (b) cross sectional view of the unit cell.

Fig. 2. Six measurement locations for shrinkage pots and moulded specimen
Electrically Conductive Nanocomposites as Electromagnetic Interference Shielding Materials

Sima Kashi*, and Russell Varley

Institute for Frontier Materials, Deakin University, Waurn Ponds, VIC 3216, Australia

*Email: sima.kashi@deakin.edu.au

Abstract

The extensive use of electronics and communication devices in today's modern life has increased the electromagnetic (EM) radiations, leading to a new type of pollution. EM waves emitted from wireless equipments could interfere with the proper function of susceptible devices and even have adverse impact on human health. Consequently, interest in new EM shielding materials with tuneable properties has increased. In this study, electrically conductive nanocomposites were fabricated by embedding graphene nanoplatelets in a flexible polymeric matrix at different concentrations. The performance of the nanocomposites as EM radiation shielding materials was investigated over a wide range of microwave frequency covering from 5.85 GHz to 18 GHz. Effect of nanofiller concentration, nanocomposite thickness, and frequency on the performance of the nanocomposites in attenuating the EM radiation were studied.

Keywords: Electromagnetic interference shielding, Nanocomposite, Conductive, Graphene, PLA

Fig. 1 SET of 1 mm thick samples of pure PLA and nanocomposites with 6 wt% and 12 wt% GNPs over (a) C-band, (b) X-band, and (c) Ku-band.
Session: Graphene based nanocomposites

Comp-9-2-O4

Effect of Flame Synthesis Method Parameters on the Quality of Produced Carbon Nanotubes

Guixiang Zhao¹, Hong-Yuan Liu², Yiu-Wing Mai², Yuan-Yuan Jia³ and Wenyi Yan¹,*

¹Department of Mechanical and Aerospace Engineering, Monash University, Wellington Road, Clayton, Victoria 3800, Australia
²School of Aerospace, Mechanical and Mechatronic Engineering, JO7, The University of Sydney, Sydney, NSW 2006, Australia
³Xi’an You Ji Composite Materials, Xi’an, Shanxi Province, 710075, China
*Email: wenyi.yan@monash.edu

Abstract

One-step flame synthesis method was used to graft carbon nanotubes (CNTs) onto glass fibre woven fabric. Comparing to the chemical vapour deposition (CVD) technique to synthesise CNTs, flame synthesis is energy efficient and equipment simplified. Nickel chloride, as the catalyst, was applied onto glass fibre woven fabric, and the CNTs were formed in ethanol flame. In this paper, catalyst solution concentration, fabric immersing time in catalyst solution as well as synthesis time were quantitively investigated to evaluate the quality of the flame synthesis method produced CNTs. Moreover, AFM was employed to measure the catalyst cluster size. SEM and TEM images were taken to examine the composition of the synthesized carbon materials. Results show that different carbon materials, including carbon soot, carbon nanofibers (CNFs) and CNTs, were generated, and the carbon products are sensitive to synthesis parameters. CNTs length, diameter and density were used as criteria to investigate the synthesis quality. Furthermore, the optimised flame synthesis parameters were identified for the further production of CNTs hybrid composite laminates.

Keywords: Carbon nanotubes (CNTs), Flame synthesis method, Scanning electron microscope, Transmission electron microscopy, Atomic force microscopy
Bioinspired Construction of Graphene-Based Composite as Anode Toward Superior Lithium Storage
Shenmin Zhu*, Chengling Zhu, and Hui Pan

State Key Laboratory of Metal Matrix Composites, Shanghai Jiao Tong University, Shanghai 200240, P. R. China
*Email: smzhu@sjtu.edu.cn

Abstract
The hierarchical structures in nature have great inspiration on the design of materials with high performance. Learning from nature, the pomegranate-like wrapped-cluster structure is an impressive model in the construction of anode materials to accommodate a large volume expansion. Herein, we summarize our recent work on the fabrication of graphene-based composites taking advantage of the unique properties of graphene together with the fantastic wrapped-cluster structure. The synthesis of an anode material based on SnO2 is demonstrated, where mesoporous SnO2 clusters were encapsulated by amorphous carbon layers and then wrapped with rGO sheets. The obtained materials exhibited a high reversible capacity of 924 mAh g⁻¹ at 100 mA g⁻¹. In order to solve the problem that the encapsulated dual thick carbon shell hindered the rapid penetration and transfer of Li⁺, we pioneered a brand new structure for extremely high-performance SnO2—rGO composite anode. Small sheets of graphene oxide (SGO) were used to construct this delicate structure of SnO2 anodes (SnO2@C@half-rGO), in which the porous clusters of SnO2 nanoparticles are partially supported by rGO sheets and partially exposed. The SnO2 nanoparticles inside the porous clusters are individually covered by thin amorphous carbon shells. The structure in whole is just like partitioned pomegranates. When served as anode for lithium-ion batteries, SnO2@C@half-rGO exhibited considerably high specific capacity, superior rate performance and remarkable durability. This facile and scalable approach demonstrates a new architecture for graphene-based composite for practical use in energy storage with high performance.

Keywords: Bioinspired, Construction, Lithium battery, Graphene

Fig. 1 Figure 1. (a) Graphical synthesis route of SnO2@C@half-rGO and SnO2@C/rGO. (b,c) TEM images of the SnO2 nanoparticles. (d,e) SEM images of SnO2@C@half-rGO.
Silica Coating onto Graphene for Improving Thermal Conductivity and Electrical Insulation of Graphene/Polydimethylsiloxane Nanocomposites

You Zeng¹*, Chaoxuan Shen¹,², Han Wang¹,², and Tengxin Zhang¹,²

¹Shenyang National Laboratory for Materials Science, Institute of Metal Research, Chinese Academy of Sciences
²School of Materials Science and Engineering, University of Science and Technology of China, Shenyang 110016, P.R. China
*Email: yzeng@imr.ac.cn

Abstract

Graphene possess extremely high thermal conductivity, and they have been regarded as prominent candidates to be used in thermal management of electronic devices. However, addition of graphene inevitably causes dramatic decrease in electrical insulation, which is generally unacceptable for thermal interface materials (TIMs) in real electronic industry. Developing graphene-based nanocomposites with high thermal conductivity and satisfactory electrical insulation is still a challenging issue. In this paper, we developed a novel hybrid nanocomposite by incorporating silica-coated graphene nanoplatelets (Silica@GNPs) with polydimethylsiloxane (PDMS) matrix. The obtained Silica@GNP/PDMS composites showed satisfactory electrical insulation (electrical resistivity of over 10¹³ Ω•cm) and high thermal conductivity of 0.497 W∙m⁻¹∙K⁻¹, increasing by 163% compared with that of neat PDMS, even higher than that of GNP/PDMS composites (see Fig 1). Such high thermal conductivity and satisfactory electrical insulation for the Silica@GNP/PDMS nanocomposites is mainly attributed to the insulating silica-coating, good compatibility between components, strong interfacial bonding, and uniform dispersion of GNPs throughout PDMS. There is great potential for the Silica@GNP/PDMS composites to be used as high-performance TIMs in electronic industry.

Keywords: Graphene, Silica coating, Nanocomposites, Thermal conductivity, Electrical insulation

Fig. 1 (a) Thermal conductivity and (b) electrical insulation of the GNP/PDMS and Silica@GNP/PDMS composites as a function of graphene loadings.
Wearable Strain Sensors Based on Graphene/Polymer Nanocomposites
Shuying Wu¹*, Chun Wang²

¹School of Mechanical and Manufacturing Engineering, University of New South Wales, Sydney, NSW 2052, Australia
²School of Mechanical and Manufacturing Engineering, University of New South Wales, Sydney, NSW 2052, Australia

*Email: shuying.wu@unsw.edu.au

Abstract
Strain sensors with high sensitivity, broad sensing range, and high linearity are highly desirable due to the increasing demand for wearable devices for applications in human health monitoring, electronic skin, etc. Various methods have been proposed to develop such sensors by using nanomaterials, such as metal nanoparticles, nanowires, carbon nanotubes, and graphene nanosheets. Particularly, graphene is emerging as a leading solution due to their superior mechanical and electrical properties. However, there remains great challenges to fabricate sensors that simultaneously demonstrate high sensitivity and stretchability. Here we present the fabrication of highly sensitive stretchable strain sensors based on the composite of graphene and polydimethylsiloxane (PDMS). Graphene is either assembled into three-dimensional structure (graphene aerogel, GA) or grown into vertically aligned structure (vertical graphene, VG). The GA (Fig 1a) is fabricated using a chemical reduction-induced self-assembly of GO sheets followed by freeze-drying and thermal treatment. The VG (Fig 1c) is grown onto copper substrate by plasma-enhanced chemical vapor deposition. The subsequent infiltration with PDMS results in flexible and stretchable composites (Figs 1b and 1d) with high electrical conductivities and robust mechanical properties. The composites exhibit high sensitivity with a gauge factor ~ 36 (Figs 1e-f) and excellent durability, with the electrical response remaining nearly unchanged after nearly 10,000 cycles.

Keywords: Wearable sensors, Piezoresistive, Graphene aerogel, Vertical graphene

Fig. 1 SEM images for (a) graphene aerogel and (b) its PDMS composites; (c) vertical graphene and (d) its PDMS composites; (e) and (f) relative resistance change (ΔR/R₀) under monotonic tension for the graphene/PDMS composite sensors.
Session: Graphene based nanocomposites
Comp-9-3-O2

Silver and Gold Nano-Island Arrays Grown on Graphene Oxide Substrate for SERS Biodetection
Wei-Lin Syu, and Ting-Yu Liu*

Department of Materials Engineering, Ming Chi University of Technology, New Taipei City Taiwan
*Email: tyliu0322@gmail.com

Abstract
Nanohybrids of silver (Ag) and gold (Au) nano-islands arrays (NIA) grown on graphene oxide (GO) substrates were developed by thermal evaporation co-deposition methods for surface enhanced Raman scattering (SERS) sensing. The deposition rate of silver and gold would be well-controlled to attain the optimal signal to background (S/B) ratio of SERS intensity. Incorporation of graphene layer can suppress the signal distortion and background fluorescence caused by photocarbonization, which leads to the excellent resolution and stability of SERS signals and great S/B ratio. The results show that Ag and Au NIA-GO substrate displays high sensitivity (limit of detection: <10^-8 of R6G), which is attributed to the efficient “hot-spots” enhancement from the enormous plasmonic resonance of Ag NIA with close interparticle distance. Furthermore, it shows high reproducibility and strong background suppression due to the passivation layers of Au and GO. Thus, the novel SERS substrate is promising for quantitatively detection of various biomolecules and water pollutants with ultra-dilute concentration.

Keywords: Surface-enhanced Raman scattering (SERS), Nano-island arrays, Thermal evaporation deposition, Graphene oxide

Fig. 1 The schematic diagrams of Ag and Au nano-islands arrays (NIA) grown on graphene oxide (GO) substrates were developed by thermal evaporation co-deposition methods.
Flexible Supercapacitors Based on Mno/C/Rgo Fibers Assembled from Colloidal Liquid Crystals
Hao Yuan, Hui Pan, Chengling Zhu, Xin Meng, and Shenmin Zhu*

State Key Laboratory of Metal Matrix Composites, School of Materials Science and Engineering, Shanghai Jiao Tong University, China. Mailing address: 800 Dongchuan Road, Minhang District, Shanghai, China

*Email: smzhu@sjtu.edu.cn

Abstract
Flexible supercapacitors based on fibre shaped electrodes exhibit great potential for practical application owing to their light weight, good flexibility, and excellent weavability1,2. A facile and scalable liquid crystal spinning method was employed to fabricate manganosite/nanocarbon/reduced graphene oxide (MnO/C/rGO) ternary composite fibers. The incorporation of nanocarbon and MnO nanoparticles can not only prevent rGO sheets from restacking, but also enhance the device performance — nanocarbon contributes for additional electric double layer capacitance while MnO for faradic pseudocapacitance. Fibre supercapacitors were assembled by arranging two fibres in parallel coated with gel electrolyte. The fabricated devices exhibit an energy density of 0.048 mWh cm⁻³ at 4 mW cm⁻³ and the maximum power density of 100 mW cm⁻³. Good cycling stability and bending robustness (capacitance remains under different bending states) were demonstrated. The ternary composite fibres with high performance is promising for the future spreading of wearable electronic products.

Keywords: Flexible supercapacitor, Liquid crystal, Graphene, manganosite
Session: Graphene based nanocomposites
Comp-9-3-O4

BN/Graphene Hybrid Polymer Composite for Thermal Management and High Temperature Dielectric Applications
Fengmei Guo¹, Qingbin Zheng¹,², Dan Liu¹, Haomin Chen¹, Jeng-Hun Lee¹, Zilong Liu¹, and Jang-Kyo Kim¹*

¹Department of Mechanical and Aerospace Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong
²Institute for Advanced Study, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong
*Email: mejkkim@ust.hk

Abstract
The miniaturization of electronics and energy supply systems urgently demands for new dielectric materials with high thermal conductivity and good dielectric properties in order to fulfil efficient energy storage and heat management. Polymer composites with amounts of different nanofillers are attracting people’s attention for their improved thermal conductivity and dielectric properties¹,². In this work, we designed and fabricated sandwich like BN/graphene polymer composite by introducing two of the best nanofiller candidates, graphene and boron nitride (BN) nanosheets and using unidirectional freeze casting and planar stacking method. The composite shows good thermal conductivity and stable dielectric properties over a broad temperature (-100 to 100 °C) and frequency range (10⁻¹⁰⁵ Hz). It is demonstrated that the sandwich structure of hybrid composite can fully exploit the high thermal conductivity of BN and graphene, as well as the excellent dielectric properties of BN. The graphene provides sufficient pathway for heat dissipating, while the insulating BN nanosheets can effectively suppress the increase of electrical conductivity caused by graphene. Our work furtherly revealed the advantages of BN and graphene nanofillers, and offered a practical pathway to fabricate polymer composites with excellent dielectric breakdown strength, low dielectric loss and high thermal conductivity, which is of great importance for applications such as thermal interface materials and high temperature dielectrics.

Keywords: Composite, Dielectric properties, Thermal conductivity, Graphene, Boron nitride

Fig. 1 Schematic illustration of fabrication process of sandwich structure BN/graphene hybrid polymer composite.
A Facile Electrochemical Approach for the Production of Graphite Oxide with Controllable Chemistry

Yu Lin Zhong*

School of Environment and Science, Centre for Clean Environment and Energy, Griffith University, Gold Coast Campus, QLD 4222, Australia

*Email: y.zhong@griffith.edu.au

Abstract

Graphene oxide is promising for a variety of applications due to its good dispersibility and scalable synthesis. However, current chemical synthesis and oxidation routes have several drawbacks, including the use of explosive oxidising agents, residual metal ions contaminations and the creation of irreparable hole defects. The electrochemical exfoliation and oxidation of graphite is a potentially greener approach without the need for extensive purification steps. Most reported electrochemical methods employ a single bulk graphite as electrode, which limits their scalability, reproducibility and degree of oxidation. Reproducible and in-depth studies of the electrochemical graphite intercalation and oxidation processes were carried out with the use of an electrochemical setup. The electrochemical method allowed simpler and greater controllability over the level of oxidation/functionalization, relative to the commonly employed chemical oxidation approach (e.g. the modified Hummers method). Extensive characterization was carried out to understand the properties of the electrochemically-derived graphite oxide (EGrO) and it was found that the abundance of each functionality is highly dependent on the electrochemical reaction time or by varying the concentration of the electrolyte (perchloric acid) employed. Notably, the amount of oxygen functional groups on EGrO could be as high as 30 wt.%, but the degree of oxidation did not proceed beyond the generation of carbonyl species. The controllable oxidation level of the EGrO makes it an attractive precursor for many applications, such as electronics and nanocomposites.

Keywords: Electrochemical, Graphene oxide, Controlled Chemistry, Nanocomposite
High Performance Epoxy Adhesives Reinforced with Graphene Nanoplatelets

Panta Jojibabu¹, Y.X. Zhang¹,*, Gangadhara Prusty², and Lin Ye³

¹School of Engineering and Information Technology, The University of New South Wales, Canberra, ACT 2612, Australia
²School of Mechanical and Manufacturing Engineering, The University of New South Wales, Sydney, NSW 2052, Australia
³Centre for Advanced Materials Technology, School of Aerospace, Mechanical and Mechatronic Engineering, The University of Sydney, NSW 2006, Australia

*Email: y.zhang@adfa.edu.au

Abstract

In this paper, a high strength graphene nanoplatelets (GNP) reinforced epoxy adhesive material is developed to enhance the shear strength of the adhesive joints. A high strength Diglycidyl ether of biphenyl-A (DGEBA) epoxy is employed as the base adhesive and varying content of GNP, i.e. 0.2, 0.5, and 1 wt.% were added to the epoxy to study the effect of the content on the joint shear strength via conducting single lap shear tests. Uni-axial tensile tests were also conducted to determine the effect of the various amounts of GNP reinforcement on the tensile material properties. It is found that the tensile strength and Young’s modulus of the composites increase significantly with the increase of the GNP content. The joint shear strength is found to increase with the GNP content, with an increase of 15%, 29%, and 16% for 0.2, 0.5 and 1 wt.% respectively compared to that of pure epoxy. Scanning electron microscopy studies were conducted to observe the distribution of the GNP in the epoxy and the change of the morphology of the fracture surfaces with the different amount of GNP addition.

Keywords: Adhesive bonding, Epoxy, Graphene nanoplatelets, Material properties, Lap shear strength

Fig. 1 Tensile strength and Young’s modulus of GNP/EP nanocomposites at different weight fractions.
Session: Graphene based Nanocomposites
Comp-9-4-O1

Processing Polymers with Graphene Sheets
Jun Ma*

University of South Australia, Adelaide, SA 5095, Australia
*Email: Jun.Ma@unisa.edu.au

Abstract
Of all engineering materials, polymers have witnessed rapid increase in applications over the past decades due to their low manufacturing cost and decent specific strength. However, polymers are limited by low absolute stiffness and strength and lack of functionality such as electrical and thermal conductivity. Processing polymers with nanomaterials holds great potential to address these limitations.

In spite of extensive studies of utilizing carbon nanotubes and silicate layers to address the limitations, the rise of graphene [1] now provides a more promising candidate due to its exceptionally high mechanical performance, electrical and thermal conductivities, and specific surface area. My research team since 2008 has conducted extensive research of developing new graphene platelets [2–3] and using them for processing of epoxy [2–6], elastomers [7–9] and conducting polymers [10,11]. Graphene platelets contain only 7 atom% oxygen and have a thickness of 2–4 nm depending on the suspension medium for measurement. They have a Raman Id/Ig ratio of 0.07, corresponding to an electrical conductivity of 1456 S/cm measured by a four-probe method.

Keywords: Graphene, Polymer composites
Abstract

Strain sensors with good transparency, broad sensing range, and high sensitivity are highly desirable for many potential applications. Although cracked structure-based strain sensor has been demonstrated to possess high sensitivity,1 the stretchability is limited due to its complete fracture. To circumvent the issue, we design a low dimensional hybrid carbon film by combing cracked graphene and aligned carbon nanotube (CG/ACNT) to form a hybrid sensor whose detection capability much better than either of graphene or ACNT acting alone. Cracked graphene with periodic buckling patterns is produced by applying a prestrain-release-buckling strategy. ACNTs are then deposited via a self-assembly technique to obtain an ultra-sensitive and stretchable hybrid strain sensor exploiting the synergy arising from the two components. Since ACNT can bridge between the buckled graphene ribbons, the integrated hybrid strain sensor possesses both high sensitivity at a small strain from the cracked graphene and good stretchability due to the bridging effect. The hybrid strain sensor not only maintains high sensitivity (> 200), but also performs greatly improved stretchability (>50%), making it capable of capturing a wide range of human physical movements.

**Keywords:** Strain sensor, Cracked-graphene, Aligned carbon nanotube, Ultra-stretchable, High sensitivity

Fig. 1 Schematic diagram of fabrication process of CG-ACNT strain sensors.
Spider Web-Inspired Graphene Woven Fabric Structures for Highly Flexible and Wearable Sensors

Dan Liu¹, Xu Liu¹, Qingbin Zheng¹,² *, Haomin Chen¹, Jeng-Hun Lee¹, Fengmei Guo¹, Zilong Liu¹, and Jang-Kyo Kim¹ *

¹Department of Mechanical and Aerospace Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong
²Institute for Advanced Study, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong
*Email: mezheng@ust.hk; mejkkim@ust.hk

Abstract

Advanced wearable strain sensors with high sensitivity and stretchability are an important functional component for flexible and soft electronic devices.¹,² Inspired by the highly flexible spider web architecture, we propose ultraselective and wearable strain sensors based on a graphene woven fabric (GWF) structure for monitoring human physiological signals. Elastomer-filled GWF (e-GWF) composite sensors are prepared by filling the graphene tubes of GWF with a highly stretchable elastomer, which show advanced strain-sensing capabilities including high stretchability, linearity, sensitivity and structural stability. For example, the stretchable piezoresistive e-GWF can be reversibly stretched up to 20% in tension while generating resistance output nearly proportional to the applied tensile strain. The gauge factor, which is the ratio of relative change in electrical resistance to the mechanical strain, can reach up to 282 at 20% strain, demonstrating extremely high sensitivity. More interestingly, a reversible switching behaviour has been observed at a high strain of 30-50% depending on the loading direction. Based on the excellent sensing performance of e-GWF, its capabilities with physiological signal detections and wearable LED displays are further demonstrated. The unique e-GWF structure offer a wide range of practical applications, such as health monitoring, medical diagnosis, and wearable displays.

Keywords: Strain sensor, Spider web-inspired, Graphene woven fabric, Physiological monitoring, Wearable displays

Fig. 1 Spider web-inspired e-GWF for highly flexible and ultrasensitive strain sensors.
Research on Modification of Wood Surface Properties by SiO$_2$ Water-borne Coating

Zhigao Liu, Penglian Wei, and Yunlin Fu*

*Forestry College, Guangxi University, Nanning, 530004, China

Abstract

Nano-SiO$_2$ was added into water-borne coating to obtain SiO$_2$ water-borne coating through co-mixing method. The SiO$_2$ water-borne coating was coated on Pinus massoniana wood surface in order to study their coating properties. The paper focused on coating property of wood surface with different SiO$_2$ concentration. Modification of SiO$_2$ in aqueous medium was conducted by using sodium carboxymethy cellulose as a dispersant and KH-560 as a silane coupling agent. The nano-SiO$_2$ dispersion in coating were characterized by SEM/EDX. The results showed that: modified silicon dioxide’s dispersivity in the water-borne coating was more uniform than non-modified silicon dioxide’s. The coating properties of wood surface was improved in some extent, its hardness, aging resistance were significantly increased; and the properties of modified SiO$_2$ in water-borne coating is better than non-modified’s in adhesion, impact resistance property, hardness, durability.

Keywords: Silicon dioxides, Water-borne coating, Wood surface properties

Fig. 1 SEM/EDAX image of water-borne wood coatings surface with unmodified SiO$_2$ and modified SiO$_2$. 
Multifunctional Composites for Structural Dielectric Capacitors
Kit-Ying Chan¹,*, Baohua Jia¹, Han Lin¹, Hwa-yaw Tam², and Kin-Tak Lau¹,³

¹Faculty of Science, Engineering and Technology, Swinburne University of Technology, Hawthorn Melbourne VIC 3122 Australia
²Department of Electrical Engineering, Faculty of Engineering, The Hong Kong Polytechnic University, Hung Hom, Hong Kong
³Department of Creative Product Design, College of Creative Design, Asia University, Taichung Taiwan
*Email: kychan@swin.edu.au

Abstract
Structural power composites have attracted a great attention in the research field of material engineering because of the most efficient utilisation of materials and significant weight reduction of systems, resulting in a higher system efficiency and lower cost. In this article, the development and characterisation of structural dielectric capacitors made by integrating a graphene oxide film into carbon fibre reinforced composites are demonstrated in terms of electrical and mechanical performance. An improvement of up to two orders of magnitude in the specific capacitance could be achieved by using graphene oxide film as dielectric separator in structural dielectric capacitors, compared to all existing structural dielectric capacitors. Furthermore, the graphene oxide film in the middle of carbon fibre reinforced composites can further enhance the interlaminar shear strength of structural dielectric capacitors. Therefore, the multifunctional efficiency of this new structural dielectric capacitor has been significantly enhanced, indicating that graphene oxide represents a promising type of dielectric material for structural power composites.

Keywords: Multifunctional composites, Structural dielectric capacitors, Carbon fibre reinforced composites, Graphene oxide, Energy storage

Fig. 1 Schematic configuration of a GO based structural dielectric capacitor.
CM1 Preparation, Crystallization Behavior and Properties of Biodegradable Polymer Nanocomposites

Jingnan Li, Kangjing Zhang, and Zhaobin Qiu*

State Key Lab of Chemical Resource Engineering, Beijing University of Chemical Technology, Beijing, China

*Email: qiuzb@mail.buct.edu.cn

Abstract

Biodegradable polymers have recently received considerable attention; however, some disadvantages, such as the relatively poor mechanical properties, slow crystallization rate, and slow degradation rate, have seriously restricted their wider practical application. Only a small amount of nanofillers may significantly improve the physical properties and extend the final end uses of biodegradable polymers. In our lab, we have been investigating the crystallization behavior and properties of biodegradable polymer nanocomposites by using carbon nanotubes, polyhedral oligomeric silsesquioxanes, and graphene as the nanofillers and PLLA, PCL, PHB, PBS, PE5, PBA, PEA, etc as the polymer matrix. In this topic, I will briefly introduce our recent process of the preparation, crystallization behavior and properties of biodegradable polymer nanocomposites.

Keywords: Biodegradable polymer, Polymer nanocomposites, Crystallization, properties

Fig. 1 Effect of CNTs on the polymorphism control of PBA.
Session: Carbon (other than graphene) Composites
Comp-1-1-O3

Improvement in Mechanical and Thermal Properties of Epoxy Nanocomposites using Self-Assembled Montmorillonite–Carbon Nanotube

Shaohua Zeng*, Mingxia Shen*, and Lu Yang

College of Mechanics and Materials, Hohai University, Nanjing 211100, China
*Email: shzeng@hhu.edu.cn; mxshen@hhu.edu.cn

Abstract

A nanostructured hybrid wherein varied multi-walled carbon nanotube (MWCNT) contents were attached on the exfoliated montmorillonite (Mt) was constructed through a self-assembly method. This design of Mt–MWCNT hybrids could maximize the excellent structural performance of Mt and MWCNTs and even produce a synergistic strengthening effect in epoxy-based nanocomposites. Results showed that MWCNTs anchored on the Mt nanosheets could transfer the stress or heat and provide the interlocking structure in the matrix, while the Mt could efficiently resist the microcrack extension and delay the thermal decomposition. Under an optimal weight ratio of Mt:MWCNTs (10:1), the tensile and flexural strength of epoxy nanocomposites were improved by 42.0% and 31.0%, respectively; the storage modulus in the glassy region increased by 21.2%, as compared with pure epoxy. Meanwhile, the glass-transition and thermal decomposition temperatures were significantly improved, signifying the superior thermal stability of epoxy-based nanocomposites

Keywords: Polymer-matrix composites (PMCs), Carbon nanotubes, Montmorillonite, Nanostructures
Session: Carbon (other than graphene) Composites
Comp-1-1-O4

**Novel Method of Coating Graphene Oxide onto CFRP Composites to Improve Their Properties at Low Temperature Environment**

Pui-yan Hung¹⁺, Kin-tak Lau¹, Bronwyn Fox¹, Nishar Hameed¹, and Joong Hee Lee²

¹Swinburne University of Technology, Faculty of Science, Engineering and Technology, Hawthorn, Melbourne VIC 3122 Australia

²BIN Convergence Technology, Chonbuk National University, Jeonju, South Korea

*Email: phung@swin.edu.au

**Abstract**

Recently, the use of graphene oxide (GO) added into polymer-based composites has attracted much attention to improve their mechanical properties at room temperature (RT). However, the increasing use of these composites for applications, such as aerospace and aircraft at low temperature environments has brought an issue of their reliability and safety. Many research have been focused on coating GO onto the surface of carbon fiber and/or mixing them into polymer matrix to enhance the overall mechanical properties of composites. However, the property enhancement is not targeted to low temperature, and also time and cost are critical concerns to the real-life applications [1]. In this study, the focus is placed on coating GO onto the surface of carbon fabric, which provides a fast and low cost method to manufacture a GO/carbon fiber reinforced polymer composite with 35% of strength enhancement at low temperature as compared to a pristine sample at RT (Fig 1). Adding GO into CFRP composite could substantially enhance its mechanical properties, which also alter its coefficient of thermal expansion. The addition of GO would help restrict the degradation of matrix at low temperature and reduce the decrement of mechanical properties owing to its contrary thermal response to the matrix (Fig 2).

**Keywords:** Fibre/matrix bond, Carbon fibre reinforced polymer composites, Cryogenic, Graphene

![Fig. 1 Electrophoretic deposition to coat GO onto surface of CFF.](image)

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Effects of CNT Contents on the Etching Rate of CNT-PDMS Composites

Soo Ho Hanr, Ha Eun Ji, and Hui Yun Hwang*

Department of Mechanical Design Engineering, Andong National University
*Email: hyhwang@anu.ac.kr

Abstract

Various studies were conducted to mimic Gecko’s feet and micro-nano hierarchical structures make very important role on the superior adhesion strength. Precision engineering such as MEMS was adapted to fabricate hierarchical structures for synthetic dry adhesives, but there is limitation on the size. We suggested novel fabrication method of micro-nano hierarchical structures consisted of multi-wall carbon nanotubes and Polydimethylsiloxane. For this, we should develop a selective etching method to remove some part of PDMS effectively using a solution of TBAF and NMP. We studied changes of etching rate and surface morphology with respect to the weight fraction of MWCNTs and etching conditions by experiments. From experiments, we found that the etching rate of PDMS decreased as the weight fraction of MWCNTs increase but had different tendencies at etching time. This made etched surface roughness as well as exposed MWCNTs as shown in Fig 1.

Keywords: MWCNT, PDMS, Wet etching, Hierarchical structures

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Fig. 1 Etched surfaces of MWCNTs-PDMS composites.
Session: Carbon (other than graphene) Composites
Comp-1-3-O4

Mechanical Modification of Carbon Nanotube Hybrid Aramid Fiber Composites
Tianshu Li, Min Li*, Junpeng Wang, Shaokai Wang, Yizhuo Gu, Zuoguang Zhang

Key Laboratory of Aerospace Advanced Materials and Performance (Ministry of Education), School of Materials Science and Engineering, Beihang University No. 37 Xueyuan Road, Haidian District, Beijing 100191, China
*Email: leemy@buaa.edu.cn

Abstract
Aramid fibers are well known for their unique toughness and impact resistance, which are widely used in advanced composites such as helmets, bulletproof vests, and aviation industry. Carbon nanotubes (CNT) with large aspect ratio and high mechanical properties will further improve the impact resistance of aramid composites. Here, CNT powders were employed to modified phenolic resins, meanwhile, continuous CNT film prepared by floating catalytic chemical vapor deposition (FCCVD) method was also intercalated to prepare CNT hybrid aramid/phenolic composites.

The composite with interlaminar hybrid CNT films (PF/AF/CNT) had the highest tensile strength. The fracture image showed that cracks mainly occurred at the interface of aramid/phenolic resin. With the load increasing, cracks penetrated through the CNT films, resulting in numerous pull-out of CNTs. Meanwhile, the two types of CNT powder modified aramid composites, i.e. CNT-PF/AF and CNT-PF/AF/CNT, had the similar tensile strengths with the control sample (PF/AF), showing no obvious improvement. Both the storage modulus and tanδ of the hybrid aramid laminate were increased significantly due to the modification of CNT power (CNT-PF/AF), with the peak value increased by 23% and 29%, respectively. However, the intercalated CNT films composite had no significant effect on the dynamic mechanical properties of the composites. These results indicate that the inside distribution of CNT has important influence on the impact resistance of the hybrid aramid composites.

Keywords: Aramid fiber, Carbon nanotubes, Hybrid composites, Dynamic mechanical properties
Building Functional Nanocomposites on Biomass Platform

Tuo Ji, and Jiahua Jack Zhu*

Department of Chemical and Biomolecular Engineering, The University of Akron, Akron, Ohio, 44325, USA

*Email: jzhu1@uakron.edu

Abstract

Biomass is one of the most abundant sustainable resources in our planet. Not only their valuable compositions, such as cellulose, lignin and hemicellulose, can be processed into value-added chemicals (e.g. biofuel), but also the unique structure and assembly pattern of these components make biomass a natural platform to design various functional materials. In this talk, we will discuss the opportunities and recent progress on the research topic of converting biomass into functional nanocomposite materials. The talk will cover a brief introduction on biomass skeleton structure, a green processing of biomass into ultrahigh surface area mesoporous carbon, and utilization of such materials in water purification and catalysis.

Keywords: Mesoporous materials, Green processing, Water treatment, Environmental catalysis
A Study on the Defect Detectability in Adhesive Joints using Electrical Impedance Method

So-Jung Baek, Cheol-Hwan Kim, and Jin-Ho Choi*

School of Mechanical, Aerospace and Information Engineering, ReCAPT, Gyeongsang National University

*Email: choi@gnu.ac.kr

Abstract

Two typical joint methods of composites are mechanical joint and adhesive bonding. In the mechanical joint method, the bolt fastening method has high reliability, but it increases the weight of the structure, cut the composite fiber, and cause stress concentration and strength drop. Although the adhesive bonding method has a higher strength than the mechanical joint, the bonding strength may be lowered by various parameters related to the environmental conditions and the manufacturing process. In addition, the bonding strength may be significantly reduced due to contamination on the bonding surfaces or poor surface treatment. The electrical resistance method is a very promising technique for detecting the surface defects of adhesive joints by measuring the electrical properties of the adhesive joints in which the CNTs are dispersed in the adhesive. In this study, we fabricated composite to composite single lap joints with CNTs and evaluated the defect detectability by using electrical resistance method. The AC and DC impedances of composite adhesive joints with artificial defects were measured using the LCR meter and a high resistance meter to evaluate their defect detection capabilities.

Keywords: CNT, Defect Detectability, Adhesive, Composite

Fig. 1 Schematic diagram.
In Situ High-Resolution Microscopic Characterization on Mode II Fatigue Delamination in CFRP Laminates

Yu Adachi¹*, Aya Mamishin¹, Rikuro Somiya¹, Narumichi Sato², Masaki Hojo¹*, Naoki Matsuda¹, Masaaki Nishikawa¹, and Manato Kanesaki³*

¹Department of Mechanical Engineering and Science, Kyoto University, Building C3, Nishikyo-ku, Kyoto 615-8540, Japan
²Toray Industries, Masaki-cho, Ehime 791-3193, Japan
³Innovative Composite Center, Kanazawa Institute of Technology, Yatsukaho, Hakusan, Ishikawa 924-0838, Japan

*Email: adachi.yu.87r@st.kyoto-u.ac.jp; hojo_cm@me.kyoto-u.ac.jp

Abstract

Interlaminar fatigue crack propagation behavior under mode II loading was investigated in detail by using 3-point End Notched Flexure tests. In situ fatigue experiments (1Hz) using high-resolution optical microscope were carried out to characterize the micromechanisms of fatigue delamination. Fatigue tests were carried out by controlling the maximum energy release rate. The results are shown in Fig. 1. The in situ observation (Fig. 2) show fiber de-bonding (micro-delamination) ahead of the main crack tip, creating a preferential damage path, followed by resin damage (microcrack and plastic deformation) near the fiber/resin de-bonding due to stress concentration. Then, the critical mechanism of fatigue crack growth for the present laminates is probably the fiber/resin de-bonding. Ex situ fatigue experiments (10Hz) using optical microscopy, scanning electron microscopy and X-ray CT were also carried out to evaluate the micromechanisms from various viewpoints and at different crack propagation rates. The observed crack propagation mechanisms agreed with those of in-situ tests. Comparison with other laminates indicates that the relative contribution of fiber/resin interface and resin strengths strongly affects the fatigue delamination micromechanisms.

Keywords: In situ observation, Fatigue fracture, Fracture mechanics, Optical microscope, X-ray CT

Fig. 1 SEM images of fracture surface (a) static fracture, (b) (c) fatigue fracture (10Hz, R = 0.1, da/dN = 10-7m/cycle).
Study on Microwave Absorption Properties of Silica/Phenol Aldehyde Modified with Carbon Black/Graphite

Le Chen\(^1\)*, Huimin Sun\(^1\), Juan Wang\(^2\), Mingxue Zhang\(^1\), and Zhaozhan Gu\(^1\)

\(^1\)Department of Electronic Engineering, School of Electronic Science and Engineering, Nanjing University, Nanjing 210093, China.

\(^2\)College of Material Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 211106, China

*Email: chenle26@nju.edu.cn

Abstract

The traditional coating materials are usually sprayed on the surface of product, which restricts application in high temperature environment. Considering the carbon powder to be a new-type microwave-absorbing material, we employed the structure-function integration design to realize the wide band microwave absorbing property of silica/phenol aldehyde heat-protect shell materials. The effect of the content of carbon black/graphite on the microwave absorbing properties of the composites was studied using the arch method in an anechoic chamber accordingly. Due to the RC network formation and introduction of conducting paths to the composites, the addition of carbon black/graphite powder markedly increased the complex conductivity, complex permittivity and microwave absorption coefficient of the sample (in Fig. 1). When the carbon black/graphite content was 5 wt%, the modified composites with thickness of 10 mm displayed microwave attenuation at 2-18 GHz, and the peak value of the reflectivity reached -15dB at 3 GHz (in Fig. 2). The tested results of plate specimen indicated that filling appropriate amount of carbon powder would exhibit the feasibility and engineering practicality of our structure-function integration design of stealth-heat-protection composites.

Keywords: Carbon black/graphite, Silica/phenolic, Heat-protection, Microwave absorption property

Fig. 1 The real and the imaginary of permittivity of silica/phenolic composites.
Tuned Double-Walled Carbon Nanotube Bundles using Molecular Dynamics Simulation
Hanqing Wei, Min Li*, Yanjie Wang, Shaokai Wang, Yizhuo Gu, and Zuoguang Zhang

Key Laboratory of Aerospace Advanced Materials and Performance (Ministry of Education), School of Materials Science and Engineering, Beihang University, No. 37 Xueyuan Road, Haidian District, Beijing 100191, China
*Email: leemy@buaa.edu.cn

Abstract
Tuning the alignment and packing density of CNTs in a macroscopic structure is the basis for achieving diverse mechanical properties, so the exact knowledge of the stable sub-bundle structures is very much important in designing unique CNT assembly. The mechanical behavior of double-walled carbon nanotubes (DWCNTs) bundles were investigated using molecular dynamics simulation in this article. The critical spacing for the spontaneous self-assembly of the bundle sources with 25 carbon nanotubes is found to be approximately 0.6 nm for armchair DWCNTs, 2 nm in diameter, and 100 nm in length. Larger gap produces an unstable state with disintegration into individual carbon nanotubes in the 1D bundles. These findings provide a fundamental basis for tuning the effect of individual carbon nanotubes to design novel DWCNT bundles.

Keywords: Double-walled carbon nanotubes, Bundle, Mechanical behavior, Molecular dynamics

Fig. 1 (a) Cross section of initial state with intertube gap in 0.3 nm (b) Equilibrium state of the close-packed bundle with initial intertube gap in 0.3 nm (c) Cross section of initial state with intertube gap in 0.6 nm (d) Equilibrium state of the close-packed bundle with initial intertube gap in 0.6 nm (e) Cross section of the initial state with intertube gap in 1.0 nm (f) Equilibrium state of the bundle with initial intertube gap in 1.0 nm (g) Cross section of the initial state with intertube gap in 1.5 nm (h) Equilibrium state of the bundle with initial intertube gap in 1.5 nm.
Session: Carbon (other than graphene) Composites
Comp-1-2-O5

Performance of High Thermal Conductivity C/SiC Composites for Hypersonic Applications

Christian Kudisonga¹*, Luigi-Jules Vandi², David Hartley³, and Michael Heiztmann⁴*

¹School of Mechanical and Mining Engineering, The University of Queensland, Australia,
²Centre for Advanced Materials Processing and Manufacturing (AMPAM), The University of Queensland, Australia, l.vandi@uq.edu.au
³Defence Science & Technology Group, S&T Discipline Lead – High Temperature Aerostructures,
⁴School of Mechanical and mining Engineering, The University of Queensland, Australia,
*Email: c.kudisonga@uq.edu.au; m.heitzmann@uq.edu.au

Abstract
Carbon fibre reinforced Silicon Carbide composites (C/SiC), are being widely investigated as structural material for high-temperature aerospace applications. Hypersonic represents the pinnacle of these applications where highly oxidative environments and high temperature (±2800°C) are experienced. Highly graphitic carbon fibres have a higher thermal conductivity than conventional carbon fibres, which makes them attractive for conducting heat and managing thermal loads within the structure. On the other hand, these carbon fibres have a lower Coefficient of Thermal Expansion (CTE) that increases the mismatch with ceramic matrices. In this paper, we discuss the challenges involved with using high graphite content carbon fibres in the Polymer Infiltration Pyrolysis (PIP) process. Manufacture of C/SiC, mechanical and thermal characterisation was conducted in order to quantify the benefits of these fibres. We first investigated the densification efficiency of C/SiC (as shown Fig 1). It was found that maximum densification was reached after 9PIP cycles, which corresponds to a density increase of 100%. Secondly, the research showed that high graphite content carbon fibers are more inclined to delamination due to the largest CTE difference between the matrix and the fibre.

Keywords: Ceramic matrix composite, PIP process, C/SiC composites, Hypersonic application

Fig. 1 C/SiC composite before/after delamination.
Nickel Encapsulated Carbon Nanotubes-Carbon Nanofiber Mat for Supercapacitor Electrode

Tolendra Kshetri¹, Jeong Hyeon Woo¹, Tran Duy Thanh¹, Thangjam Ibomcha Singh¹, Nam Hoon Kim¹,*, and Joong Hee Lee ¹,²

¹Advanced Materials Institute of BIN Convergence (BK plus Global) & Department of BIN Convergence Technology, Chonbuk National University
²Center for Carbon Composite Materials, Department of Polymer & Nano Science and Technology, Chonbuk National University, Jeonju, Jeonbuk, 54896, Republic of Korea

*Email: nhk@chonbuk.ac.kr

Abstract
Preparation of new carbon nanocomposites to obtain an enhanced performance of energy storage devices has attracted great attention¹. Herein, a hierarchical nanostructure of nickel encapsulated carbon nanotubes on electrospun carbon nanofiber networks (Ni-CNTs@CNFs) was successfully fabricated using two step methods: Electrospinning and chemical vapor deposition (CVD). The Ni-CNTs@CNFs composite showed the uniform and high density of CNTs grown on the surface of the carbon nanofiber networks with a large specific surface area and highly porous characteristics. The CNTs were found to have a good interaction with the CNFs networks which subsequently improve the electrical conductivity and electrochemical stability of the composite. The Ni-CNTs@CNFs composite showed to be a potential electrode material for supercapacitor, in which a high specific capacitance of 305 F g⁻¹ at 1 A g⁻¹ and long term stability with 95 % retention after 5000 repeated charge-discharge cycles were achieved. Thus, the present Ni-CNTs@CNFs hybrid is a promising candidate for supercapacitor electrode.

Keywords: Nickel encapsulated carbon nanotube, Electrospun carbon nanofiber, Chemical vapor deposition, Supercapacitors
Session: Carbon (other than graphene) Composites
Comp-1-3-O1

Grafting CNTs on Carbon Fabric for Enhanced Tribological Properties of Carbon Fabric/Phenolic Composites
Beibei Wang*, Yewei Fu*, and Qiangang Fu*

State Key Laboratory of Solidification Processing, Shaanxi Province Key Laboratory of Fiber Reinforced Light Composite Materials, Northwestern Polytechnical University, Xi’an, Shaanxi 710072, PR China

*Email: 15249271900@163.com; yeweifu@nwpu.edu.cn; fuqiangang@nwpu.edu.cn

Abstract
Carbon nanotubes (CNTs) were in-situ synthetized on carbon fabric by chemical vapor deposition to improve friction and wear properties of carbon fabric reinforced phenolic composites. Results show that the thermal conductivity and tensile strength of the CNTs modified composites were enhanced by about 21% and 45%, respectively, owing to the high thermal conductivity of CNTs and the improved interfacial adhesion between the carbon fabric and resin matrix. The friction coefficient of the composites modified by CNTs increases from 0.12 to 0.14, while the wear rate decreases from 3.7×10^{-14} m^3(N•m)^{-1} to 2.8×10^{-14} m^3(N•m)^{-1}, attributing to the improved interfacial bonding strength of the composites by the introduction of CNTs.

Keywords: Carbon fabric/phenolic composites, CNTs; Interfacial bond, Tribological performance
Toughening Modification of Immiscible Polymer Blends by adding Carbon Nanotubes or Carbon Nanofibers

Yong Wang*, Jing-hui Yang, Chao-jin Yang, and De-xiang Sun

Key Laboratory of Advanced Technologies of Materials (Ministry of Education), School of Materials Science & Engineering, Southwest Jiaotong University, Chengdu, 610031, China

*Email: yongwang1976@163.com

Abstract

Polymer blending is a well-known method to prepare the new materials with promising properties. However, most of polymer blends are immiscible and the fracture toughness of the material is poor due to the weak interfacial adhesion. Carbon nanotubes (CNTs) and carbon nanofibers (CNFs) are widely used to prepare the reinforced polymer composites. However, the toughening effect of CNTs or CNFs in the polymer composites is seldom reported. In our work, CNTs and CNFs were introduced into immiscible polymer blends to prepare the blend composites, respectively. The selective localization of fillers, the microstructure changes of the blends and the fracture behaviors of samples were comparatively investigated. The results show that CNTs and CNFs exhibit excellent toughening effect in the blend composites, which leads to the great enhancement of impact strength at relatively high filler content. Specifically, the toughening effect of CNFs is better than that of CNTs. The toughening mechanisms are suggested to be related to the dispersion and localization of fillers, the morphological changes as well as the crystalline structure changes of the blends induced by fillers.

Keywords: Immiscible polymer blends, Carbon nanotubes, Carbon nanofibers, Microstructure, toughening
Incorporation of Titanium Dioxide Nanocrystals Into S-Doped Carbon Matrix for Anode Materials

Pengyuan Gao, Yun Lu, Shuyi Deng, and Yingkui Yang*

School of Chemistry and Materials Science, South-Central University for Nationalities, Wuhan 430074, China

*Email: ykyang@mail.scuec.edu.cn

Abstract

Metal oxides have been recognized as next generation anode materials for lithium-ion batteries. Due to their low electronic conductivity and huge volume variation during the charge-discharge process, however, such promise has been hampered by low cycling capability and poor rate performance. In this work, metal oxide nanocrystals (10-20 nm) were well embedded in the S-doped carbon matrix (TiO$_2$/SC) by simultaneous polymerization of 2-thiophenemethanol and tetrabutyl titanate followed by a carbonization process (Fig. 1a). The TiO$_2$/SC anode shows the initial charge and discharge capacities of 375 and 700 mAh/g, respectively, corresponding to the coulombic efficiency of 53.6%. The retention of specific capacity is as high as 97% after 500 charge/discharge cycles at a high rate of 1 A/g. Excellent rate capability can also be observed in Fig. 1b. Such excellent electrochemical performances are attributable to the construction of nanosized oxides confined in the S-doped carbon matrix. The carbon matrix functions as a buffer to inhibit the volume change during cycling.[2] The S-doped carbon skeleton also bridges a continuous conductive network for fast transport of ions and electrons within the electrode. The proposed method may open a new way to develop high-performance anode materials.

Keywords: Simultaneous polymerization, Titanium dioxide, Composites, anode, Lithium-ion batteries

![Fig. 1](image-url) (a) Typical TEM image of the TiO$_2$/SC composites, and (b) rate performance of the as-fabricated half-cells employing the TiO$_2$/SC composites as the anode.
Abstract

A novel phosphorus-containing ionic liquid with tosylate anion and DOPO modified imidazole cation ([Dmim]Tos) has been successfully synthesized and used as a flame retardant for epoxy resin (EP). It is found that unlike most reported flame retardants, [Dmim]Tos not only doesn’t delay the curing of EP, instead of accelerating curing process (Figure 1). Part of the substituted imidazole also can react with DGEBA to form an adduct, which will further initiate the polymerization of diglycidyl ether, therefore, the curing process of epoxy resin is accelerated. Except stress at break and Young modulus, the elongation at break and impact strength of EP/[Dmim]Tos are almost as same as that of pure EP. The thermal stabiliy of [Dmim]Tos has a little lower than that of pure EP due to the poor stability of [Dmim]Tos. This phosphorus-containing ionic liquid impart excellent flame retardancy to EP. With only 4 wt% addition, EP/[Dmim]Tos can pass UL-94 V0 rating, possess the LOI value of 33.5%. In addition, the p-HRR, THR, av-EHC, TSR values of EP/[Dmim]Tos have been reduced compared with that of pure EP. The flame retardant action mechanism of [Dmim]Tos also has been well investigated.

Keywords: Phosphorus, Ionic liquid, Flame retardant, Epoxy resin, Mechanical properties
Recent Advances on Flame Retardant Thermoplastic Polyurethane Composites

Xiaodong Liu¹,², Hongfei Li¹,², Jun Sun¹,², Xiaoyu Gu¹,², and Sheng Zhang¹,²,*

¹Beijing Key Laboratory of Advanced Functional Polymer Composites, Beijing University of Chemical Technology, Beijing, 100029, China
²Center for Fire Safety Materials, Beijing University of Chemical Technology, Beijing, China
*Email: zhangsheng@mail.buct.edu.cn

Abstract

Bio-based flame retardants have attracted more and more attention recently in fire science community owning to its bio-degradability and sustainability1-3. Our previous work has demonstrated that chitosan can be directly used as charring agent in polylactic acid (PLA) composites4-5. This presentation summarized our recent efforts on improving the thermal stability and charring ability of CS by reacting with different aldehyde groups containing intermediate to obtain different CS derivatives. CS derivatives in association with ammonium polyphosphate (APP) was then introduced into thermoplastic polyurethane (TPU) to prepare flame retardant TPU composites. It is suggested that chitosan derivatives can improve the fire resistance of TPU composites effectively. The sample containing 18.75% APP and 6.25% salicylaldehyde modified CS (SCS) achieved the maximal limiting oxygen index of 29.5%, passed the V-0 rating and significantly decreased the peak heat release rate from 840.8 kW/m² of neat TPU to 206.2 kW/m². For another sample, with only 10 wt% flame retardants, the limiting oxygen index was increased from 20.8 to 29.0%, the vertical burning (UL-94) rating was upgraded from no rating to V-0. It was proposed that the synergism between CS derivatives and APP might be responsible for the improvement of flame retardancy.

Keywords: Thermoplastic polyurethane, Bio-based flame retardants, Separated by a comma

Fig. 1 HRR curves of TPU composite samples.
A Novel Organophosphorus Hybrid toward Flame Retarding Semi-Aromatic Polyamide Composite

Li Chen*, Xue-Bao Lin, and Yu-Zhong Wang

Center for Degradable and Flame-Retardant Polymeric Materials, College of Chemistry, State Key Laboratory of Polymer Materials Engineering, National Engineering Laboratory of Eco-Friendly Polymeric Materials (Sichuan), Sichuan University, Chengdu 610064, China.

*Email: l.chen.scu@gmail.com

Abstract

Phosphinates have been widely used for flame retarding engineering plastics owing to high-efficiency and hypotoxicity. However, the thermal stability of phosphinates depended on the different substituent groups and cations1, meaning that few kinds of phosphinates were proper to flame retard semi-aromatic polyamides (HTN for instance) with high processing temperature. Hybridization has provided a new strategy to design functional additives, therefore endow interesting performances for the derivative composites. For preparing high-temperature-resistant flame retardant for HTN, BM@Al–OPi hybrids were prepared by using boehmite (BM) as the inorganic part and organic phosphonic aluminum salts (Al–OPi) with different organic phosphonic acids as the organic component (Fig. 1) via analogue suspension in aqueous solution2.

Fig. 1 Hybridization of BM@Al–OPi (taking phenylphosphinic acid (PPiA) as an example). Formation process of BM@Al–PPi hybrid (a), microscopic morphology of Al–PPi aggregates (without residual BM) (b), and BM@Al–PPi hybrid with BM particle coated outside (c).

Keywords: Hybrid, flame retardance, Thermal stability, Semi-aromatic polyamide, Composite
Fire Performance of Basalt Fiber Reinforced Thermoplastics: a Comparative Study

Yousof Ghazzawi*, Michael T. Heitzmann, and Andres Osorio

*The University of Queensland St. Lucia 4072 Brisbane, Australia
*Email: y.ghazzawi@uq.edu.au

Abstract

Fibers have a major contribution to the fire performance of composite materials. Glass and carbon fibers are commonly used as a reinforcement for composite materials. In this research, Basalt fiber and glass fiber reinforced Polycarbonate composite laminates were produced via film stacking and compression molding. The fiber volume fraction and thicknesses for all samples were similar for all samples. Cone calorimetry test was used to determine heat release rate, time to ignition, and mass loss of the basalt fiber and glass fiber reinforced Polycarbonate. The heat flux was chosen to be 35 kW/m².

The aim of the investigation was to compare the fire behaviour of basalt fiber composites to the fire performance of glass fiber composites. The results presented show that peak heat release rate of basalt composites was around 15 % lower than glass fiber composites. However, the basalt fiber composites were found to ignite faster than glass fiber reinforced composites.

Keywords: Thermoplastic composite, Glass Fiber, basalt Fiber, Polycarbonate, Fire performance

Fig. 1 Heat release rate for Basalt fiber and Glass fiber reinforced PC.
Flame Retardant Modified Ammonium Polyphosphate and Its Increased Thermal Stability

Linshan Li, Yajun Chen*, and Lijun Qian

School of Materials Science and Mechanical Engineering, Beijing Technology and Business University, Beijing 100048, PR China

*Email: chenyajun@th.btbu.edu.cn

Abstract

A novel flame retardant surface modification agent was synthesized by phenylphosphonic dichloride (MPCP), polyether polyl and γ-aminopropyltriethoxysilane (KH-550). Ammonium polyphosphate (APP) was modified with this agent and M-APP was obtained. The chemical structure and thermal stability of M-APP was characterized by FTIR (Fig 1a) and TGA (Fig 1b). And the pyrolysis behavior was investigated by thermogravimetry-fourier transform infrared spectroscopy (Fig. 2). The TGA results presented that M-APP exhibited two-step thermal degradation process in nitrogen atmosphere. For M-APP, the initial decomposition temperature was 283 °C (Td, 5%) which was lower than that of APP (333 °C), but the temperature at maximum weight loss rate of M-APP (600 °C) was higher than that of APP (595 °C). Moreover, M-APP had a higher residual weight (21.87%) than APP (16.47%). Fig. 2 showed that the initial release temperature of NH3 decreased to 292 °C and the temperature range became narrow (292 °C~500 °C) for M-APP. It infers that the initial release temperature of NH3 became earlier and the released speed of NH3 became quicker.

Keywords: Ammonium polyphosphate, Flame retardant agent, Surface modification, Thermal stability

Fig. 1 a) FTIR spectrum of APP, M-APP and surface modification agent and b) TGA curves of APP and M-APP.
Preparation of Intumescent Flame Retardant Poly(butylene Succinate) using Urea Intercalated Kaolinite as Synergistic Agent

Lingling Gu\textsuperscript{1,2}, Sheng Zhang\textsuperscript{1,2}, Hongfei Li\textsuperscript{1,2}, Jun Sun\textsuperscript{1,2}, and Xiaoyu Gu\textsuperscript{1,2,*}

\textsuperscript{1}Beijing Key Laboratory of Advanced Functional Polymer Composites, Beijing University of Chemical Technology, Beijing, China

\textsuperscript{2}Center for Fire Safety Materials, Beijing University of Chemical Technology, Beijing,

*Email: guxy@mail.buct.edu.cn

Abstract

Urea has been intercalated into kaolinite (Kaol) by a solution method\textsuperscript{1}. In this work, urea was intercalated into kaolinite by simply grinding at different time and heating temperature. Then poly (butylene succinate) (PBS)/intumescent flame retardants (IFR)/ K-U composites were prepared by melt blending\textsuperscript{2}. The flame retardancy, thermal degradation of PBS composites were characterized. Table 1 and Fig. 1 demonstrated that the introduction of 20 wt % IFR and 5 wt % K-U into PBS increased the LOI to 40.1, improved the UL-94 rating to V-0 rating, and significantly reduced melt dripping. The char formation was significantly enhanced.

Keywords: Kaolinite, Hexakis (4-aldehyde phenoxy) cyclotriphosphazene, Poly(butylene succinate), Flame retardant

\begin{figure}
\centering
\includegraphics[width=\textwidth]{fig1}
\caption{Cone results for PBS and its composites.}
\end{figure}
Thermal Performance Analysis of Chemically Modified Carbohydrate Based Materials

Ananya Thomas, Paul Joesph*, and Khalid Moinuddin*

Victoria University

*Email: paul.joseph@vu.edu.au; khalid.moinuddin@vu.edu.au

Abstract

The increased use of fossil-based compounds in recent years has been identified to increase the frequency and intensity of natural hazards/events, such as wildland fires, building fires etc. Hence, there is an increased interest in the development of bio-based polymer additives that can act as appropriate replacements/alternatives to the petrochemical-derived materials currently in use. As bio-inspired starch-based blends are eco-friendly, inexpensive and available in abundance, they have an enormous potential to be widely used in various applications, including the paint, packaging and fire industries. However, they are inherently unsuitable to be used as such, mainly owing to their characteristic behavior of low thermal stability and degradation profiles. Therefore, to enhance the positive characteristics of bio-based starch materials, the present study attempts to chemically modify starch-based polysaccharides including beta-cyclodextrin, dextran, potato starch, tamarind kernel powder and wood dust. As phosphorus and its compounds have been long identified as fire retardants, here we propose to develop bio-inspired fire-resistant materials by chemically incorporating phosphorus-containing moieties into the carbohydrate-based substrates. Fourier transform infrared spectroscopy and Atomic absorption spectroscopy have been employed to elucidate the structural features and gauge the extent of incorporation of phosphorus-containing groups into the molecules. The unmodified counterparts have also been subjected to the same set of analyses to serve as controls for the purpose of comparison. Furthermore, we have conducted a set of small-scale experiments including, Thermo-gravimetric analysis, Differential scanning calorimetry and Pyrolysis flow combustion calorimetry to elucidate the thermal and flammability properties of the modified and unmodified substrates.

Keywords: Fire retardant, Bio-based, Eco-friendly, Small-scale experiments
Catalyzing Carbonization Flame Retardancy and Thermal Stability of Carbon Fiber Precursor

Hui Shi¹, Yunguo Yang¹, Yangqin Ou², and Jianwei Hao¹,*

¹National Engineering Technology Research Center of Flame Retardant Materials, School of Materials Science and Engineering, Beijing Institute of Technology, Beijing, China
²National Engineering Laboratory for Carbon Fiber Preparation Technology, Ningbo Institute of Material Technology & Engineering, Chinese Academy of Science, Ningbo, China.

*Email: hjw@bit.edu.cn

Abstract

The graphite-like structure formation is the essential characteristic for polymer flame retardancy in condensed phase, and thermal stabilization and carbonization process of carbon fiber precursor. The catalyzing carbonization of solid acid for polyhydroxy compound and polymer materials reported in previous studies1,2. In this paper, poplar lignin (PPL), pine lignin (PNL), wheat-straw lignin (WSL) as bio-based flame retardants3 were mixed with PAN respectively, the thermal stability of PAN/lignin composites as carbon fiber precursors was compared, the effect of boron phosphate (BP) on graphite-like structure formation for PAN/lignin composites was studied by X-ray Photoelectron Spectroscopy (XPS). The results showed that graphite-like structure content increases with temperature increase for each precursor, and PAN/PPL illustrates higher graphite-like structure content than PAN due to PPL has the lower C/O ratio; and the addition of BP can further improve the thermal stability of PAN/lignin composites by catalysing carbonization (Fig.1). These results confirms that the addition of flame retardants could be beneficial for improving thermal stability of carbon fiber precursor.

Keywords: Catalytic carbonization, Flame retardancy, Thermal stability, Carbon fiber precursor
Fullerene: a Potential Synergist for Fire Retardant Polyolefins
Zhengping Fang*, Zhenghong Guo, and Shiya Ran

Laboratory of Polymer Materials and Engineering, Ningbo Institute of Technology, Zhejiang University, Ningbo 315100, China
*Email: zpfang@zju.edu.cn

Abstract
The combustion of polyolefin is a thermal oxidative degradation process, usually by free radical chain reaction, in which HO• and other live free radicals is of key importance. Elimination of lively free radicals can delay the degradation and combustion of polymers. The fullerene (C60) is well known as the free radical sponge. C60 can indeed effectively improve the polymer thermal stability and flame retardant properties. The flame retardant mechanism is mainly through the capture of free radicals generated when the polymer is decomposed to form a more stable network cross-linked structure, reducing the possibility of further degradation. Furthermore, C60 was added into aluminium hydroxide (ATH) flame retardant polyethylene (PE) as a synergist. When PE/ATH was 100/120, the addition of 3 phr C60 could improve the combustion grade of the system to UL-94 V-0 level, which is comparable to the flame retardant effect of 160 phr ATH. The reduction of the total amount of the flame retardant reduces the adverse effect of the flame retardant on the mechanical properties and the processability. Based on this principle, a variety of additives with free radical trapping ability, such as rare earth compounds, carbon black, hindered amine and so on, was used for flame retarding polyolefin. Some systems also achieved synergistic flame retardant, showing the potential of free radical scavenger as flame retardant synergist.

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Keywords: Polyolefin, Flame retardant, Fullerene, Free radical scavenger
Synthesis, Thermal Behavior and Combustion of Novel Uv-Cured Flame Retardant Coatings

Weiyi Xing*, Lei Song, and Yuan Hu

State Key Laboratory of Fire Science, University of Science and Technology of China, Hefei, Anhui 230026, P.R.China

*Email: xingwy@ustc.edu.cn

Abstract

The novel organo-phosphorus acrylate BTP containing acid and carbon source, and BDEEP were synthesized successfully (as shown in Scheme 1 and Scheme 2). The structures for these flame retardants were characterized by Fourier transformed infrared spectroscopy (FTIR), 1H nuclear magnetic resonance spectroscopy (1H-NMR). The combustion behavior of flame retarded materials was evaluated by Limited Oxygen Index (LOI), Micro-scale Combustion Calorimeter (MCC) and Cone Calorimeter (Cone). It was found that the addition of BTP obviously increased the flame retardancy of PUA. The LOI of PUA could increase from 19.0 to 30.5, and the heat release rate decreased by 66.0%. Thermal degradation of flame retarded materials was studied by thermogravimetric analysis (TGA), and thermogravimetric analysis/infrared spectrometry (TGA-IR). It was found that the phosphate in BTP decomposed to form poly(phosphoric acid) at low temperature, which catalyzed PUA carbonization, and increased the thermal stability at high temperature. The volatilized products formed on thermal degradation of BDEEP were CO, CO2, water, alkane, carbonyl, phosphorus compounds and aromatic compounds according to the temperature of onset formation.

Keywords: Synthesis, Flame Retardant Coating, Thermal Behavior, Flame Retardancy

Fig. 1 The 3D surface graph for the FTIR spectra of the evolved gases (a) and the relationship between intensity of characteristic peak and temperature (b).
Session: Flame Retardant Composites
Comp-6-2-O2

Flame-Retarding, Mechanically Strong Elastomeric Composites
Jun Ma*

University of South Australia, Adelaide, SA 5095, Australia; Jun.Ma@unisa.edu.au
*Email: jun.ma@unisa.edu.au

Abstract
Of all engineering materials, polymers have witnessed rapid increase in applications over the past decades due to their low manufacturing cost and decent specific strength. However, polymers are limited by low absolute stiffness and strength and lack of functionality such as electrical and thermal conductivity. Processing polymers with nanomaterials holds great potential to address these limitations.

In spite of extensive studies of utilizing carbon nanotubes and silicate layers to address the limitations, the rise of graphene now provides a more promising candidate due to its exceptionally high mechanical performance, electrical and thermal conductivities, and specific surface area. My research team since 2008 has conducted extensive research of developing new graphene platelets [2–3] and using them for processing of epoxy elastomers and conducting polymers. Graphene platelets contain only 7 atom% oxygen and have a thickness of 2–4 nm depending on the suspension medium for measurement. They have a Raman Id/Ig ratio of 0.07, corresponding to an electrical conductivity of 1456 S/cm measured by a four-probe method.

Keywords: Graphene, Polymer composites
Mechanically-Strong and Flame-Retardant Gelatin/Poly(Vinyl Alcohol)/Clay Composite Aerogels

Hai-Bo Zhao1,*, Yu-Tao Wang1, Yu-Zhong Wang1, and David A. Schiraldi2

1Center for Degradable and Flame-Retardant Polymeric Materials, College of Chemistry, National Engineering Laboratory of Eco-Friendly Polymeric Materials, Sichuan University, Chengdu 610064 2Department of Macromolecular Science and Engineering, Case Western Reserve University, Cleveland, Ohio 44106-7202, United States

*Email: haibor7@163.com

Abstract

Novel mechanically-strong and flame-retardant polymer/clay composite aerogels were designed and fabricated from biomass gelatin, poly(vinyl alcohol) (PVA) and montmorillonite (MMT) via a simple and environmentally friendly freeze-drying method. Benefitting from strong interfacial adhesion between PVA and gelatin, the resultant PVA/MMT/gelatin composite aerogels exhibited a compressive modulus value of 12.4 MPa, nearly 3 times higher than that of the control PVA/MMT aerogel. The co-continuous microstructure of the aerogel with gelatin implied an increasing interaction between the different phases in the PVA/MMT/gelatin aerogels, compared with in the control. Furthermore, the limiting oxygen index (LOI), vertical burning test and cone calorimetry test confirmed that the low flammability of the aerogels could be achieved by the flame retardancy of gelatins and MMT. The composite aerogels reached V-0 rating in the vertical burning tests and exhibited a high LOI value of 28.5% and low heat release rate in the cone calorimetry tests. Thermogravimetric analysis demonstrated that the gelatins slowed the sharp decomposition of the PVA matrix polymer and increased the thermal stability of the aerogels at the major decomposition stage of the composite aerogels. This mechanically-strong and flame-retardant polymer/clay composite aerogels show promising prospects in the field of thermal insulation.

Keywords: Aerogel, polymer, Clay, flame retardance, Mechanical property

Fig. 1 Compress moduli, SEM images, fire out times and LOI values for aerogels.
Intercalation and Functionalization of Mxene for Flame Retardant Polymer Nanocomposites

We Yang 1,2,*, Anthony Chun-Yin Yuen2, and Bin Yu3

1Department of Chemical and Materials Engineering, Hefei University, 99 Jinxiu Avenue, Hefei, Anhui, 230601, People’s Republic of China

2School of Mechanical and Manufacturing Engineering, University of New South Wales, Sydney, NSW 2052, Australia

3Department of Architecture and Civil Engineering, City University of Hong Kong, 88 Tat Chee Avenue, Kowloon, Hong Kong, People’s Republic of China

*Email: weyang@ustc.edu.cn

Abstract

Since the pioneering preparation of multi-layered Ti3C2 by etching Ti3AlC2 with hydrofluoric acid in 2011, Ti3C2 has generated great research interest in energy storage and transfer, and polymer composites due to their outstanding electrical conductivity and mechanical properties 1, 2. However, the huge challenge of Ti3C2 for application in polymer composites is to achieve effective exfoliation and uniform dispersion of Ti3C2 within polymer matrix. As demonstrated by recent work, Ti3C2 can be easily intercalated with increased interlayer spacing using various cationic surfactants, which is beneficial to exfoliation of Ti3C2 3, 4. Noticeably, transition metal elements in Ti3C2 is well known for smoke and toxic gases suppression, while the nanosheets could serve as the barrier for flame retardant polymers. Therefore, it is expected to fabricate high-performance flame retardant polymer nanocomposites. Herein, functionalized MXene will be designed relying on the layered structure of Ti3C2 as the “frame” and cetyltrimethyl ammonium bromide (CTAB) as both intercalator and modifier. Functionalized Ti3C2 (CTAB-Ti3C2) exhibited disordered and exfoliated Ti3C2 nanosheets in a conductive tape (Fig 1c). Evaluation of combustion from cone calorimeter revealed that the addition of Ti3C2 (1 wt%) is capable of reducing the fire hazards of thermoplastic polyurethane elastomer (TPU) and thermally cured epoxy resin (EP), respectively.

Keywords: Metal carbide Polymer nanocomposites, Flame retardancy, Mechanical properties
The Enhanced Flame-Retardant Effect of Organosilicon Compound to Phosphorus/Silicon Compound on Polycarbonate

Pei Ni, Lijun Qian*, and Yajun Chen

School of Materials Science and Mechanical Engineering, Beijing Technology and Business University, Beijing 100048, PR China

*Email: qianlj@th.btbu.edu.cn

Abstract

A phosphorus/silicon flame retardant, MVC-DOPO, was synthesized from 9,10-dihydro-9-oxa-10-phosphaphenanthrene-10-oxide (DOPO) and 2,4,6,8-tetra-methyl-2,4,6,8-tetra-vinyl-cyclo-tetrasiloxane (MVC) and its flame-retardant effect on polycarbonate was investigated. MVC-DOPO increased the limited oxygen index and UL-94 rating and reduced the heat release rate. Organic silicon compound, octa-phenyl-cyclo-tetra-siloxane (OPC), was introduced into the flame-retardant PC composites to enhance the flame-retardant effect. After incorporation of OPC, the limited oxygen index and UL-94 rating were increased to a higher level and the heat release rate also reduced. MVC-DOPO exerted flame-retardant effect in both the gaseous and condensed phase during combustion, the introduction of OPC can effectively promoting formation of more viscous residue in condensed phase. Accordingly, OPC and MVC-DOPO jointly worked to enhance the flame retardancy of PC composites.

Keywords: Phosphorus, Silicon, Flame retardant, Polycarbonate

Fig. 1 SEM photos (200×) of inner surface of residues after cone calorimeter test: (A) PC; (B) 6%MVC-DOPO/1%OPC/PC; (C) 8%MVC-DOPO/1%OPC/PC; (D) 10%MVC-DOPO/1%OPC/PC.
Inorganic-Orginic Hybrids: a New Approach to Fire Safety Polymeric Materials
Xin Wang*, Zhou Gui, and Yuan Hu

State Key Laboratory of Fire Science, University of Science and Technology of China, 96 Jinzhai Road, Hefei, Anhui 230026, P.R. China. E-mail: *Email: wxcmx@ustc.edu.cn

Abstract
Over the last decade, inorganic-organic hybrid technology has attracted considerable attentions in the field of flame retardant polymeric materials. In this context, various kinds of inorganic nano-materials like layered double hydroxide, graphene, and silica have been hybridized by organic molecules for enhancing the flame retardancy and smoke suppression of polymer composites. With a relatively low loading of inorganic-organic hybrid materials (< 10 wt%), the resultant polymer composites showed the significantly suppressed heat release rate as well as smoke and toxic gases release. For instance, the addition of 1 wt% and 3 wt% of boron nitride hybrid into the EP matrix results in the 47.2% and 53.1% reduction in PHRR, respectively. As well, epoxy composites containing 3 wt% boron nitride hybrid showed a approx. 40% reduction in smoke production rate (Fig. 1). In another study, the addition of 4 wt% melamine cyanurate/MoS2 hybrid results in reductions in PHRR and total smoke production by 40% and 20%, respectively (Fig. 2). These studies demonstrated that inorganic-organic hybrid materials are one kind of highly efficient flame retardant in polymer composites.

Keywords: Inorganic-Organic Hybrids, Flame Retardant, Smoke Suppressant, Polymer Composites

Fig. 1 (a) HRR and (b) SPR versus time curves of epoxy and its composites.
Synthesis of Novel Compound Based on Chitosan and Ammonium Polyphosphate

M.N. Prabhakar*, and Jung-il Song

Department of Mechanical Engineering, Changwon National University, Changwon-51140, Korea

*Email: manoj.prabhakarn@gmail.com

Abstract

Generally, the incorporation of particle filler (flame retardant) causes a decrease in the mechanical strength of the natural fibre reinforced polymer composites due to chemical interaction/incompatibility. Moreover, alone APP also not efficient flame retardant, but combining with carbonizing agents would induce synergistic effect which greatly promote the char formation and eventually improve flame retardancy, therefore the present study concentrated to full fill and overcome the problems. Eco-friendly novel bio-phosphate flame retardant (BPF) was synthesized by utilizing chitosan (CS) and ammonium polyphosphate (APP) through solution mixing process. The obtained BPF molecular structural interaction was corroborated by Fourier transform infrared (FTIR) spectroscopy, X-Ray diffraction (X-RD), nuclear magnetic resonance (NMR) techniques and characterized by field emission scanning electron microscopy (FESEM), thermogravimetric analysis (TGA), differential scanning calorimetry (DSC) for morphology, thermal stability respectively. CS and APP molecules could interact via chemical interaction between -OH groups of CS and polyphosphoric group of APP resulting formation of new chemical bonds with new structure (as shown in Fig.1). TGA thermograms clearly prove that BPF has good ability of char formation, ~35% char residue formed at temperature ranging from 300 to 800 oC as well as thermal stability compared with pristine CS, APP and physical mixture of CS-APP. The results presented in this study show a novel with economical approach for the development of eco-friendly intumescent flame-retardant system.

Keywords: Chitosan, Ammonium Polyphosphate, Thermal stability, Flame retardancy

Fig. 1 Proposed reaction between CS and APP.
Abstract

This research work is to evaluate the influence in thermal properties and flammability behaviour of Jatropha bio-epoxy blended with synthetic resin by weight percentage. Jatropha bio-epoxy was produced by epoxidation process then it was blended with synthetic epoxy by weight percent of 0%, 25%, 50%. These matrices were reinforced with carbon fibre and samples were fabricated by using vacuum infusion method. Samples were sent for TGA, DMA, and DSC for thermal analysis and flammability test. Results exhibited that by increasing the amount of Jatropha bio-epoxy as resin, the matrix becoming more thermally stable at below 390 °C, damping ability reduced, storage modulus reduced and glass transition temperature also reduced. Even though the behaviour displayed decreasing pattern, sample with 25% blended Jatropha bio-epoxy showed acceptable behaviours compare to the control sample. As for flammability behaviour, time to self-extinguished becoming faster as amount of synthetic epoxy increase. These analysis verify that 25% Jatropha bio-epoxy is the right amount as to make the composite structure greener without losing much thermal and flammability performance.

Keywords: Bio-epoxy, Jatropha, Flammability, Thermal, Carbon Fibre
Self-Assembly of Zinc Hydroxystannate on Amorphous Hydrous TiO₂ Solid Sphere for Enhancing Fire Safety of Epoxy
Yongchun Ka¹*, and Yuan Hu²
University of Science and Technology of China
*Email: yckan@ustc.edu.cn

Abstract
Zinc hydroxystannate (ZHS) was fabricated on the surface of amorphous hydrous TiO₂ solid spheres (AHTSS) via a layer-by-layer method for improving the fire safety of epoxy resin. AHTSS@PEI@ZHS was prepared by self-assembly of AHTSS, PEI and ZHS. The well-organized fabrication process was proved by TEM, XPS, XRD and SEM tests. TG results illustrated that the incorporation of AHTSS@PEI@ZHS show a higher residue compared with the addition of AHTSS or ZHS alone. In addition, AHTSS@PEI@ZHS filled EP composites exhibits improved flame retardancy and smoke suppression properties evaluated by cone calorimeter test. TG-IR results also indicated that the catalytic labyrinth structure of AHTSS@PEI@ZHS can effectively decrease the permeation of volatile organic compounds, thereby improving the fire safety of EP resin.

Keywords: Self-assembly, Zinc hydroxystannate, TiO₂, Epoxy, Fire safety

Fig. 1 a–c) SEM images, d) SEM-EDX information and e–h) TEM images of AHTSS@PEI@ZHS with different magnification e-g) 200 nm and h) 50 nm; i) ζ-potential of AHTSS, AHTSS@PEI and AHTSS@PEI@ZHS.
Flame Retardant Properties of Polyethylene Terephthalate/Alginate Composite Nonwoven Fabrics
Yun Liu, Ping Li, Quan-Quan Wang, Zhao-Hong Dong, and Ping Zhu*

College of Textile and Clothing, Institute of Functional Textiles and Advanced Materials, Qingdao University, Ningxia Road, 308, Qingdao 266071, China
*Email: pzhu99@163.com

Abstract
Alginate fibers, which are bio-based fibers, are one of inherently flame retardant materials. Can the addition of alginate fiber to polyethylene terephthalate (PET) fiber improve the flame retardancy of prepared PET/alginate composite nonwoven fabrics? In order to resolve this question, in the present work, the effect of the additive amount of alginate fibers to PET fibers on the flame retardancy of prepared PET/alginate composite nonwoven fabrics were investigated by cone calorimeter. Cone results indicated that the addition of alginate fiber obviously reduced the peak heat release rate (PHRR), Av-HRR and total heat release (THR) of prepared PET/alginate composite nonwoven fabrics, showing the improvement on flame retardant properties of prepared PET/alginate composite nonwoven fabrics. Compared with PET nonwoven fabric, the 20 wt% additive amount of alginate fibers to PET fibers (the sample of PET4/alginate1) seviously decreased the PHRR value of prepared PET/alginate composite nonwoven fabrics, from 360 to 193 kW/m2. This result indicates that alginate fibers can be utilized as a kind of flame retardants to flame-retard PET fibers. Compared with the time to ignition (TTI) values of PET and alginate nonwoven fabrics, the TTI values of prepared PET/alginate composite nonwoven fabrics are shorter, and the reason for this phenominon is being investigated.

Keywords: Flame retardant properties, Alginate fiber, PET/alginate composite nonwoven fabrics

Fig. 1 The HRR and THR curves of PET, alginate and PET/alginate composite nonwoven fabrics as a function of time.
Session: Flame Retardant Composites
Comp-6-4-12

Orientation Effects on Fire Reaction Properties of Flax Fibre Reinforced Polymeric Composites
Nam Kyeun Kim*, Swagata Dutta, and Debes Bhattacharyya

Centre for Advanced Composite Materials, Department of Mechanical Engineering, The University of Auckland, Auckland, 1142, New Zealand
*Email: nam.kim@auckland.ac.nz

Abstract
The orientation of a heat source or material has been recognised as one of major factors to determine the fire hazard1, 2. In particular, horizontal and vertical orientations of samples have been selected for the heat release rate measurements of flame regulations in the construction and aviation industries, respectively, as these two heating environments create different heat transfer and air entrainment mechanisms1. The cone calorimeter, as a versatile fire testing equipment, can set up the horizontal and vertical orientations of the conical heater and sample, and can measure fire reaction properties, such as time to ignition, heat and smoke production rates. In this research, the effects of orientation on the ignition and combustion behaviour of flax fibre reinforced composites have been investigated in the cone calorimetry tests. Furthermore, a flame retardant has been employed to reduce the composites flammability and to explore the orientation effect on char formation. The long flax fibre-polypropylene composites oriented vertically has shown longer time to ignition and lower peak heat release rate than samples oriented horizontally, Table 1, due to the establishment of boundary condition at bottom of sample. Moreover, the total smoke production has demonstrated the similar trend with the heat release rate results.

Keywords: Orientation, Cone calorimeter, Fire reaction properties, Flax fibre reinforced composites

Tab. 1 Cone calorimeter results of flax fabric based polypropylene composite laminates.

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Heat flux (kW/m²)</th>
<th>Time to ignition (s)</th>
<th>Peak heat release rate (kW/m²)</th>
<th>Total heat release (MJ/m²)</th>
<th>Total smoke production (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>55</td>
<td>39</td>
<td>558.4</td>
<td>128.4</td>
<td>135.2</td>
</tr>
<tr>
<td>Vertical</td>
<td>35</td>
<td>48.5</td>
<td>469.1</td>
<td>105</td>
<td>99.6</td>
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<tr>
<td>Horizontal</td>
<td>50</td>
<td>21</td>
<td>692.4</td>
<td>122.9</td>
<td>79.1</td>
</tr>
<tr>
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<td>50</td>
<td>25.7</td>
<td>684.6</td>
<td>98.2</td>
<td>75.1</td>
</tr>
</tbody>
</table>
Session: Flame Retardant Composites  
Comp-6-4-O1

**PSA Fiber Reinforced PTFE Composite and Its Properties**  
Yu Mingming*, Musu Ren, Fang Lin, and Xie Wang  
*Research Center for Composites, No.149 Yanchang Rd., Shanghai, P.R.C.*  
*Email: mmyu@shu.edu.cn*

**Abstract**

PTFE has been widely used in the fields of bearing and sealing, because this material has excellent flame retardant and self-lubricating property, and it could be used at high temperature. But the further application was limited due to its less wear resistance property. However, it could be improved significantly when PTFE was reinforced with fiber. In this paper, PTFE was mixed with chopped polysulfonamide fiber (PSAf) by special process, then polysulfonamide fiber reinforced polytetrafluoroethylene composite (PSAf/PTFE) was prepared by molding the mixture. Furthermore, the physical and mechanical properties, together with the friction and wear properties of PSAf/PTFE composite were evaluated in detail. The results showed that all the properties were improved when PTFE modified with chopped polysulfonamide fiber. And the hardness, the compression strength and the impact strength of the composite was 57HD (Shore), 31MPa and 36KJ/m² respectively, when the fiber content was 10wt%. Besides, the composite exhibited excellent self-lubricating property and wear resistant since its friction coefficient was less than 0.13 and the wear loss was less than 0.16mm. Moreover, the friction and wear properties of the composites were greatly influenced by the load, while the speed had little effect. In addition, the tribology mechanism of PSAf/PTFE composite was investigated.

**Keywords:** hypoeutectic Al-Mg2Si composites; Bi addition; eutectic Mg2Si; tensile properties

![Fig. 1 The tribology properties of PSAf/PTFE composite at different load.](image)
Facile Preparation of Organic Nano-Layered Aluminum Phosphonate for Effectively Reducing the Flame Hazards of Polystyrene

Weizhao Hu, Yanbei Hou, and Bibo Wang*

State Key Laboratory of Fire Science, University of Science and Technology of China, PR China

*Email: wbibo@ustc.edu.cn

Abstract

Heavy soot and toxic gases will be released during combustion of polystyrene (PS). These potential fire risks of PS can be decreased by effective combustion suppression. In this work, organic nano-layered aluminum phosphonate (OAHPi) was simply synthesized by one-step and firstly incorporated into PS to reduce flame hazards. The morphology and thermostability of OAHPi was characterized by various characterizations. Fire hazard assessment and flame retardancy of composites were also investigated. Results revealed that laminar OAHPi with nano scale was formed by a facile method. With relatively low additive amount, thermostability and char yield increased with increasing OAHPi content in PS, while total heat release, CO2 output and smoke density decreased. Above results indicated that OAHPi had a significant effect on the flame retarding and heat endurance, which was beneficial to decrease fire potential risk of PS. The high efficiency was attributed to layered structure and phosphorus-containing. Meanwhile nanoscale size and organic fraction improved compatibility of OAHPi and PS. Theoretically, homogeneous dispersed lamellar sheets blocked the heat and energy transfer, and phosphorous compounds worked in condensed or gas phase. The possible flame-retardant mechanism was also proposed according to experiment results.

Keywords: Layered aluminum phosphonate, Polystyrene, Flame retardancy, Nanocomposites

Fig. 1 Synthetic route for organic layered OAHPi.
Facile and Novel Preparation of Hybridized Ammonium Polyphosphate with Cellulose Nanofiber and Their Poly(Lactic Acid) Composites for Flame Retardancy and Mechanical Properties

Jinfeng Dai¹, Weida Yin², Pingan Song³,* Chunde Jin¹,* and Yutao Yan¹

1 Department of Materials, College of Engineering, Zhejiang A&F University, Hangzhou China
2 School of Chemical Engineering and Technology, Harbin Institute of Technology, Harbin China
3 Department of Materials, College of Engineering, Zhejiang A&F University, Hangzhou 311300, China; Center for Future Materials, University of Southern Queensland, West Street, Toowoomba, Queensland 4350, Australia

*Email: pingansong@gmail.com; jincd@zafu.edu.cn

Abstract

Despite extraordinary mechanical properties and excellent biodegradability, the intrinsic flammability and brittleness of poly(lactic acid) (PLA) is still restricting the further application⁻³⁻⁴. In this study, we have demonstrated a facile and novel synthesis of flame-retardant reinforcement additive system (APP@CNF), via hybrizing cellulose nanofiber (CNF) with ammonium polyphophate (APP) by hydrogen bonds interaction. APP@CNF as flame retardant mixes within PLA matrix for flame retardancy PLA composites. The fire retardancy, thermal degradation behavior, mechanical properties of the PLA composites are well-investigated. The results demonstrate that 10 wt% APP@CNF endows high-efficient flame retardancy and reinforcement to PLA/APP@CNF, with 30.0% limiting oxygen index (LOI), UL-94 V-0 flammability rating, lower peak heat release rate (255 kJ/m²) and total heat rate (57.9 kJ/m²), and higher elastic modulus (2.73 GPa). The morphology analysis shows that CNF winds around APP causing APP@CNF well dispersed within PLA matrix, thus obtaining excellent flame retardancy and reinforcement PLA composites. This work provides an innovative approach to designing flame retardant reinforcement additive for polymer materials.

Keywords: Ball-mill, nanofiber, Ammonium polyphosphate, Flame retardant, Mechanical properties
Online Study on the Pyrolysis of Polypropylene/Glycidyl Polyhedral Oligomeric Silsesquioxane Nanocomposite with Pyrolysis Photoionization Time-of-Flight Mass Spectrometry

Shibin Nie¹,*, Lei Liu², Changguo Xue¹, and Can Zhou¹

¹School of Energy Resources and Safety, Anhui University of Science and Technology, Huainan, Anhui 232001, China;
²School of Mechanical Engineering, Southeast University, Nanjing, Jiangsu 211189, China

*Email: nsb@mail.ustc.edu.cn

Abstract

Abstract: Polypropylene/glycidyl polyhedral oligomeric silsesquioxane (PP/G-POSS) nanocomposites were prepared by physical blending, and the pyrolytic behavior of composites was studied using online pyrolysis photoionization time-of-flight mass spectrometry (Py-PI-TOFMS) under different temperatures from 400 oC to 700 oC in real time. Kinds of pyrolytic products divided into alkenes, aromatics and so on are identified in PP/G-POSS pyrolytic process, and the primary products are short chain hydrocarbons (C3-C6), indicating that the PP/G-POSS is inclined to form short chain hydrocarbons at high temperature. Meanwhile, the silicon and oxygen elements couldn’t be found in gas phase. This work is helpful for further understanding the pyrolysis mechanism of polymer/POSS nanocomposites.

Keywords: Polypropylene, Glycidyl polyhedral oligomeric silsesquioxane, Pyrolysis, Nanocomposite

Fig. 1 Mass spectra of the pyrolytic products of PP/G-POSS at different temperature.

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Comp-6-5-11

Fire Hazard Assessment on Thermal Polyurethane and Its Nanocomposites with AHP Analysis
Ruowen Zong¹,*, Chen Liu¹, and Haiyan Chen¹

*Email: zongrw@ustc.edu.cn

Abstract

Fire risk of polymer is related to the release of heat, smoke and toxicant, and different parameters bring about different assessment results. In this paper, montmorillonite (MMT), aluminium hydroxide (ATH) and ammonium polyphosphate (APP) were added as flame retardants for thermal polyurethane (TPU). Static state tube furnace, steady state tube furnace and cone calorimeter have been used to measure the data. Total HCN concentration was regarded as special toxicity hazard index, CO and CO2 yields were regarded as general toxicity hazard indexes. The heat release rate, average heat release rate and total heat release were regarded as heat hazard indexes. The smoke produce rate was regarded as smoke hazard. In this paper, the impact of different toxic gases on the fire risk of materials in fire smoke was subdivided. Fire hazard of TPU and its nanocomposites were assessed by analytic hierarchy process, which was used to calculate the weights of indexes. The results showed that the lowest fire risk appeared in the TPU with 6wt% APP, 3%wt ATH and 3%wt MMT, which proved that it was feasibility to reduce fire hazard of polymers from heat, smoke and toxicity simultaneously.

Keywords: Analytic hierarchy process, Fire risk, Thermal polyurethane, Tube furnace, Cone

Fig. 1 Schematic diagram of the tube furnace.
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Comp-6-5-I2

Polyacrylonitrile Copolymer Composites with Catechol Unit in the Backbone: Synthesis and Thermal Properties

Ki-Ho Nam, Nam-Ho You, and Bon-Cheol Ku*

Institute of Advanced Composite Materials, Korea Institute of Science and Technology (KIST), Jeonbuk 565-902, Republic of Korea

*Email: cnt@kist.re.kr

Abstract

Polyacrylonitrile (PAN) is an important and well-established example of a fibre-forming polymer and is the precursor to carbon fibre. Herein, mussel-inspired acetonide-protected dopamine methacrylamide (ADMA) were synthesized and copolymerized with acrylonitrile (AN), under radical initiation in an inert atmosphere, in aqueous slurries. Then, well-defined acrylonitrile-dopamine methacrylomide copolymer, Poly(AN-co-DMA) bearing free-catechol units were prepared by facile deprotection by p-toluenesulfonic acid treatment. The resulting copolymers were subjected to a variety of characterization techniques, such as 1H and 13C nuclear magnetic resonance (NMR), Fourier transform infrared spectroscopy (FTIR), differential scanning calorimetry (DSC), X-ray diffraction (XRD), gel fraction tests, thermogravimetric analysis (TGA), and pyrolysis combustion flow calorimetry (PCFC). The thermal degradation and combustion behaviours of the Poly(AN-co-DMA) were assessed primarily with a view to designing comonomers, for AN-based polymers, bearing flame retardant moieties. From the PCFC tests, catechol-functionalized comonomers were found to improve fire performance. Furthermore, the effects of incorporating of functionalized graphene oxide (FGO) into P(AN-co-DMA) were investigated in terms of the flammability, thermal and mechanical properties. It is established that FGO-based P(AN-co-DMA) composites showed better mechanical, thermal, and flame retardant properties.

Keywords: Polyacrylonitrile, Catechol-functionalized monomer, Heat of combustion, Pyrolysis combustion flow calorimetry, Heat release capacity

Fig. 1 Bio-inspired low temperature stabilizable PAN copolymer for low-cost carbon fibre precursor.
Ctab-Bentonite Coated Filter Paper for Efficient and Rapid Removal of Dyes

Wenyun Li, Yunshan Bai*, Dandan Xu, Min Wu, and Hongzhu Ma*

School of Chemistry and Chemical Engineering, Shaanxi Normal University, Xi’an, Shaanxi, 710119, People’s Republic of China

*Email: hzmachem@snnu.edu.cn

Abstract

Adsorption is proven to be a practical way for the treatment of dye wastewater. Bentonite, and cellulose were frequently used as the adsorbents1-2. Here, filter paper coated with CTAB-bentonite and polyacrylic acid layer composite (PAA/CTAB-Bent-FP) with various ratios(CTAB/Bent) was synthesized and evaluated(Fig.1). The results of adsorption and separation performance of PAA/CTAB-Bent-FP showed that the anionic dye ORII and cationic MB both could be adsorbed efficiently and rapidly by simple filtration, 80% ORII and 86% MB removal efficiency within 150 s were achieved by 30%PAA/CTAB-Bent-FP. More importantly, rapid adsorption and simply separated were realized simultaneously by conventional filtration operation. The possible adsorption interaction was proposed(Fig.2). As a practical feature, PAA/CTAB-Bent-FP worked at a wide pH range and could be used either as a solid adsorbent or a membrane for continuous wastewater treatment.

Keywords: Composite coating, Adsorption, Dye, Bentonite, Filter paper

Fig. 1 Comparison of various adsorbents.      Fig. 2 Possible adsorption interaction.
Session: Naturally Derived Composites
Comp-12-1-12

Novel Functionalized Lignin as Potential Material for Biobased Composites

M. Gaugler*, J.H. Bridson, K.M. Torr, D.J. van de Pas, A.P. Vogt, D.A. Smith
Scion, 49 Sala Street, Private Bag 3020, Rotorua 3046, New Zealand
*Email: marc.gaugler@scionresearch.com

Abstract
Natural materials as fillers or reinforcement in thermoset and thermoplastic composites have been researched and used for decades. Polysaccharides in plant fibre, for example wood fibre, are surrounded by an aromatic polymer matrix known as lignin, which is hydrophobic and water impermeable.1 For example, lignin constitutes up to 30% of the dry weight in softwoods making it one of the most abundant natural polymers in the world.2 Its availability in large quantities makes it a good candidate molecule as reinforcement, additive or filler to polymers. Furthermore, its unique properties could yield unique and beneficial polymeric composite properties. However, non-reactive fillers in polymers often reduce some physical properties and much research has gone into identifying suitable compatibilisers for composites comprising biomaterials.3 Challenges and opportunities of utilising lignin as well as a novel functionalized lignin as an inactive or functional additive in polymer composites will be discussed.

Keywords: Lignin, Functionalised, Bio-based composites, Natural materials
A Study Of Diatomite/Nylon Phase Change Material Composite
Yeng-Fong Shih¹,*, Chih-Hung Wang¹, Ming-Hui Tseng¹, and Jih-Mirn Jehng²
¹Department of Applied Chemistry, Chaoyang University of Technology, No. 168, Jifeng E. Rd., Wufeng District, Taichung 41349, Taiwan
²Department of Chemical Engineering, National Chung Hsing University, No. 145, Xingda Rd., South Dist, Taichung 402, Taiwan
*Email: syf@cyut.edu.tw

Abstract
This study reports on the functionalization of recycled diatomite (DT) for preparing green and shape-stabilized phase change material (SSPCM); the DT-based SSPCM can be employed in Nylon to form thermo-regulating textiles. To avoid PCM leakage, PCM is adsorbed on DT with a stable structure, and such SSPCM can be synthesized by easy and low-cost methods. After purification, the purified DT (P-DT) adsorbs polyethylene glycol (PEG) by the straight dipping process for producing SSPCM. P-DT shows a high surface area of 58.2 m²g⁻¹ and low organic impurity (<1%); the PEG/P-DT SSPCM exhibited high latent heat of 45 Jg⁻¹ and low leakage (<0.2%). The thermal cycling test also showed excellent stability after 50 cycles. By adding PEG/P-DT SSPCM into the Nylon, the composite improved the 5% decomposition temperature (Td5) from 426.3°C to 436.7-442.1°C. The composite containing 7 wt% of PEG/P-DT SSPCM (NCPCM7) exhibited impact and tensile strengths of 54.89 J/m and 45.95 MPa, respectively. Moreover, NCPCM7 can reduce the temperature from 36°C to 32.7°C, while Nylon only reduces to 34.9°C, indicating that PEG/P-DT SSPCM possesses the ability of thermo-regulating.

Keywords: Diatomite, Phase change material, Nylon, Polyethylene glycol

Fig. 1 DSC thermograms of PEG and SSPCM.
Session: Naturally Derived Composites
Comp-12-1-O2

Recycling used Coffee Grounds as a Reinforcement in Polymer Composites
Richard J.T. Lin\textsuperscript{1,}\textsuperscript{*}, William M.S. Cran\textsuperscript{2}, and Matthew L. Noland\textsuperscript{3}
\textsuperscript{1}Centre for Advanced Composite Materials, Department of Mechanical Engineering, University of Auckland
\textsuperscript{2}Department of Mechanical Engineering, University of Auckland
*Email: rj.lin@auckland.ac.nz

Abstract
Used coffee grounds (UCG) are a by-product of one of the world’s most popular beverages, coffee. Due to the abundance, the low cost and the inherent powdery morphology of UCG, research has been conducted to determine the merit of using this waste substance as a filler or reinforcement in composite materials.

Various mass fractions (10\textendash}40 wt\%) of UCG have been blended with a linear medium density polyethylene to prepare samples for the evaluation of mechanical performance of the resulting UCG/PE composites. The effects of coffee oil extraction and addition of a coupling agent (maleated polypropylene, MAPE) on the mechanical properties have been investigated.

The outcome of this research has demonstrated that the oil-less UCG has better reinforcing effects on the moduli of UCG/PE composites compared to that of normal UCG. With the expected adverse effects of adding increasing amount of particulate UCG on the composites strengths, the oil extraction and addition of coupling MAPE have been able to alleviate the decreasing trend of tensile strength and positively influence the flexural strength, which indicates the potential of using such composites for bending applications. Nonetheless, the impact strength of the UCG/PE composites still suffers damaging effects by the UCG addition with and without MAPE.

Keywords: Used coffee grounds, Oil extraction, Coupling agent, Mechanical performance

Fig. 1 Coffee oil extraction setup.  
Fig. 2 SEM image of 30/70 wt\% UCG/PE.
Session: Naturally Derived Composites
Comp-12-1-O3

**Dimensional Stabilization of Wood with the Combination of PEG Immersion and Wax Heatment**

Sun Fangli¹,²,*, Liu Tingsong¹, Raojin¹, and Yang xiushu¹

¹School of Engineering, Zhejiang A&F University, Lin’an 311300, Zhejiang China
²National Center for Comprehensive Utilization of Wood Resources
*Email: sun-fangli@163.com

**Abstract**

A two-step process with PEG impregnation followed by wax heat treatment was carried out to stabilize the dimension of Shorea(Richetioides).spp timber. Results showed that the color of modified blocks changed from light red to dark red. The treatment helped in reducing the number and length of existing cracks, as well as restraining the swelling and shrinking of blocks under water drying cycles and moistening drying cycles. The number of crack reduced from 10 to 3, and the total length from 317.6 cm to 41.8 cm after treatment. With weight increment exceeding 26.2%, a volume swelling over 6.2% was attained. The crystallinity of treated wood decreased from 47.2% to 41.3%. The anti-swelling efficiency of modified wood under three cycles of water soaking and drying procedure reached 71.5%, 46.1% and 62.3%, respectively, while under three humidification and drying cycles, 55.7%, 48.2% and 64.1% were obtained.

**Keywords:** Wood, Crack resistance, Anti-swelling efficiency, PEG, Wax

![Fig. 1 Images of blocks before and after modification.](image-url)
Session: Naturally Derived Composites
Comp-12-3-O1

Microwave Drilling of Glass and Polymeric Composite
Apurbba Kumar Sharma*, Gaurav Kumar, Inderdeep Singh
Department of Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee, Roorkee – 247667, India
*Email: akshafme@iitr.ac.in

Abstract
Microwave drilling is a thermal energy based process in which a metallic concentrator is used to concentrate the electromagnetic energy at the tip of the tool. Due to high strength of electric field around tool tip, dielectric media at the tool tip gets ionised which results in plasma formation. The plasma ablates the material from the surface of the workpiece just beneath the tool tip. In the present research work, micro-hole drilling of borosilicate glass and two different composites using microwave energy in air and transformer oil has been investigated. The drilling characteristics have been assessed in terms of heat affected zone (thermal damage) and overcut; a comparison has been made while drilling in air and transformer oil. The study revealed that drilling in presence of dielectric like transformer oil reduces the defects significantly. Higher feed rate also helped in minimizing the defects around the hole.

Keywords: Microwave drilling, Glass, Composite, Overcut, Thermal damage

Fig. 1 Schematic diagram of the microwave drilling set up (inset: enlarged view of the cavity).
Naturally Derived Composites
Comp-12-2-I1

Chitin/Polyaniline based Degradable Gradient Conductive Composite Hydrogel for Peripheral Nerve Regeneration
Huiqing Wang¹,², Dingfeng Xu², and Lina Zhang²,*
¹School of Chemical Engineering, Hefei University of Technology, Anhui Province, 230009, China,
²College of Chemistry and Molecular Science, Wuhan University, Hubei province, 461000, China,
*Email: whq5469@126.com

Abstract
Electrical stimulation can significantly promote nerve regeneration¹-³, here single side conducting Chitin/PANI composite hydrogels as Fig 1a. were fabricated as peripheral nerve regeneration(PNR) conduit. Transparent chitin hydrogels with nanofibers network as shown in Fig 1b were prepared first by dissolving chitin in NaOH/Urea aq. followed by regeneration. Interface between monomer phase and initiator phase cross chitin sheets produced a gradient growth of nano PANI as Fig1c on chitin matrix, so exhibited one side conductive property as Fig 1d. The good tensile strength as Fig 1e. allowed facile sutured to be conduit as Fig 1f. The degradable in vitro and bio-compatibility property of composite hydrogel without hemolysis were tested as Fig 2 a-c. Schwann’s cell RSC96, as an important nerve tissue cell, remarkably preferred to adhering to and proliferating well on PANI side of the composite hydrogel as Fig 2d, because burr nano structure of PANI side is helpful to cell crawling contrast to smooth surface of chitin side, but chitin side is valuable for anti-blocking during PNR. Such biocompatible, biodegradable conductive Chitin/PANI composite hydrogels with high strength are promising in peripheral nerve regeneration because they meet both the conductivity demands and the requirements of tissue engineering as a whole.

Keywords: Chitin, Polyaniline Conductive, Hydrogel, Nerve regeneration

Fig. 1 Photo of Chi/PANI composite hydrogel (a); SEM images of hydrogel two sides (b,c); conductive exhibiton(d); mechanical properties(e) and sutured to be conduit (f).
Preparation and Characterization of the Magnetic-Fluorescence Composite Nanoparticles Coated with the Derivate of Chitosan

Yu Chen¹,*, Wei Yang², Kun Chen¹, Baoping Lu¹, Shaohua Jin¹, and Lijie Li¹

¹School of Material Science and Engineering, Beijing Institute of Technology, Beijing, P. R. China

²Academy of Propellants and Explosives, Beijing Institute of Technology, BeijingP. R. China

*Email: bityuchen@bit.edu.cn

Abstract

Fluorescein isothiocyanate (FITC) is one of most important organic fluorescent probes. In the current study, FITC was immobilized onto the chain of chitosan grafting quaternary ammonium salt derivate (QASC), and FITC-QASC, a kind of macromolecular fluorescent probe, was prepared (Fig. 1). The structure of the product was characterized by FTIR and XRD. The ultraviolet absorption and fluorescence-emission property of it was studied. It was found that the maximum UV absorbance was around wavelength of 493nm, and the maximum emission wavelength of fluorescence emission spectrum was around 522.5nm.

By complexing FITC-QASC with water-based Fe3O4 magnetic nanoparticles (MNPs), the magnetic-fluorescence composite nanoparticles (MFCNPs) were prepared (Fig. 2). It was found through the characterization of FTIR, XRD and XPS that FITC-QASC had been coated on the surface of the Fe3O4 MNPs. The TEM results showed that the particle size of the FITC-QASC/Fe3O4 MFCNPs dispersed in water was about 25nm. The specific saturation magnetization of FITC-QASC/Fe3O4 MFCNPs was tested by VSM and it was found that the result was related to the content of the water-based Fe3O4 MNPs. Through the results of the ultraviolet and fluorescence spectrum, it was found that the water-based Fe3O4 MNPs showed strong UV absorbance, and quenching effect to fluorescent probe. By adjusting the content of the Fe3O4 MNPs, the composite nanoparticles with certain fluorescence emission intensity and magnetic performance could be gained.

Keywords: Magnetic, Fluorescence, Composite Nanoparticles, Chitosan

Fig. 1 Synthesis route for FITC-QASC.
Study on the Chitosan/ Sodium Alginate Composite Microcapsules Containing Vanilla Oil and Its Controlled Release Properties

Ziming Yang¹,², JinLong Tao¹, MingZhe Lv¹, Zongqiang Zeng¹, Chuang Zhou¹, Chao Wang¹, Zuyu He¹, Sidong Li⁴, Yu Chen³, Puwang Li*, and Changgen Feng²,*

¹Agriculture Products Processing Research Institute, Chinese Academy of Tropical Agricultural Sciences, Zhanjiang 524001, P. R. China
²Mechanics and Engineering Department, Beijing Institute of Technology, Beijing, P. R. China
³School of Materials Science and Engineering, Beijing Institute of Technology, Beijing P. R. China
⁴School of Chemistry and Environment, Guangdong ocean university, Zhanjiang, P. R. China

*Email: puwangli@163.com; 361723949@qq.com

Abstract

In this study, chitosan/sodium alginate composite microcapsules containing Vanilla oil were prepared using complex coacervation approach. The emulsifying conditions of Vanilla oil, concentration of chitosan and the pH of complex coacervation were optimized for preparation of microcapsules. The characteristics of composite microcapsules, including morphology structure, particle size and size distribution, embedding efficiency and controlled release properties were investigated by scanning electron micro-scope(SEM), laser particle size analyzer, laser confocal microscope and ultraviolet spectrum analysis. The results showed that the Vanilla oil was successfully embedded in the composite microcapsules, with 96.5% embedding efficiency was achieved. The composite microcapsules were in spherical with a regular spherical shape in the range of 1-10 μm. The controlled release properties results showed the microcapsules represented a good slow controlled release effect, with 60% and 40% release rate after 10 days under the conditions of normal temperature and pressure, which demonstrated that the volatility of Vanilla oil was effectively decreased, and the bioavailability of Vanilla oil was improved after encapsulated. The applications of chitosan/sodium alginate composite microcapsules in plant essential oil shows that it have great potential market value.

Keywords: Chitosan, Composite microcapsules, Vanilla oil, Application, Research

Fig. 1 SEM images of chitosan/sodium alginate composite microcapsules.
Compression and Flexural Properties of Ground Macadamia Nutshell Particulate Composites

Rajesh Reddy Bode¹, Md Mainul Islam¹,²,* and Muhammad Nateque Mahmood³

¹School of Mechanical and Electrical Engineering, Faculty of Health Engineering and Sciences, University of Southern Queensland, Toowoomba, QLD, Australia
²Centre for Future Materials, University of Southern Queensland, Toowoomba, QLD, Australia
³School of Civil Engineering and Surveying, Faculty of Health Engineering and Sciences, University of Southern Queensland, Toowoomba, QLD, Australia

*Email: mainul.islam@usq.edu.au

Abstract

This paper presents results of the research conducted on the particulate composites that are fabricated using ground macadamia nutshell powder as filler and vinyl ester resin as a matrix material. Macadamia nutshell powder with particle size ranges of 300-500μm and 500-700μm were used in this study. The study focused on the compression and flexural behaviour of the fabricated particulate composites with varying volume fractions of Macadamia nutshell powder. Results obtained from the experimental study were validated to analyse the loading performance of the fabricated materials and the effect of Macadamia nutshell powder in the composites. The results illustrated that the variation of volume fraction of Macadamia nutshell powder had a substantial effect on the overall performance of the fabricated particulate composite materials. A simple scanning electron microscopic analysis (Fig 1) of the materials revealed that the void formation due to higher particle size and lower bonding between filler and matrix materials was the reason behind the minimal load carrying capacity.

Keywords: Macadamia nutshells, Vinyl ester resin, Compression and flexural properties

Fig. 1 Scanning electron micrograph of the void in the composite specimen.

Gibeop NAM\textsuperscript{1}, M.N. Prabhakar\textsuperscript{1}, and Jung Il Song\textsuperscript{2,*}

\textsuperscript{1}Engineering research centre for integrated mechatronics materials and components, Changwon National University, Korea

\textsuperscript{2}Department of Mechanical Engineering, Changwon National University, Korea

*Email: jisong@changwon.ac.kr

Abstract

Over the past few years composites have been developing by utilizing many kinds of natural materials as reinforcement. Specially, natural fibres, which are most common in green composite, has increased their cost when area of production economy has expanded, so they can loss their price competitiveness. The bio waste can solve those problems, can be gathering from domestic area’s and recycle waste materials without cost therefore it is environmental friendly. Normally waste materials (fibres) are short in length and have limit of applications. When nano-materials made of waste materials, cost can be decreased and avoid fibre length problems. Incorporating nano-materials in carbon fibre reinforced polymer composites is one of the methods for increasing mechanical properties. The purpose of the research is to utilize bio-waste materials such as shell powder, kelp, rice husk and rice husk ash (Fig.1) in the form of micro size though extraction method for the development of mechanical properties of CFRP.

Keywords: Bio-waste, Shells, Kelp, Rice husk, Extraction micro material

Fig. 1 Rice husk (left) and Rice husk ash(right).
The Effect of Different Linear Robot Travel Speed on Mass Flowrate of Pineapple Leaf Fibre (PALF) Spray up Composite

Z. M. Hanafee\textsuperscript{1,*}, Khalina Abdan\textsuperscript{3,*}, M. Norkhairunnisa\textsuperscript{4,*}, Z. Edi Syams\textsuperscript{5,*}, and Liew Kan Ern\textsuperscript{2,*}

\textsuperscript{1} Institute of Tropical Forestry and Forest Products, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia. Mailing address:
\textsuperscript{2} Aerospace Malaysia Innovation Centre, No 3-6-01, German Malaysian Institute, Jalan Ilmiah, Taman Universiti, 43000 Bangi, Selangor, Malaysia. Mailing address:
\textsuperscript{3} Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia. Mailing address:
\textsuperscript{4} Department of Aerospace Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia. Mailing address:
\textsuperscript{5} Department of Mechanical and Manufacturing Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia. Mailing address:

\*Email: hanafeezin@gmail.com; liew@amic.my; khalina@upm.edu.my; norkhairunnisa.mazlan@gmail.com; edisyam@upm.edu.my

Abstract

This paper investigates the effect of different linear robot travel speed on mass flowrate of biocomposites automated spray up. The linear robot travel speed investigated are 0.5, 0.75, 1.0, 1.25 and 1.5 m/s. In this study, the manual chop spray gun is integrated with industrial robotic arm to produce random discontinuous fibre composite from PALF roving (273 tex) and vinyl ester resin. Setting such as spray angle, distance, fibre length and path are set constant throughout the study. Samples fabricated are tested for mechanical properties including tensile and flexural, and thermal properties including TGA and DMA. The optimized robot speed is determined based on combination of mechanical properties and Coefficient of Variance (COV). The results showed that the speed of 0.75m/s yielded 28.38 MPa of tensile strength, with COV of 9.51%, which is the best combination compared to all other robot speed. However, flexural test depicted speed of 1.0 m/s to be the highest with 59.12 MPa, while speed 1.5 m/s produced the best COV of 11.97% despite lower flexural strength of 54.96 MPa. The TGA showed that 89.57% weight reduction occurred during combustion, with major burning temperature of 375.79°C. The DMA depicted the Glass Transition Temperature (Tg) of 114.57°C.

Keywords: Spray up, Bio composite, Natural fibre, Direct fibre compounding, Pineapple leaf, Vinyl ester
Incorporation of Antimicrobial Peptides (AMP) into Natural Biopolymers as a New Strategy to Design Non-Toxic Antimicrobial Textiles

Isabel C. Gouveia*, Frederico Nogueira, Cláudia Mouro, ana P. Gomes*

FibEnTech Research Center, Faculty of Engineering University of Beira Interior, Covilhã - Portugal
*Email: igouveia@ubi.pt; anapaula@ubi.pt

Abstract

Antimicrobial textile materials may significantly reduce the risk of infections and because they are able to absorb substances from the skin and release therapeutic compounds to the skin, they can also find applications as complementary therapy of skin-diseases as part of standard management.

Although functional textiles may be a promising area in skin disease/injury management, few offer complementary treatment even though they are well known to reduce scratching, aiding emollient absorption, reducing infection, and alleviating pruritus.

Several antimicrobial agents have been tested in textiles: quaternary ammonium compounds, silver, polyhexamethylene-biguanides and triclosan have been used, with success. They have powerful bactericidal activity but the majority have a reduce spectrum of microbial inhibition and may cause skin irritation, ecotoxicity and bacteria resistance. Furthermore, the rising flow of strains resistant to last-resort antibiotics rekindles interest in alternative strategies. In this regard, new functional textiles incorporating highly specific antimicrobial agents towards pathogenic bacteria, are required.

Recent research has been conducted on naturally occurring antimicrobials as novel alternatives to antibiotics. Conscious of this need our team firstly reported new approaches using L-cysteine and antimicrobial peptides (AMP). Briefly, we were able to develop different immobilization processes towards 6 Log Reduction against bacteria such as S. aureus and K. pneumoniae. Therefore, here we present several innovative antimicrobial textiles incorporating AMP and L-Cysteine which may open new avenues for the medical textiles market and biomaterials in general. Team references will be discussed as an overview and for comparison purposes in terms of potential therapeutic applications.

Keywords: Antimicrobial coatings, Antimicrobial textiles, Bacterial resistance, Non-toxic antimicrobial
Abstract

Flexible strain sensors capable of high strain (greater than 50%) have received keen interests due to their potential applications in wearable electronics for health and patient care, physical treatment, sports performance monitoring, and soft robotics. These new sensors overcome the limitation of conventional strain gauge made of metal and semiconductor that cannot detect any strain beyond 5%. Herein we present a high-strain sensor with improved sensitivity and stability by embedding a network of dual-scale carbon fillers, carbon nanofibers (CNF) and graphene nanoplates (GNP), within a highly stretchable elastic medium polydimethylsiloxane (PDMS) (Figure 1). Compared with equivalent sensors containing either CNF or GNP, this new type of dual-scale carbon filler sensors display a great linear range up to a large strain (~50%). Increasing the concentration of dual-scale carbon fillers raises the sensitivity or gauge factor. The results also reveal that GNPs play a key role in improving the gauge factor of CNF-based sensors. Under repeated loading, the flexible strain sensors based on dual-scale carbon fillers demonstrate better stability (less drift in sensor response) than those containing only CNFs or GNPs. Therefore, this sandwiched dual-scale carbon materials offer a promising technique for increasing sensitivity and stretchability of flexible strain sensors.

Keywords: Dual-scale carbon fillers, Sandwich-like structure, Sensitivity, Stability, Flexible strain sensors
Inkjet Printed of Conductive Ink Silver Traces on Flexible Substrateion

M. Mariatti¹*, Y.Z.N. Htwe¹, W.S. Chow¹ and Y. Suda²

¹School of Materials and Mineral Resources Engineering, Engineering Campus, Universiti Sains Malaysia, 14300 Nibong Tebal, Pulau Pinang, Malaysia.
²Department of Electrical and Electronic Engineering, Toyohashi University of Technology, Aichi Toyohashi 441-8580, Japan.
*Email: mariatti@usm.my

Abstract

Inkjet printing of conductive ink on flexible substrates is emerging as an attractive technology for wide variety of industrial and scientific applications due to its mildness, simplicity, low-cost and scalability of production. In this study, silver nanoparticles (AgNPs) conductive ink was printed on polyvinyl alcohol (PVA) substrates by inkjet printer. AgNPs were produced by simple chemical reduction method. The particles were synthesized via reduction of AgNO3 by trisodium citrate and ascorbic acids as a surfactant. The synthesized AgNPs were characterized by X-ray diffraction, Scanning Electron Microscopy Transmission Electron Microscopy and UV-vis. Figure 1 (a) showed TEM result of AgNPs. It was found that the average AgNPs particle size is 35 nm. The result from UV-vis showed a presence of absorbance peak at ~420 nm which indicated the AgNPs formation. AgNPs conductive ink was produced by chemical method using the ratio of Dimethylformamide: Ethylene glycol: Glyceol. Figure 1 (b) showed the AgNPs conductive ink. Zeta potential value of -38 mV was observed which identify the stability of conductive ink. Figure 1 (c) showed the conductive ink printed on flexible Poly (vinyl alcohol) substrate with 5 times printing cycles. Table 1 showed the effect of printing cycle on the electrical conductivity. As expected the highest conductivity was shown by 5 time printing cycle. Figure 1 (d) showed the optical images of electrical conductive circuits drawn on a photo paper. LEDs are added to the photo paper to prove that the ink is conductive and the idea works.

Keywords: Silver nanoparticles, conductive ink, electrical conductivity
Fabrication and Investigations on MWCNTs-Fe3O4@Ag/Epoxy Nanocomposites for Promising EMI Shielding Applications

Lei Wang, Chaobo Liang, Lixin Chen, Ping Song, Jie Kong, Junwei Gu*

MOE Key Laboratory of Material Physics and Chemistry under Extraordinary conditions, Shaanxi Key Laboratory of Macromolecular Science and Technology, Department of Applied Chemistry, School of Science, Northwestern Polytechnical University, Xi’an, China.

*Email: gjw@nwpu.edu.cn & nwpugjw@163.com

Abstract

With increasingly severe electromagnetic interference (EMI), the influence of electromagnetic wave on electronic devices and workers has been nonnegligible, and electromagnetic shielding has also become an important research topic in the world. In this contribution, the novel electric and magnetic MWCNTs-Fe3O4@Ag compounds was firstly obtained from the reaction between carboxylation of Fe3O4@Ag (Fe3O4@Ag-COOH) nanoparticles and amino functionalized multiwall carbon nanotubes (MWCNTs-NH2). And then the corresponding MWCNTs-Fe3O4@Ag/epoxy nanocomposites were fabricated via blending-casting method. The results revealed that the MF-10/epoxy nanocomposites presented optimal electric conductivity and EMI shielding effectiveness, when the mass ratio of MWCNTs-NH2 to Fe3O4@Ag-COOH was 9:1 (MF-10). The modified epoxy nanocomposite with 15 wt% MF-10 presented optimal comprehensive properties, with high electric conductivity of 0.280 S/cm and EMI SE value of 35.0 dB, which could be further applied in promising EMI shielding applications.

Keywords: MWCNTs-Fe3O4@Ag, electromagnetic interference shielding, epoxy nanocomposites

Fig. 1 (a)TEM images of, (b) FTIR spectroscopy, (c) Wide-scan XPS spectra, (d) TGA curves of MF-5, MF-10, MF-15 and MF-20.
Highly Cross-Linked Polymer Composites for Very High Temperature Structural
Samuel Swan, Benjamin Hunt, Claudia Creighton and Russell Varley*

Carbon Nexus, Institute for Frontier Materials, Deakin University, Waurn Ponds, Australia
*Email: russell.varley@deakin.edu.au

Abstract
The advantage afforded by using polymer composites in stringent mechanical loading scenarios is now almost universally recognized. Now it is not just the aerospace industry but many others from oil & gas to precision measurement device manufactures which increasingly employ composite structures. However, the modern composite end-user faces a limited set of new technologies that enable polymer matrix composites to perform adequately in extreme environments, such as temperature extremes and cyclical loading. In the case of high temperatures, polymer matrices with very high temperatures as available, but tend to suffer from poor mechanical properties or processability. Other disadvantages such as moisture absorption can also decrease some matrix systems utility. To achieve desirable mechanical performance these types of high-temperature systems generally require some means of toughening and other property enhancements. This study presents results on the temperature, environmental, mechanical, and fracture properties of a novel highly cross-linked toughened epoxy formulation. The intent is to explore alternates to the current state of the art for polymer composites that must not only perform adequately at very high temperatures, but also be durable at higher service temperatures.

Keywords: Toughness, Fracture, Thermal Stability, High Temperature
Tunable Piezoelectric Performance of Flexible PVDF Based Nanocomposites from MWCNTS /Graphene/MnO2 Three-Dimensional Architectures Under Low Poling Electric Fields

Lu Yang¹*, Jinhao Qiu²*

¹College of Mechanics and Materials, Hohai University, Nanjing 210098, China
²State Key Laboratory of Mechanics and Control of Mechanical Structures, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China

*Email: 0607yl@163.com, qiu@nuaa.edu.cn

Abstract

Over decades, developing flexible poly (vinylidene fluoride) (PVDF) based nanocomposites with high piezoelectric performance is of great concern for constructing sensors, transducers and energy harvesters. Herein, we proposed a facile strategy to design a three-dimensional hybrid nanostructure consisting of manganese dioxide/graphene/Multi-walled carbon nanotubes (MnO2/graphene/MWCNTs) to reinforce the piezoelectric performance of PVDF. By tailoring the MnO2 mass loading of hybrids, tunable breakdown strength and piezoelectric performance can be achieved in the nanocomposites. Meanwhile, employing this hybrid can reduce the high poling electric field (>100 MV/m) required for PVDF to induce good piezoelectric response. With a relative low poling electric field (50-80MV/m), high piezoelectric coefficients of 17-33 pC/N can be obtained in the nanocomposites, which are twice that of PVDF under the same poling conditions. Incorporating MWCNTs/graphene/MnO2 into PVDF demonstrates to be a cost-effective, efficient and scale-up route to yield superior and controllable piezoelectric performance with low poling electric field requirement.

Keywords: Piezoelectric polymer composites, Carbon nanotubes, Interface effect
Functional Porous Composites based on Supramolecular Macrocycles

Li-Li Tan*

State Key Laboratory of Solidification Processing, Center of Nano Energy Materials, School of Materials Science and Engineering, Northwestern Polytechnical University, Xi’an, China.

*Email: Blxiao@imr.ac.cn

Abstract

Energy crisis, environment pollutions, serious diseases have become the most severe threats that humans are facing. Thus porous materials and supramolecular macrocycles receive great attention. Herein, we combine porous materials and supramolecular macrocycles together to construct novel functional composites.

Firstly, we have successfully obtained low-density pillarene-based supramolecular organic frameworks (SOFs) with exceptionally high C$_2$H$_2$ and CO$_2$ sorption selectivity over other gases (up to 3733). New mixed-matrix membrane (MMM) materials of these SOFs were created, the collaborative effects of pore size, shape and connectivity together with chemical environment in host frameworks make these pillarene-SOFs promising candidates as highly selective porous materials for gas storage, separation and purification.

Secondly, spurred by recent advances in materials chemistry and drug delivery, a new stimuli-responsive theranostic hybrid platform, based on mechanized monodisperse nano metal-organic frameworks (NMOFs) gated by carboxylatopillar (CP5) switches with bio-friendly pH-triggered cargo release capability, has been first constructed. Given the need to develop scaffolds for advanced therapies that can improve features of conventional systems, herein, we first provide a new combination therapy principle. Mechanized Zr-MOFs with multi-stimuli responsive supramolecular gatekeepers that combine thermotherapy with chemical (low pH in osteoclasts and tumour cells) and biochemical triggers (high Ca$^{2+}$ concentration caused by osteolysis and bone resorption, high Zn$^{2+}$ caused central nervous system diseases) were designed. Our motivation is to find better central nervous system diseases and bone cancer therapies and ameliorate the adverse side effects in traditional therapy.

Keywords: Supramolecular macrocycles, Porous materials, Controlled drug delivery, Gas separation
A Smart Shape Memory Polymer Surface Modified by PDPAEMA with Multiple-Wetting States

Dongjie Zhang\textsuperscript{1}, Zhongjun Cheng*\textsuperscript{2}, Songji Yu\textsuperscript{1}, Junjun Wan\textsuperscript{1}, and Yuyan Liu*\textsuperscript{1}

\textsuperscript{1}MIIT Key Laboratory of Critical Materials Technology for New Energy Conversion and Storage, School of Chemistry and Chemical Engineering, Harbin Institute of Technology, China.

\textsuperscript{2}Academy of Fundamental and Interdisciplinary Sciences, Harbin Institute of Technology, China

*Email: chengzhongjun@iccas.ac.cn, liuyy@hit.edu.cn

Abstract

Recently, smart surfaces with switchable wettability have been extensively researched owing to their wide applications. However, all previous works only reported single control of surface chemistry or microstructure, limiting the applications of the surfaces. Herein, a new surface was prepared by grafting poly(2-(diisopropylamino)ethyl methacrylate (PDPAEMA) onto the pillar-structured shape memory polymer by ATRP. Owing to the responsivity of PDPAEMA to pH (Fig 1a) and the shape memory polymer to temperature (Fig 1b), the surface chemistry and microstructure can be regulated synergistically. In detail, when the testing droplets are acide, the contact angles are about 0° and 45° on the shape memory polymer surface with upright pillars and collapsed pillars, and when the testing droplets are basic, the contact angles are about 115° and 150° on the above two surfaces (Fig 1c). As a result, the multiple wetting states can be obtained on a single surface, including superhydrophilicity, hydrophilicity, hydrophobicity, superhydrophobicity (Fig 1c). Moreover, all these transitions are reversible for more than 5 cycles. Meanwhile, the prepared surface could be potentially used in many fields, such as rewritable platform for designing gradient wettings and to realize accurate drug delivery.

Keywords: PDPAEMA, shape memory polymers, surface chemistry and microstructure, wettability

Fig. 1 (a) Schematic illustration of the variation process of the surface microstructure. (b) Schematic illustration of the responsive mechanism of PDPAEMA. (c) Shapes of a water droplet on the surface
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Polyimide-based Composite Aerogels for Thermal Insulation and Flame Retardancy
Wei Fan*, Tianxi Liu
State Key Laboratory of Modification of Chemical Fibers and Polymer Materials, College of Materials Science and Engineering, Donghua University, Shanghai 201620
*Email: weifan@dhu.edu.cn

Abstract
Due to their unique microstructure, aerogels show impressive properties, such as extremely high porosity, quite low apparent density, and considerably high surface area, which enable them to be attractive materials for applications in thermal insulating, chemical adsorbents, catalytic carriers, and electrical applications1-3. Developing aerogels with controllable pores, outstanding mechanical properties and excellent thermal stability still remains a key challenge in evolution of aerogels. In this work, graphene reinforced polyimide (PI) composite aerogels were fabricated by an environmentally friendly freeze-drying technique followed by a thermal imidization process. The two-dimensional graphene oxide (GO) was simultaneously served as crosslinker, pore-tailoring agent, as well as reinforcing fillers. The porous structure of PI-based aerogels was controllable by changing the content of functional groups on GO. The as-prepared PI/GO aerogel showed excellent mechanical and thermal insulation properties, with a highest specific modulus of 229.9 Mpa cm\(^3\) g\(^{-1}\) and lowest thermal conductivity of 28 mW m\(^{-1}\) K\(^{-1}\). Furthermore, graphene/montmorillonite (G/MMT) hybrid synergistically reinforced PI composite aerogels were fabricated for flame retardancy. Through the strong interaction between GO and MMT, GO/MMT hybrid can be synergistically dispersed in water, providing good dispersibility in PI matrix, thus endowing the composite aerogels with enhanced thermal and flame-retardant properties.

Keywords: Polyimide, Graphene, Montmorillonite, Thermal insulation, Flame retardancy
Abstract

Flavor compounds have attracted more attention due to their excellent antibacterial activities and safety. Curcumin as a natural flavour showed a broad-spectrum antimicrobial property. However, it is difficult to dissolve in water and unstable. The development of encapsulation provide an effective utilization for curcumin. In this work, asymmetric mesoporous silica nanoparticles of Fe3O4@SiO2&EPMO (EPMO=ethane bridged periodic mesoporous organosilica) containing core@shell structured Fe3O4@SiO2 nanospheres and EPMO nanorods have been successfully synthesized via a novel degradation-restructuring induced anisotropic epitaxial growth strategy. The asymmetric mesoporous silica nanoparticles of Fe3O4@SiO2 were with a very uniform size of ~190 nm and the EPMO nanorods with controllable rod length~100nm. So, hydrophilic gentamicin sulfate(GS) and hydrophobic curcumin were chosen to load in hydrophilic Fe3O4@SiO2 nanospheres and hydrophobic EPMO nanorods for multifunctional synergetic bacteriostasis. The loading capacity of curcumin and gentamicin sulfate were 25.75mg g⁻¹ and 24.94g g⁻¹, dividedly. Compared with Fe3O4@SiO2&EPMO, the curcumin-loaded and GS-loaded Fe3O4@SiO2&EPMO exhibited bactericidal efficiency ~60% and~68%, respectively. The asymmetric deblock mesoporous silica nanoparticles simultaneously loading curcumin and GS have outstanding bactericidal efficiency (~90%), which showed enhanced antibacterial activity compared with curcumin-loaded and GS loaded Fe3O4@SiO2&EPMO alone. Furthermore, the asymmetric deblock mesoporous silica nanoparticles had good biocompatibility and low hemolytic activity.

Keywords: Asymmetric, mesoporous silica, hydrophobicity, hydrophilicity, antibacterial

Fig. 1 Synthetic procedure for asymmetric mesoporous silica nanoparticles
Electric Field Alignment of Short Carbon Fibres to Enhance the Multi-Functional Properties of Epoxy Composites

Anil R. Ravindran¹*, Raj B. Ladani¹, Shuying Wu¹,², Anthony J. Kinloch³, Chun H. Wang¹,², and Adrian P. Mouritz¹

¹Sir Lawrence Wackett Aerospace Research Centre, School of Engineering, RMIT University, Australia.
²School of Mechanical and Manufacturing Engineering, University of New South Wales, Australia.
³Department of Mechanical Engineering, Imperial College London, South Kensington Campus, UK
*Email: s3262410@student.rmit.edu.au

Abstract

This paper presents an experimental investigation into the electric field alignment of recycled/milled short carbon fibres (SCFs) to increase the electrical conductivity and fracture toughness of bulk epoxy and fibre reinforced epoxy composites. Subjecting the SCFs to an alternating current electric field while suspended within uncured liquid epoxy resin caused them to rapidly align along the field direction. The bulk epoxy containing randomly oriented SCFs (i.e. without electric field alignment) exhibited a much greater mode I fracture toughness, $G_{IC}$, and electrical conductivity compared to the unmodified epoxy. The improvement to these functional properties was increased further by the controlled alignment of the SCFs using an electric field. The addition of SCFs also improved the mode I and mode II interlaminar fracture toughness properties of carbon fibre reinforced epoxy composites.

Keywords: Recyclability, fracture toughness, electrical conductivity, short carbon fibres
Introduction of PLA Stereocomplex Crystallites for the Solid and Microcellular Poly(Lactide) Blends

Xuetao Shi, Long Wang, Lei Kang, Yuang Kang, and Guangcheng Zhang*

Department of Applied Chemistry, School of Science, Northwestern Polytechnical University, China

*Email: zhangguc@nwpu.edu.cn

Abstract

In this work, PLA-biobased polymeric foams with open cell structure using PLA as the polymeric matrix and another biodegradable thermoplastic polyurethanesor (TPU) or poly(butylene adipate-co-terphthalate) (PBAT) as second phase via batch foaming process. Both PBAT and TPU are biodegradable polymers with excellent toughness. The influence of second soft phase in the final cell morphology and the foaming mechanism of PLA-based systems are investigated in detail. In addition, the PLA stereocomplexation mechanism was introduced into the PLA blends to increase the melt strength of PLA blend. The effect of sc-PLA crystallites on the gas adsorption and diffusion behaviour, and mainly on the cell morphology are also discussed. This work provided the enhanced melt strength of PLLA matrix with sc-PLA crystallites and therefore the tunable foaming morphologies, which could widen PLA foaming processing window without the cost of its biodegradability.

Keywords: PLA, Stereocomplex, Melting strength, Microcellular foam

Fig. 1 Frequency dependences of complex viscosity $\eta^*$ of PLLA, PLLA/PBAT and PLLA/PBAT/PDLA at 190 °C.

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Preparation of In Situ Modified Styrene Butadiene Rubber New Products
Changjie Yin, Qiuyu Zhang

Department of Applied Chemistry, School of Science, Northwestern Polytechnical University, China
*Email: yinchangjie@nwpu.edu.cn

Abstract
In this research, first, graft polymerization of vinyltriethoxysilane (VTES) onto styrene-butyadiene rubber (SBR) was carried out in latex. The grafting of VTES onto SBR and its pre-crosslinking were confirmed by attenuated total reflectance-Fourier transform infrared reflectance (ATR-FTIR) and proton nuclear magnetic resonance (1HNMR). Second, the grafted SBR was further reinforced with silica produced by sol-gel reaction of tetraethoxysilane (TEOS). Results revealed that the addition of VTES could considerably improve the content of silica, bound rubber in SBR and utilized efficiency of TEOS. Meanwhile, the mechanical properties of the vulcanized in situ reinforced SBR-g-VTES were also investigated and compared with that of the silica-reinforced SBR prepared by mechanical mixing. Grafting of SBR with VTES and subsequent hydrolysis and condensation reactions of TEOS to form silica particle reinforced SBR network.

Keywords: rubber, in situ, modified, graft

Fig. 1 1H-NMR spectra of SBR (a) and SBR-g-VTES (b)
Polyaniline Stabilized Barium Ferrite Epoxy Nanocomposites with Enhanced Mechanical Properties

Hongyuan Zhang*, and Hongbo Gu*

School of Chemical Science and Engineering, Tongji University, Shanghai, China

*Email: zhy920928@163.com & hongbogu2014@tongji.edu.cn

Abstract

Owing to the excellent physical, chemical properties and good processability, epoxy resin has been widely used in the adhesives, coatings, and aerospace. Recently, the materials miniaturization and light-weight demands the high performance for multifunctional epoxy resin. Compared to the traditional materials, nanocomposite materials have unique physical and chemical properties. In this paper, barium ferrite nanoparticles were synthesized by citric acid sol-gel method. The polyaniline (PANI) was introduced via surface initiated polymerization method to improve the dispersion quality of nanoparticles within epoxy resin matrix. The X-ray diffraction analysis (XRD), FT-IR analysis data showed that PANI was successfully encapsulated on the surface of barium ferrite with the weight percentage of 12%. Finally, the epoxy nanocomposites with different loadings of nanoparticles were prepared. The results showed that the tensile strength of epoxy nanocomposites was obviously increased as the nanoparticle loading of 10 wt%. Relative to the pure epoxy resin, the tensile strength of unmodified barium ferrite/epoxy nanocomposite was increased by 2.8%, and for modified barium ferrite/epoxy nanocomposite increased by 12.2%. Based on the experiments and data analysis, it’s found that the PANI was favorable to the barium ferrite nanoparticles dispersion within epoxy matrix and provided epoxy with the enhanced mechanical property. In addition, these epoxy nanocomposite exhibited the good magnetic, dielectric properties and improved thermal stability.

Keywords: Epoxy, Barium ferrite nanoparticles, Polyaniline, Nanocomposites
Abstract
Two-dimensional layered materials with covalent intra-layer bonds and relatively weak van der Waals layer-to-layer interactions have motivated intensive research attention recently due to their intriguing mechanical, electrical, and thermal properties after exfoliation, the understanding of which is not only fundamentally important but also critical to enabling widespread applications in electronics, energy conversion and storage devices. This work studies the effects of functionalised boron nitride (BN) nanosheets and molybdenum disulphide (MoS2) nanosheets on the morphological, tensile and thermal properties of a poly(vinyl alcohol) (PVA) polymer. The incorporation of low content (<1 wt%) of BN nanosheets (with amino groups) increased tensile strength and modulus and the inclusion of low content (<0.5 wt%) of MoS2 nanosheets (with hydroxyl groups) enhanced the tensile strain immensely that resulted in significantly improved toughness. The solution casting nanocomposite preparation method led to anisotropic thermal conductivity of the nanocomposite films with the in-plane thermal conductivity significantly higher than the cross-plane thermal conductivity. The thermogravimetric analysis results indicate that both these functionalised nanosheets improve the thermal stability of the PVA polymer at elevated temperature and expand the working temperature range of the nanocomposites.

Keywords: Mechanical properties, Thermal conductivity, Functionalisation, Dispersion
Session: Functional Polymer Composites
Comp-7-3-12

Possibility to Create Creep-Less Composites by Using Tg-Less Epoxy Resin
Hirofumi Nishida¹*, Hiromu Senba² and Norio Hirayama²
¹Kanazawa Institute of Technology
²Nihon University
*Email: nisida@neptune.kanazawa-it.ac.jp

Abstract
Tg-less epoxy resin was obtained by curing conventional epoxy resin catalyzed by a salt of alkaline metal and carboxylic acid. In this system, the storage modulus (E’) of cured resin doesn’t drop and maintains high level as if the cured resin were in glassy state even at 300°C (Fig 1-(b)) while the E’ of an ordinary epoxy resin drops suddenly to low value above its Tg (Fig 1-(a)).

GFRP was prepared by impregnating Tg-less-type uncured liquid epoxy resin into glass cloths and subsequent pressing and heating them. The measurement of dynamic viscoelastic behavior for the obtained GFRP (Fig 1-(c)), revealed that the GFRP could exhibit an excellent mechanical property even around 300°C because more than 80% of modulus at 25 ℃ was maintained at 250 ℃. Creep Test at 100 or 150 ℃ for CFRP using Tg-less epoxy resin as the matrix was also performed. Creep compliance, Dc didn’t increase up to 100h of testing time. This creep-less phenomenon was considered to be attributed to no permission of relaxation in the matrix resin, corresponding to the constantly low value of tan δ in the whole temperature range.

Keywords: Tg, Creep, Epoxy resin, Relaxation Anionic polymerization

Fig. 1 Dynamic viscoelastic behaviors of (a) Conventional epoxy resin cured by imidazole, (b) Tg-less epoxy resin cured by potassium carboxylate and (c) Composite using Tg-less epoxy resin.
Engineering Thermal Conduction Micro-Channels in Polymer via Hydrogen Bonding

Nitin Mehra, Liwen Mu, and Jiahua Jack Zhu*

Department of Chemical and Biomolecular Engineering, The University of Akron, USA

*Email: jzhu1@uakron.edu

Abstract

Existing research to develop thermally conductive polymer composite are based on traditional fillers (metallic/ceramic/carbonic) and matric system which requires high loading of fillers and in turn suffers with various cost and fabrication issues. Intermolecular interaction has been demonstrated an effective way to engineer thermal transport channels in materials and thus improve thermal conductivity. In this talk, thermal conduction micro-channels were introduced by engineering intermolecular interactions in three representative material systems. Thermal conductivity enhancement of around 2-3 times of the neat polymer can be achieved without using any traditional fillers. The critical factor responsible for thermal conductivity enhancement was found to be the “thermal bridges” formed by hydrogen bonding between molecular species. These thermal bridges lead to the formation of continuous thermal highways for the efficient phonon transport. This talk presents a unique approach to engineer material interaction at molecular level and achieves macro-scale function as desired.

Keywords: Thermal conduction, hydrogen bond, polymer, microstructure
Session: Functional Polymer Composites
Comp-7-3-O2

Evaluation of Impact Properties for CFRTP Using High Tg Thermoplastic Epoxy Resin
Daichi Kaji¹, Norio Hirayama¹, Hirofumi Nishida² and Kiyoshi Uzawa²

¹Nihon University
²Kanazawa Institute Technology
*Email: cida14059@g.nihon-u.ac.jp

Abstract
In the application of automobile, thermoplastic resins attract attention as the matrix because of their toughness more excellent than thermosetting resins. The impregnation of thermoplastic resin into continuous fibers is, however, very difficult because its melt viscosity is too high. Thus circumstances, we have been investigating the use of ‘Thermoplastic Epoxy Resin’, one of in situ-polymerizing thermoplastic resins which has low viscosity before curing and polymerizes linearly after impregnation, to create thermoplastic composites for automobile. The previous studies from our laboratory have revealed that the CFRTP using standard type thermoplastic epoxy resin which has the Tg around 100℃ exhibited much higher energy absorption property in impact compression test than the CFRP using a conventional thermosetting epoxy resin. In this study, we developed a high Tg CFRTP using a new type of thermoplastic epoxy resin with a higher Tg (around 135℃), since Tg of 100℃ is not attractive in the automotive field. It is clear from Fig 1 that the Tg of high Tg CFRTP is approximately 35℃ higher than that of standard CFRTP. Additionally, high Tg CFRTP exhibited comparable or higher energy absorption property than the standard CFRTP.

Keywords: CFRTP, Tg, Thermoplastic epoxy resin, Impact properties, Energy absorption property

Fig. 1 Temperature dependence in E’ and tanδ of standard CFRTP and high Tg CFRTP.
Biomimetic Surface by Immobilized Zwitterionic Polymer on Pdms-Pva-Graphene Oxide Substrate by Atmospheric Plasma-Induce Polymerization

Yi-Shao Ting, Ting-Yu Liu*

Department of Materials Engineering, Ming Chi University of Technology, New Taipei City, Taiwan
*Email: tyliu0322@gmail.com

Abstract

In this study, the multilayers of the polydimethylsiloxane (PDMS)-polyvinyl alcohol (PVA)-graphene oxide (GO) membranes were fabricated by thermal curing methods for the wound dressing usage. The outer layers of the membranes were transferred to the shark-skin structure1 as the antifouling-layer, and the internal layers were incorporated with PVA and GO and then grafted zwitterionic polymer brushes (2-methacryloyloxyethyl phosphorylcholine, MPC) on the PDMS-PVA-GO surface by atmospheric plasma-induce polymerization2 for enhancing wound repair. The characterization of PDMS-PVA-GO membranes were evaluated by scanning electron microscopy (SEM)/ energy dispersive X-ray spectroscopy (EDX), Fourier transform infrared spectroscopy (FTIR), contact angle (CA) measurement, and X-ray photoelectron spectroscopy (XPS). The result shows that it displays more hydrophobic (CA from 90o to ~110o) in the outer layer after transferred shark-skin structure, whereas it become very hydrophilic (CA from 90o to ~20o) in the internal layer after immobilized PVA-GO layers and MPC polymer brushes. The hydrophobic outer layer can form a antifouling surface to resist bacteria, and the hydrophilic internal surface can improve the biocompatibility to enhance the cells proliferation, which is potential to apply in the advanced wound dressing.

Keywords: polydimethylsiloxane (PDMS), polyvinyl alcohol (PVA), zwitterionic, graphene oxide, antibacterial

Fig. 1 The schematic diagrams of grafting zwitterionic on PDMS-PVA-GO membranes by atmospheric plasma-induced polymerization
Proton Exchange Membranes of Polysulfone and Graphene Oxides Nanohybrids for Vanadium Redox Flow Battery

Yi-Cih Chuang¹, Ting-Yu Liu¹,*, and Chien-Hong Lin²,*

¹Department of Materials Engineering, Ming Chi University of Technology, New Taipei City 24301, Taiwan
²Chemistry Division, Institute of Nuclear Energy Research, Longtan Township, Taoyuan County, 32546, Taiwan

*Email: tyliu0322@gmail.com; chlin0805@gmail.com

Abstract

Graphene oxides (GO) based-polysulfone (PSF) membranes were developed for the proton exchange membranes of the vanadium redox flow battery (VRFB). GO/PSF nanohybrid membranes were fabricated by spining coating methods, and the various ratios of GO/PSF and thickness were manipulated to evaluate the optimal voltage efficiency (VE), coulombic efficiency (CE), and (EE) of VRFB. The characterizations of GO-PSF membrane were measured by Scanning Electron Microscope (SEM), Atomic Force Microscope (AFM), Electron Spectroscopy for Chemical Analysis (ESCA) and contact angle. The result shows that EE of VRFB in GO-PSF membrane is higher than that in pristine PSF membrane. Furthermore, GO-PSF membranes display great chemical stability during the long-term operation, would be potential to apply in VRFB (Fig. 1).

Keywords: Vanadium redox flow battery, Polysulfone membrane, Graphene oxides

Fig. 1 Schematic digrams of graphene oxides (GO) based-polysulfone (PSF) membranes were developed for the proton exchange membranes of the vanadium redox flow battery (VRFB).
Preparing Dark, Infrared Reflective and Superhydrophobic Polymer Films in Large Scale

Jing Zhang, Chenxi Zhu, Weicheng Zhang, Weiqiang Lin, Jie Feng*

College of Materials Science & Engineering, Zhejiang University of Technology, Hangzhou, China

*Email: fengjie@zjut.edu.cn

Abstract

Recently, polymer films containing deep color and infrared reflective pigments have attracted much attention. They can be used on roof, tent and even automotives body to decrease the utilization of air-conditioning. However, in practical application environment, dusts in the air are readily adsorbed and adhered to the surface of them, thus abates their NIR-reflectivity gradually. In this work, black and infrared reflective pigment was firstly melt blended with LDPE and then the resulted blend was thermally pressed on a metal template with micro- and nano surface roughness. After being cooled to suitable temperature, the black LDPE film was peeled from the template. Ultraviolet-visible-near infrared spectral and indoor infrared lamp irradiation test both confirmed that the as-prepared films possess high infrared reflectance and high heat reflectance. Moreover, films either containing infrared reflective pigments or not, they all exhibited superhydrophobic (SH) property. This may endow films self-cleaning performance in practical application thus avoiding deterioration of the infrared reflective property. We believe that these color adjustable, infrared reflective, SH and inexpensive films would have great potential in reducing building energy consumption.

Keywords: Dark, infrared reflective, superhydrophobic, LDPE film, self-cleaning

Fig. 1 The UV-visible-infrared reflectance of LDPE films with different contents of "cool cold" black infrared reflective pigment.
High Thermal Conductivity Polycarbonate Composites Obtained by Phase Separation Method

Takashi Kurose¹, Yumi Yamada¹, Hiroshi Ito¹*, Yuu Takahashi², Fumio Keitoku², Hironari Sano², and Yuji Fujita²

¹Graduate School of Organic Material Science, Yamagata University 4-3-16 Jonan, Japan
²Mitsubishi Chemical Corporation 1, Toho-cho, Yokkaichi, Mie 510-8530, Japan

*Email: ihiroshi@yz.yamagata-u.ac.jp

Abstract

This study demonstrates the effects of high thermal conductive filler on the thermal conductivity of PC/PP immiscible polymer blend. Boron Nitride (BN) is used as a high thermal conductive filler. It has been known that phase separation occurs in the immiscible polymer blend system and the phase separation structures can be controlled by volume ratio and viscosity ratio in the blend system¹. PC/PP polymer blend consisting of the PC sea phase and the PP island phase are obtained by adjusting blends ratio PC/PP (70/30 wt%). PC/PP/BN composite is also prepared by using a twin screw extruder. SEM observation of PC/PP/BN (35/15/50 wt%) composite shows that phase separation structure in PC/PP blend is still remained and BN fillers are selectively dispersed in the PC phase (Figure 1). Thermal conductivity of the composite is improved compared with PC/BN composite (50/50 wt%) (Figure 2). The reason would be explained by the creation of continuous high thermal conductive paths due to high filler contents in the PC matrix phase. PC-based high thermal conductive and high flow composite is successfully fabricated by utilizing phase separation in immiscible polymer blends system.

Keywords: Thermal conductivity, Boron nitride, Phase separation, Polymer blends

Fig. 1 Cross sectional SEM image in PC/PP/BN (35/15/50 wt%).
Session: Functional Polymer Composites
Comp-7-4-I3

Grafted Thermoplastic Nanopolystyrene Strengthened Epoxy Nanocomposites
Hongbo Gu*

School of Chemical Science and Engineering, Tongji University, Shanghai, China
*Email: hongbogu2014@tongji.edu.cn

Abstract
The transparent epoxy nanocomposites strengthened and toughened by thermoplastic nanopolystyrene which is grafted with epichlorohydrin (g-PS) have been prepared at a low loading level. The polymer backbone of PS was manipulated by the epoxide and hydroxyl groups confirmed by Fourier transform infrared spectroscopy (FT-IR), thermogravimetric analysis (TGA), and X-ray photoelectron spectroscopy (XPS). The contact angle and differential scanning calorimetry (DSC) tests indicated that the grafting process could decrease the surface tension and increase the compatibility between PS and epoxy resins. The effects of g-PS loading and grafting process on both the viscosity of liquid epoxy resin suspensions, as well as the physicochemical properties of cured epoxy composites have been systematically investigated. The cured g-PS/epoxy composites demonstrated an enhanced tensile strength than either cured pure epoxy or PS/epoxy composites. The modulus of toughness for g-PS/epoxy composites is up to 355.9 MJ m⁻³, which is respectively 176.6 and 141.1% higher than that of cured pure epoxy and PS/epoxy composites. The uniform g-PS distribution in the cured g-PS/epoxy composites was observed by scanning electron microscope (SEM). The glass transition temperature (Tg) of cured g-PS/epoxy composites was shifted to a higher temperature in the dynamic mechanical analysis (DMA) compared with that of cured pure epoxy. The obtained strong interfacial interaction between g-PS and epoxy matrix was responsible for the enhanced mechanical and thermal mechanical properties. This work provides a new sight for the investigation of interaction and compatibility between thermoplastic and thermoset materials.

Keywords: Nano polystyrene, Epoxy, Nanocomposites, Mechanical Property
Near Infrared Light Activated Shape Memory Polymer Composite for Space Applications

Madhubhashitha Herath\textsuperscript{1,2}, Jayantha Epaarachchi\textsuperscript{1,2}, Mainul Islam\textsuperscript{1,2}, and Jinsong Leng\textsuperscript{1,2,3}

\textsuperscript{1}School of Mechanical and Electrical Engineering, Faculty of Health Engineering and Sciences, University of Southern Queensland, Toowoomba, QLD 4350, Australia
\textsuperscript{2}Centre for Future Materials, University of Southern Queensland, Toowoomba, QLD 4350, Australia
\textsuperscript{3}Center of Composite Materials and Structures, Harbin Institute of Technology, Harbin, China

*Email: Madhubhashitha.Herath@usq.edu.au, Jayantha.Epaarachchi@usq.edu.au

Abstract

Light activated shape memory polymer (SMP) composites are significant in developing breakthrough technological advancements since the shape memory effect can be remotely controlled by light. This paper presents the structural performance and photothermal recovery behaviour of 0/90 woven carbon fibre reinforced shape memory polymer composite (SMPC). The structural performance of SMP has increased significantly due to carbon fibre reinforcements as anticipated. The SMPC specimens were exposed to three different power densities of 808 nm near infrared radiation and respective temperature variations and shape recovery behaviours have been observed. The results revealed that, beside the typical activation by heating, the SMPC can be activated by photothermal heating, as a result of its ability to absorb near infrared radiation. This study has evidently shown the ability of carbon fibre reinforced SMPCs for space engineering applications. Accordingly, two prospective applications of carbon fibre reinforced SMPCs, i.e. a deployable space habitat and a deployable hinge for a solar panel of a satellite are presented.

Keywords: Shape memory polymer, Near-infrared light, Carbon fibre, Photothermal effect, Space applications

Meehye OH¹, Yeo Seong YOON², and Seung-Young LEE³

¹Korea Automotive Technology Institute
²Korea Automotive Technology Institute
³VITZRO Miltech Co.

*Email: mhoh@katech.re.kr, ysyoon@katech.re.kr, sylee@vitzrocell.com

Abstract

EV market is rapidly growing up, therefore it is interested environmental friendly industry of future. Performance of EV depends on high performance battery, motor and charger. High power battery for EV must have long life and safety. The most important factor for life and safety of battery system is thermal management. In this study, we developed materials of heat sink and housing for thermal management in battery system. We developed thermal conductivity polymer composite for alternative metal. Thermal conductivity materials are applied to heat sink for heat dissipate, thermal interface and heat pipe of heat exchanger. Key technologies of thermal conductivity composite are dispersion, orientation, network path and molding technology of fillers. These filler control technologies determinate the performance of composite. Battery housing is manufacture by the high performance thermal composite with carbon fillers. The high performance thermal composite usually has low mechanical properties. But, we developed superior composite with mechanical and thermal properties. The developing composite has a specific gravity of 1.3, impact strength of 113 J/m, thermal conductivity of 3W/mK and spiral flow of 50. Also, we carried out modeling for thermal management according to properties of composites. As results, we can suggest to correlate material and structure design. From this study, it will be possible to manufacture the light-weight and high performance battery package housing. We plan to analyse the influence of electromagnet shield effect with developing composite during the charging in the future.

Keywords: thermal conductivity, electromagnet wave shield effect, functional composite, energy storage system, electric vehicle
Network Architecture of a Novel Ether Amine Epoxy for High Performance Applications

Larry Q Reyes¹*, Buu Dao²*, Juan Zhang¹, Luke Henderson¹*, Russell John Varley¹

¹Carbon Nexus, Institute of Frontier Materials, Deakin University-Waurn Ponds Campus, Australia
²CSIRO Manufacturing, Clayton, Victoria, 3800

*Email: reyesl@deakin.edu.au, buu.dao@csiro.au, luke.henderson@deakin.edu.au

Abstract

High performance epoxy resin systems containing a unique combination of physicochemical properties (e.g. excellent solvent resistance, high glass transition temperature, excellent toughness, excellent flexibility, appropriate stiffness, etc.) for aerospace or other applications are in high demand. However, these are properties that do not usually go hand in hand. Therefore, the present study aimed to synthesize an innovative high performance epoxy resin that will form a polymer network that contains a unique combination of flexibility and stiffness. The novel epoxy resin is based on a 1,3-bis(4-aminophenoxy)benzene (134-BAPB) molecule, which triaromatic amine linked together with ether linkages, epoxidized with epichlorohydrin. The synthetic diagram of the epoxidation process is shown in Fig 1. The resulting epoxy monomer is a tetracyglycidyl 134-BAPB (134-TGAPB). The success of epoxidation was monitored by the High-Performance Liquid Chromatography (HPLC), Fourier Transform Infrared Spectroscopy (FTIR) and Proton and Carbon Nuclear Magnetic Resonance (1H and 13C-NMR) spectroscopies. The 134-TGAPB epoxy monomer was cured with 4, 4-diaminodiphenyl sulphone (44-DDS) and 134-BAPB amine producing an epoxy network with novel polymer microarchitecture and were characterized based in their network structure, glass transition temperature, strength and solvent ingress.

Keywords: epoxy, epoxidation, aerospace grade, curing

Fig. 1 Epoxidation of 134-BAPB with epichlorohydrin.
Session: Functional Polymer Composites
Comp-7-5-11

Filler Self-Networking in Epoxy/Polyethersulfone Composites via Reaction-Induced Phase Separation

Yucai Shen\textsuperscript{1,2}, Tingwei Wang\textsuperscript{1,2}

\textsuperscript{1}Advanced Materials Research Institute of Nanjing Tech University in Suqian, Suqian, China
\textsuperscript{2}College of Materials Science and Engineering, Nanjing Tech University, Nanjing, China

*Email: ycshen@njtech.edu.cn

Abstract

Epoxy/polyethersulphone (PES) blends are prepared as matrix resins for composites using carbon-based nanofillers as functional fillers. The epoxy/PES blends form a network structure via reaction-induced phase separation (RIPS) during the curing process, and the nanofillers are selectively localized in the phase inverted PES phase and at the interface leading to a three-dimensional continuous filler network. With this unique structure, the thermal conductivity, electrical conductivity and mechanical properties of the epoxy/PES composite are improved, and they are correlated to the final morphology. The structural development of the composites is also discussed. This work may provide a simple and efficient method without solvent to construct high-performance, functional epoxy based composites.

Keywords: Epoxy, Phase separation, Networking

Fig. 1 OM images of epoxy/PES/GNPs and epoxy/GNPs composites at different GNPs contents.
Solid Polymer Electrolyte of Graphene Oxide/ Poly (Vinyl Alcohol) / Polyethylene Glycol Borate Ester for Lithium-Ion Battery

W. H. Ruan¹*, Y. F. Huang¹,², M. Q. Zhang², M. Z. Rong²

¹Key Laboratory for Polymeric Composite and Functional Materials of Ministry of Education of China, School of Chemistry and Chemical Engineering, Sun Yat-sen University, China
²Materials Science Institute, Sun Yat-sen University, 510275 Guangzhou, China
*Email: cesrwh@mail.sysu.edu.cn

Abstract

A new solid polymer electrolyte of graphene oxide /poly (vinyl alcohol) blended with polyethylene glycol borate ester (GO/PVA/B-PEG) is prepared. The chemical structure of composited electrolyte is characterized by 1H-, 11B- and 19F-NMR spectra and ATR-FTIR spectrum. The component interactions among PVA, B-PEG and GO are investigated by DSC and XRD measurements. The surface of electrolyte is observed by SEM images to characterize morphological structure. Furthermore, ionic conduction behaviour of electrolyte enhanced by GO is investigated under consideration of GO on the interactions of electrolyte components, with the best obtained conductivities of 7.83×10⁻³ S / cm (30 oC) and 1.48×10⁻² S / cm (100 oC) when GO wt% is 0.125. It is found that GO and B-PEG have synergistic effect on enhancement of ion transport of the electrolyte (schematic drawing shown in Fig 1). It is also shown that thermal stability (~ 273 oC) and electrochemical stability (~ 4 V) of the electrolyte could be enhanced by GO. In addition, the solid electrolyte assembled in a lithium-ion battery is found to own a higher lithium-ion transfer number (~0.49) than commercial PP separator (~0.28). This type of solid polymer electrolyte is bendable and has potential application in flexible electrochemical devices.

Keywords: Polymer electrolyte, Poly (vinyl alcohol), Graphene oxide, Borate ester, Ionic conduction
Superhydrophobic Composite Coatings with Good Abrasion and Chemical Resistance

Yan Zhang*, Jing Zhang, and Yujian Liu

Key Laboratory for Specially Functional polymers and related Technology of Ministry of Education, School of Materials Science and Engineering, East China University of Science and Technology, Shanghai, China

*Email: yzhang@ecust.edu.cn

Abstract

Superhydrophobic coating has aroused much interesting in recently for its wide application. It allows water droplets to roll freely towards all directions and simultaneously remove the contaminants for its high water repellency. Whereas, a big challenge for the application is the poor mechanical stability and low anti-corrosion, ascribing to the relative weak bonds of most low surface energy substances and unstable microstructure. Epoxy resin with excellent mechanical properties, adhesive strength, solvent and chemical resistance, is copolymerized with hydrophobicity polymethylphenylsiloxane (HT-PMPS) to obtain a low surface energy matrix in the paper. And the hierarchical structure was achieved by using silica nanoparticles as the fillers. Moreover, multi-walled carbon nanotubes (MWCNTs) is selected to further improve the properties of the coatings, owing to its unique heat and corrosion resistance, self-lubrication and hydrophobicity. When the amount of MWCNTs reaches 3.0 wt%, the composite coating (EPPM3) shows superhydrophilicity with high water contact angle (WCA) of 154º and small sliding angle (SA) of 5º, excellent adhesive strength of 5B and hardness of 6H. In addition, the composite coating maintains the water repellency and dirt-removal properties either after 10 times abrasion tests (Fig.1) or immersed in 2500ppm boron-containing solution at 80ºC for 15h.

Keywords: Superhydrophobic, MWCNTs, anti-abrasion, chemical resistance

Fig. 1 WCA of composite coating (EPPM3) after abrasion
Session: Cement Based Composites
Comp-3-1-11

Influence of Rice Husk Ash and Silica Fume on Sulfate Attack of Metakaolin Geopolymer
Yueyue Wu¹, Ping Duan¹,²*

¹Faculty of Materials Science and Chemistry, China University of Geosciences, Wuhan, China
²Engineering Research Center of Nano-Geomaterials of Ministry of Education, China University of Geosciences, Wuhan 430074, China
*Email: duanping@cug.edu.cn

Abstract
This study aims to investigate the sulfate attack resistance of metakaolin (MK) geopolymer blended with rice husk ash (RHA, 0-20%, by mass) and silica fume (SF, 0-40%, by mass). Rice husk ash was obtained by the calcination of rice husk at 500°C, 550°C, 600°C and 700°C, respectively. Flowability of fresh mixture and the compressive at different curing ages were measured. Sulfate attack parameters including compressive strength loss and mass loss before and after sulfate solution immersion were assessed. The pore structure and microstructure were also evaluated by using mercury intrusion porosimeter and SEM/EDS. The result showed that RHA has the highest reactivity after calcination at 550°C for four hours. The addition of RHA and SF to replace MK decreased the fluidity of fresh geopolymer mixtures. With the increase content of RHA or SF, the strength of geopolymer increased firstly and then decreased. The highest compressive strength of MK geopolymer was obtained with addition of 10% RHA or 20% SF due to the optimal pore structure. The compressive strength of SF blended geopolymer decreased significantly after sulfate attack, while the decreasing in compressive strength of RHA group was only 0.3%. The same trend in mass loss was also observed. The compressive strength of geopolymer was closely related to the pore structure and microstructure regardless of sulfate solution immersion. RHA is a promising substitute in MK geopolymer production.

Keywords: Rice husk ash, Silica fume, Sulfate attack

Fig. 1 compressive strength of different samples.
Session: Cement Based Composites
Comp-3-1-I2

Self-Healing Technology for Durablre Recucled Concrete Development

Wengui Li¹,*, Caihong Xue¹, Vivian W. Y. Tam², and Surendra P. Shah³

¹School of Civil and Environmental Engineering, University of Technology Sydney, Australia
²School of Computing, Engineering and Mathematics, Western Sydney University, Australia
³Department of Civil and Environmental Engineering, Northwestern University, Evanston, USA

*Email: wengui.li@uts.edu.au

Abstract

Self-healing technique had been widely considered as an effective method for repairing and maintaining of crack-deteriorated concrete structures. Among all available self-healing techniques, capsule-based self-healing was the most prevailing one. Basing on the general discussion on the efficiency of various self-healing concrete technology, this review provided some clue for introducing the self-healing technology into reinforced recycled aggregate concrete (RAC). It was clear that self-healing mechanism based on urea decomposition was almost the same with the modification of RAC by calcium carbonate biodeposition, referring to the current researches. On the other hand, the mechanical properties of reinforced RAC could be comparative or even equal to natural aggregate concrete (NAC). Therefore, there might be an excellent probability to apply the capsule-based self-healing technology to reinforced RAC.

Keywords: Self-healing concrete, Healing agents, Capsule, Recycled concrete

Fig. 1 The autonomic self-healing concept for cementitious materials.
Influence of Vibration Induced Instability at Fresh State on Performance Degradation of Hardened Concrete
Xiaojian Gao¹ *, Xiuli Lu², and Junyi Zhang¹

¹School of Civil Engineering, Harbin Institute of Technology, China
²Harbin FRP Institute, China
*Email: gaoxj@hit.edu.cn

Abstract
Vibrating consolidation process is widely applied to field construction of cement concrete. Excessive vibration can easily lead to the segregation and bleeding of fresh concrete and induce strength and durability degradation of hardened concrete. In this study, two vibration amplitudes and vibrating duration were carried out for different rheological concrete mixtures to prepare column specimens. The variation of coarse aggregate content and apparent density along casting depth was determined to evaluate the homogeneity of concrete. Mechanical strength and chloride permeability were performed on selected samples at different casting depths. It was found that plastic viscosity plays a main role in controlling segregation and the increase of vibrating duration causes more segregation increment for concrete with lower yield stress and plastic viscosity. It can be concluded that the performance degradation of hardened concrete becomes worse under higher vibration amplitude and longer vibrating duration, with lower yield stress and plastic viscosity at fresh state.

Keywords: Fresh concrete, Rheological properties, Vibrating parameters, Homogeneity

Table 1 Rheological properties of concrete mixtures.

<table>
<thead>
<tr>
<th>Number</th>
<th>W/C</th>
<th>SP (%)</th>
<th>FA (%)</th>
<th>Slump (mm)</th>
<th>Yield stress (Pa)</th>
<th>Plastic viscosity (Pa·s)</th>
<th>Mortar Density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.36</td>
<td>1.0</td>
<td></td>
<td>210</td>
<td>2.516</td>
<td>6.354</td>
<td>2401</td>
</tr>
<tr>
<td>2</td>
<td>0.39</td>
<td>0.8</td>
<td></td>
<td>210</td>
<td>4.572</td>
<td>3.085</td>
<td>2347</td>
</tr>
<tr>
<td>3</td>
<td>0.36</td>
<td>0.8</td>
<td>0</td>
<td>200</td>
<td>63.309</td>
<td>7.640</td>
<td>2432</td>
</tr>
<tr>
<td>4</td>
<td>0.36</td>
<td>0.7</td>
<td></td>
<td>185</td>
<td>283.951</td>
<td>8.885</td>
<td>2464</td>
</tr>
<tr>
<td>5</td>
<td>0.32</td>
<td>1.3</td>
<td></td>
<td>195</td>
<td>56.491</td>
<td>13.005</td>
<td>2499</td>
</tr>
<tr>
<td>6</td>
<td>0.32</td>
<td>1.6</td>
<td></td>
<td>215</td>
<td>0.755</td>
<td>11.484</td>
<td>2380</td>
</tr>
<tr>
<td>7</td>
<td>0.36</td>
<td>0.8</td>
<td>10</td>
<td>220</td>
<td>40.012</td>
<td>8.267</td>
<td>2397</td>
</tr>
<tr>
<td>8</td>
<td>0.36</td>
<td>0.8</td>
<td>20</td>
<td>230</td>
<td>1.831</td>
<td>8.451</td>
<td>2358</td>
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</tbody>
</table>
A Study on Marble Based Geopolymer Green Concrete
Wei-Hao Lee*, Ta-Wui Cheng, Yung-Chin Ding
Institute of Mineral Resources Engineering, National Taipei University of Technology, Taiwan.
*Email: glowing955146@hotmail.com

Abstract
The greenhouse effect is an important issue since it has been responsible for global warming. Carbon dioxide also plays a part of role in the greenhouse effect. Therefore, human has the responsibility of reducing CO2 emissions in their daily operations. Except iron making and power plants, another major CO2 production industry is cement industry. Estimation by EPA of Taiwan, production 1 ton of cement will produce 520.29 kg carbon dioxide. There are 7.8 million tons of CO2 produced annually. Thus, to synthesize low CO2 emission geopolymeric green cement/concrete is important and can reduce CO2 emission problems in Taiwan.

The purpose of this study is trying to use marble wastes as the raw material to fabricate geopolymer green concrete. Experiment results show the marble based geopolymer green concrete with optimal parameters have good workability. The compressive strength after curing 28 days can be reached 44MPa indoor environment, and 28MPa in outdoor environment. The acid and alkali resistance tests show the marble based geopolymer green concrete have good resistance to chemical attack. By comparing with Portland cement products, the marble based geopolymer is not only reduce CO2 emission problems but also provides great performance in practices. All of the test results showed that marble based geopolymer green concrete has very good potential for further engineering application, the new material could be expected to replace the traditional Portland cement in the future.

Keywords: Marble, Geopolymer, Green concrete, CO2 emission.

Table 1. CO2 emission estimate of green concrete (compare with OPC concrete).

<table>
<thead>
<tr>
<th>CO2 emission estimate</th>
<th>OPC Concrete</th>
<th>CMSSS-1.28</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 emission estimate</td>
<td>0.3206 ton CO2/m³</td>
<td>0.1595 ton CO2/m³</td>
</tr>
<tr>
<td>CO2 emission reduction (%)</td>
<td>-</td>
<td>50.2</td>
</tr>
</tbody>
</table>
Characterization of Air Void in Alkali-Activated Foam Concrete by Image Analysis

Yuwei Ma¹, ², *, Dexia Zhao¹

¹Guangzhou University - Tamkang University Joint Research Center for Engineering Structure Disaster Prevention and Control, Guangzhou University, Guangzhou 510006, China
²Centre for Future Materials, Faculty of Health, Engineering and Sciences, University of Southern Queensland, Toowoomba, Australia
*Email: yuwei.ma@usq.edu.au

Abstract

The pore structure of foam concrete is an important characteristic to influence its engineering properties. In this study, the pore structure (mainly air void) of foam concrete prepared by alkali-activated fly ash/slag was characterized by image analysis based on backscattered electron images. The pore size distribution of alkali-activated foam concrete (AAFC) prepared with different fly ash content was compared. It was found that samples with higher fly addition had a higher volume of pores larger than 800 µm, which led to a lower compressive strength. AAFC samples with higher content of pores between 0-100 µm had higher compressive strength. The pore shape factor, reflecting the roundness of pores, was found closely correlate to thermal conductivity and water adsorption of AAFC samples.

Keywords: Alkali-activated materials; Foam concrete; Air void characterization; Image analysis

Fig. 1 Cumulative distribution of area fraction of pores.
Abstract

Fibre reinforced polymer (FRP) composites have become promising choice to conventional construction materials due to their high strength-to-weight ratio, durability, light weight, and corrosion resistant characteristics. Recently, a new type of FRP tube called hollow composite shear connectors (HCSC) has been developed by Composite Reinforcement Solutions (CRS), in cooperation with the Centre for Future Materials (CFM), in University of Southern Queensland (USQ) to reinforce the hollow concrete panels with HCSC. At the same time, HCSC has four outer flanges to provide better interlocking to concrete. HCSC also reduce the weight of RC panels, since the created hollow part leads to less consumption of concrete. However, the benefits and the actual performance of RC with HCSC has not been investigated yet. This paper investigates the flexural behaviour of six slabs reinforce with HCSC and different section configuration was investigated under 4-point static bending. The flexural behaviour of precast hollow RC panels with different spacing of HCSC will be determine to evaluate the effect of hollow-to-total area (Ah/At). The first slab has a solid cross section, the second with a 3-hollow-core, and the third one reinforced with 2-HCSC, fourth with 3-HCSC, then with 3-epxy HCSC, finally, with 4-HCSC (Fig.1). All slabs have an overall thickness of 175 mm thick and reinforced with 12 mm diameter steel bars at the top and bottom spaced at 200 mm on centres.

The results demonstrated that the solid and hollow slab behaved similarly due to the compressive stress in the concrete is above the voids. On the other hand, the slab reinforced with HCSC has twice the capacity to that of solid RC slabs. This indicates that the thickness of this slab can be further reduced to carry the same load carried by solid RC slabs but at significantly lower weight and lesser material usage. Overall, this paper demonstrated that the HCSC reinforcement is a beneficial technology and is suitable for hollow precast concrete slabs. It could make concrete slabs much lighter and more cost effective than solid and traditional hollow slabs.

Keywords: FRP composites, HCSC, Hollow concrete panels, Flexural strength
Preparation and Properties of Steel Slag Reinforced Fly Ash-based Geopolymer

Xiaolu Guo¹,², *, Junyi Yang², Huisheng Shi¹,²

¹ Key Laboratory of Advanced Civil Engineering Materials of the Ministry of Education, Tongji University, Shanghai 201804, China
² School of Materials Science and Engineering, Tongji University, Shanghai 201804, China
*Email: guoxiaolu@tongji.edu.cn

Abstract

In order to promote utilization of industrial solid wastes, fly ash and steel slag were used to synthesize geopolymer by using the compound alkali activator. The influence of steel slag content on the compressive strength of fly ash based geopolymer paste was studied, and the effects of steel slag on the mechanical properties of the fly ash based geopolymer mortar were also studied. The results showed that the incorporation of steel slag can improve the compressive strength of geopolymer paste to a certain extent, especially the early strength, and the suitable content of steel slag should be controlled within 40wt%. With the increase of steel slag content, both the compressive strength and flexural strength of the two kinds of mortar were improved, indicating that steel slag can play a significant reinforcing and toughening effect on geopolymeric mortar, and the suitable amount of steel slag in mortar is 30wt%.

Keywords: Fly ash, Geopolymer, Steel slag, Reinforcing and toughening effect, Resource utilization

Fig. 1 Compressive strength of geopolymer with different contents of steel slag.
Application of Gap-Graded Particle Size Distribution Theory in Design of Engineered Cementitious Composites
Qijun Yu1, *, Shaolong Liu1, Tongsheng Zhang2, Jiangxiong Wei1 and Kang Wang1

1School of Materials Science and Engineering, South China University of Technology, China
2Department of Civil, Environmental and Geomatic Engineering, University College London, WC1E 6BT, UK

*Email: concyuq@scut.edu.cn

Abstract
To attain robust tensile strain-hardening behaviors of engineered cementitious composites (ECC), the particle size distribution (PSD) of solid constituents in ECC matrix is standardized and guided by gap-graded PSD theory1. In the present study, three types of matrix were designed using constituents with different PSDs (Fig 1) and researched as systems composed of unevenly distributed phases, instead of homogeneous systems. The first one is the classic matrix2 (as reference) with recommended compositions of sand, ordinary cement and fly ash (FA). The second is a series of matrix with high packing density and relatively homogeneous microstructure, guided by gap-graded PSD theory. The third matrix (composed of ultrafine FA and cement) provides an ultra homogeneous environment for fibers to freely distribute and transfer stress. With compressive strengths of about 44 MPa, the homogeneous ECC showed a strain capacity of 5.9% and an average loaded crack width of 53 μm, while those of the reference matrix are 2.3% and 83 μm. For gap-graded ECC, as the largest particle sizes increase from 10 μm to 120 μm, the strain capacity of ECC slightly decreases and is still higher than 4.5% with an average loaded crack width of 66 μm (Table 1).

Keywords: Gap-graded particle size distribution, Engineered cementitious composites, Homogeneous microstructure, Blended cement, Fly ash

Table 1 Mechanical performance and crack parameters of homogeneous ECC, reference ECC and gap-graded ECC.

<table>
<thead>
<tr>
<th>D50 (μm)</th>
<th>Strain capacity (%)</th>
<th>Ultimate tensile strength (MPa)</th>
<th>Compressive strength (MPa)</th>
<th>Crack number</th>
<th>Average loaded crack width (μm)</th>
<th>Average Crack spacing (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref-ECC</td>
<td>2.32±0.42</td>
<td>3.15±0.21</td>
<td>41.3±2.2</td>
<td>11±4</td>
<td>84</td>
<td>3636</td>
</tr>
<tr>
<td>5 grades</td>
<td>4.50±0.57</td>
<td>2.63±0.18</td>
<td>32.7±1.6</td>
<td>27±6</td>
<td>66</td>
<td>1481</td>
</tr>
<tr>
<td>4 grades</td>
<td>5.00±0.28</td>
<td>3.20±0.14</td>
<td>35.5±2.4</td>
<td>33±5</td>
<td>60</td>
<td>1212</td>
</tr>
<tr>
<td>3 grades</td>
<td>5.20±0.28</td>
<td>3.28±0.11</td>
<td>38.5±1.2</td>
<td>37±8</td>
<td>57</td>
<td>1081</td>
</tr>
<tr>
<td>Homo-ECC</td>
<td>5.85±0.49</td>
<td>3.75±0.07</td>
<td>44.7±2.1</td>
<td>44±7</td>
<td>53</td>
<td>909</td>
</tr>
</tbody>
</table>
Flexural Response of BTRC with Pre-Tension and Short Fibres under Low Speed Impact Loads

Sai Liu, Deju Zhu*

Key Laboratory for Green & Advanced Civil Engineering Materials and Application Technology of Hunan Province, College of Civil Engineering, Hunan University, Changsha 410082, China

*Email: dzhu@hnu.edu.cn

Abstract

The flexural impact properties of basalt textile reinforced concrete (BTRC) specimens with pretension, short carbon, steel, and AR-glass fibres were investigated. The flexural strength, flexural modulus and toughness, were determined under different impact speeds. The flexural strength and toughness of the BTRC specimens without pre-tension significantly increased when the impact speed (1.0–3.0 m/s) and the number of basalt textiles layers were increased (Fig. 1). The flexural modulus initially increased and subsequently decreased with increasing impact speed. When the basalt textile had four reinforcement layers, the BTRC reinforced with 0.5 Vol% of short carbon fiber or short steel fiber exhibited varied different flexural responses under different impact speeds (1.0–4.0 m/s). In addition, pre-tensioned BTRC with different short fibers were tested under an impact speed of 1.0 m/s. The flexural strength decreased as the short carbon fiber and glass fiber contents increased. The highest flexural strength was observed in the pre-tensioned specimen with 0.5 Vol% of short glass fiber and three layers of basalt textile (Fig. 2). The addition of short fibers in cement matrix, the number of textile layer used as reinforcement, the pretension on textile, and the impact speeds used in the tests can significantly affect the dynamic impact behaviour of BTRC specimens.

Keywords: Basalt textile reinforced concrete, Short fibers, Pre-tension, Impact load

Fig. 1 Flexural strength and Toughness of BTRC specimens under the impact speed of 1.0 m/s.
Microtomography Study of Polymer Fibre Orientation in Concrete Composite Foam
Alireza Kashani* and Tuan D. Ngo*
Department of Infrastructure Engineering, University of Melbourne, Victoria 3010, Australia
*Email: kashani.a@unimelb.edu.au, dtngo@unimelb.edu.au

Abstract
Concrete foam is a lightweight insulating material with high strength to weight ratio. It offers thermal insulation and fire-resistant properties. Addition of fibre results in higher ductility, reduced brittleness and improved flexural strength of concrete foam. This study shows the effect of polymer fibres i.e. nylon and polyvinyl alcohol (PVA) on mechanical properties of concrete composite foam. Also, Microtomography (μ-CT) analysis was conducted on the samples. For the first time, a new technique was used to recognise polymer fibres in the cement matrix. As the results, 3D orientation, xyz coordination, curved length and diameter of fibres were analysed. Figure 1 shows a 2D slice of μ-CT scan of concrete composite foam with PVA fibres. The fibres are barely visible in the red boxes. However, the new technique is able to show and analyse fibre orientation as shown in Figure 2. The properties of fibres inside the matrix such as fibre orientation within the porous structure of concrete foam were consequently related to the mechanical properties of the concrete foam composite.

Keywords: Concrete, Composite, Polymer Fibre, Microtomography, Fibre Orientation

Fig. 1 2D slice of μ-CT scan of concrete composite foam with PVA fibre.
Adsorption of Polymeric Micelles on Cement and Their Influence on the Early Age Properties of Fresh Cement Paste

Hu Jie*, Yangyang Zhu, and Qijun Yu

School of Materials Science and Engineering, South China University of Technology, China

*Email: msjiehu@scut.edu.cn

Abstract

In this study, the adsorption of the micelles prepared by poly(ethylene oxide)-b-polystyrene (PEO-b-PS) copolymers on cement particles and clinkers and their influence on the workability and early hydration of cement paste were investigated. The adsorption behaviour of micelles on cement particles and clinkers was investigated by total organic carbon (TOC), optical fluorescence microscopy (OFM) and scanning electron microscopy (SEM) observations associated with energy dispersive spectroscopy (EDS); the effect of micelles on the workability of cement paste was characterized by zeta potential, mini slump measurements and rheological tests. The results show that the micelles efficiently adsorbed on the surface of cement particles within 30 s. The distribution of micelles was very uniform in cement matrix, however they preferred to adsorb on the surface of C₃A and potassium-containing phase, leading to a retarded hydration rate of C₃A during the very early hydration age. The workability of cement paste, both the fluidity and fluidity retention ability, was improved by the micelles. The relevant mechanisms were mainly attributed to the steric hindrance effect on cement particles and retardation effect on C₃A hydration rate at very early hydration age, respectively, leading to the defloculation of cement particles.

Keywords: Micelles, Adsorption, Distribution, Workability, Early hydration

Fig. 1 Fluidity of cement paste with different content of the micelles.
Session: Cement Based Composites
Comp-3-2-O2

Experimental Evaluation on Flowability and Mechanical Properties of CNT/cement Composites Dispersed by Silica Fume

Million Tafesse, Hyeong-Ki Kim*

School of Architecture, Chosun University, 309 Pilmun-daero, Dong-gu, Gwangju, South Korea
*Email: hyeongki@chosun.ac.kr

Abstract
Incorporation of Carbon nanotube (CNT) has a significant influence on the mechanical and electrical property of cement paste as studies show. However, up to date, there is no stable and common way of using CNT inside the paste matrix without compromising the functionality of the composite. In this study, silica fume a common material that is being consumed currently in the construction industry is used as a dispersing agent to avoid any adverse effect on the composite. The silica fume is used to disperse the CNT on 0.25 and 0.4 water-cement ratio mixtures. Based on the dispersion, the mechanical property of the CNT cement composite is investigated including flowability of the paste. From the experimental result the flowability decrease as the amount of CNT increase in the mixture. On the other hand, the compressive strength, flexural strength, and dynamic Young's modulus have shown diverse result.

Keywords: CNT, Silica fume, Flowability, Compressive strength, Flexural strength, Dynamic Young's modulus

Fig. 1 Flowability result for each mixture.
Capillary Water Absorption of Loading Concrete under Freezing-Thawing Circumstance

Yanru Wang¹,²*, Peng Zhang², Zuhua Zhang¹,³*, Yubin Cao², Hao Wang¹, Tiejun Zhao²

¹CFM, University of Southern Queensland, Toowoomba QLD 4350
²Civil Engineering College, Qingdao University of Technological, Qingdao, 266033, China
³Key Laboratory for Green & Advanced Civil Engineering Materials and Application Technology of Hunan Province, College of Civil Engineering, Hunan University, Changsha, 410082, China

*Email: Yanru.Wang@usq.edu.au, Zuhua.Zhang@usq.edu.au

Abstract
Durability of concrete structures is governed by a range of factors. In coastal areas, the durability of concrete structures is affected not only by own load but also the freeze-thaw cycle. This study aims to research the influence of coupling action of load and freeze-thaw cycles on capillary water absorption (CWA) which was measured by ASTMC1585-13 test. Concrete specimens under 0, 30% and 50% of ultimate compressive strength (fc), were subjected to 25 and 50 freeze-thaw cycles, respectively. Then the unloaded specimens were cut into four parts (Fig 1). Experimental results showed that CWA increased with the increase of freeze-thaw cycles, which was consistent with the initial capillary absorption coefficient. CWA of the concrete under 0.5fc was highest amount the studied loading range, following by 0.3fc and 0 fc; CWA of outside part (o) is higher than inside part (i). The proportion of large pores was examined and was shown to increase due to the coupling damage.

Keywords: Concrete, Applied pressure, Freeze thaw, Pore structure, Capillary water absorption

Fig. 1 Schematic diagram of cutting.
Effect of Particle Size Distribution Modified Fly Ash on the Macro-Micro Structure and Hydration Properties of CementitiousComposite

Jun Liu1, *, Runqing Liu1, *, Yunpeng Cui2, and Yuanquan Yang2, *

1School of materials science and engineering, Shenyang Ligong University, Shenyang, China
2Faculty of infrastructure engineering, Dalian University of technology, Dalian, China

*Email: liujun2699@126.com, 13940195514@163.com, aquarius0109@163.com

Abstract

Particle size distribution of the mineral admixtures is one of the important factors affecting the properties of cement based composites. A reasonable particle size distribution could contribute to good pore structure and improved hydration properties of cement based composites. Fly ash, which is a kind of excellent mineral admixture, could play micro-aggregate effect and volcanic ash effect in mortar. In this work, the fly ash with range of 0~80µm was screened and divided into 0~3µm, 3~5µm, 5~8µm, 8~10µm, 10~15µm, 15~20µm, 20~26µm, 26~30.8µm, 30.8~38.5µm, 38.5~43µm, 43~50µm, 50~61µm and 61~80µm intervals. Fly ash corresponding to different functions were prepared by adjusting the content of the obtained thirteen fly ash samples. The effect of the prepared fly ash on the mechanical properties, durability, pore structure and parameters of hydration kinetics were investigated. Mathematical models were established concerning the relationship between the particle size distribution of the fly ash and the strength of cementitious composites, which were based on the grey multiple linear regression analysis theory and the grey buffer operator theory. Thereafter, an optimal function of particle size distribution was simulated. Further, the relative content of the fly ash with different particle size distribution was used as the input neuron of artificial neural network, the pore structure properties and parameters of hydration kinetics pertaining to the cementitious composites were used as implicit neuron, and the mechanical properties and durability as output neuron. The relationship between the particle size of the admixture and the mechanical properties and durability of the cementitious composite was thus established directly by artificial neural network. It provides the theoretical basis and judgment basis for optimizing the particle sizegradation of mineral admixture in practical construction.

Keywords: Particle size distribution, Fly ash, Mechanical property, Durability, Hydration kinetics
Structure, Stability and Formation Rates of the Main Binding Gels in Alkali-Activated Materials

Claire White*

Princeton University, USA

*Email: whitece@princeton.edu

Abstract

With the world facing a climate crisis due to increasing CO2 emissions there is pressing need to develop and implement sustainable construction materials across the globe. Alkali-activated materials (AAMs) pose as one such sustainable alternative to conventional ordinary Portland cement (OPC) concrete, however, questions remain regarding the long-term performance of AAMs which is hampering implementation of this sustainable solution in the construction industry. In this presentation I will outline how fundamental materials research on the structure, stability and formation rates of the main binding gels is helping to address the long-term performance unknowns of new sustainable concretes, where we are linking key experimental techniques (such as in situ atomic structure evolution measurements from synchrotron experiments and pore structure determination) with atomistic and larger length scale simulations.

Keywords: Alkali-activated materials, Sustainable cements, Atomic structure, Durability, Modeling
Influence of Ultra-Fine Ash Spheres on Rheological Properties
Enhancement of Alkali-Activated Fly Ash/Slag Pastes

Tao Yang¹,², Huajun Zhu¹, and Zuhua Zhang³,*

¹ School of Materials Engineering, Yancheng Institute of Technology, Jiangsu, 224051, China
² China Building Materials Academy, Beijing, 100024, China
³ Centre for Future Materials, University of Southern Queensland, Toowoomba, QLD, Australia

*Email: Zuhua.Zhang@usq.edu.au

Abstract

The highly viscous property of alkali silicate-activated cements is always one of the critical challenges that obstacle their wide application. The present study focuses on ameliorating the rheological performance of sodium silicate-activated fly ash/slag cement pastes by using ultra-fine ash sphere (UFAS), which are highly spherical particles collected from fly ash with electrostatic adsorption classification technology. The results show that the plastic viscosity of the pastes decreases sharply as the UFAS content increases. The UFAS particles work as ‘ball-bearings’ in the suspension to overcome the internal friction among the fly ash and slag particles, and meanwhile mitigate the agglomeration of the flocs and fragmentation to release the immobilized free water. The incorporation of UFAS brings more calcium in the alkali-activation systems. This leads to the formation of more C-A-S-H gel phase, and consequently more compact microstructure and higher mechanical strength of the products. The interrelationship between the plastic viscosity and the UFAS particle geometry is well described by the Krieger-Dougherty equation, which also supports the proposed mechanisms of ‘ball-bearings’ effects. This paper discovers UFAS as an inorganic dispersing agent to improve the workability of the alkali-activated cement products for a varied of application aspects.

Keywords: Ultra-fine ash sphere, Alkali-activated cement, Rheology, Microstructure

Table 1 Yield stress and plastic viscosity of the AAC pastes.

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Yield stress (Pa)</th>
<th>Plastic viscosity (Pa·s)</th>
<th>Yield stress (Pa)</th>
<th>Plastic viscosity (Pa·s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS0</td>
<td>2.512</td>
<td>1.052</td>
<td>1.424</td>
<td>1.363</td>
</tr>
<tr>
<td>AS10</td>
<td>4.466</td>
<td>0.660</td>
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<td>0.569</td>
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<tr>
<td>AS20</td>
<td>3.144</td>
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<td>2.684</td>
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<tr>
<td>AS30</td>
<td>2.930</td>
<td>0.165</td>
<td>2.660</td>
<td>0.170</td>
</tr>
<tr>
<td>AS40</td>
<td>2.352</td>
<td>0.110</td>
<td>3.036</td>
<td>0.105</td>
</tr>
</tbody>
</table>
Efflorescence in Calcined Kaolin-based Geopolymers

Márlon A. Longhi¹, Zuhua Zhang¹, *, Erich Rodriguez², Ana P. Kirchheim³ and Hao Wang¹

¹Centre of Excellence in Engineered Fibre Composites, University of Southern Queensland, Toowoomba, QLD 4350, Australia.
²Department of Structures and Civil Construction, Technological Center, Federal University of Santa Maria (UFSM), Santa Maria, RS, Brazil.
³Building Innovation Research Unit, Federal University of “Rio Grande do Sul” (NORIE/UFRGS), Porto Alegre, Brazil.

*Email: Zuhua.Zhang@usq.edu.au

Abstract

Even with all the research done and development in recent years on activated alkali cement (AAC) or geopolymers, the phenomenon of efflorescence is still not fully understood nor controlled. This phenomenon is generated by the transportation and reaction between the free alkalis in the geopolymer matrix with the CO₂ of the wet environment. This process was initially related only to surface aesthetics damage due to the formation of carbonate(s), which can also present in OPC systems¹, however, some studies have observed changes in the mechanical behavior and integrity of the samples²,³,⁴, which may compromise the use of such materials. This study will evaluate the mechanism of formation of efflorescence and its effects on the mechanical behaviour and alkali leaching potential for geopolymeric systems produced with using metakaolin as precursor at different activation conditions (content of Na₂O and soluble silicate MS). Some results show that the activation parameters are determinant to the alkali stability which reflects in the efflorescence formation (fig 1). Is also evident the reduction of compressive strength after efflorescence process (fig 2). The pore structure, alkali leaching and mechanical properties are dependent of the reaction degree provided for the activation parameter.

Keywords: Alkali-activated cement (AAC), Geopolymer, Metakaolin, Efflorescence, Durability.

Fig. 1 Capillary water absorption of geopolymer samples.
Control Interface to Enhance Strengthening in SiC Particulate Reinforced Al-Zn-Mg-Cu Composites

B.L. Xiao*, G.N. Ma, D. Wang, and Z.Y. Ma

Shenyang National Laboratory for Materials Science, Institute of Metal Research, Chinese Academy of Sciences, 72 Wenhua Road, Shenyang 110016, China

*Email: blxiao@imr.ac.cn

Abstract

Particulate reinforced aluminium matrix composites (PRAMC) have found a wide industrial application due to their high good mechanical properties. In order to develop PRAMC for bearing structures, high strength Al-Zn-Mg-Cu alloys have been employed as matrix alloys. However, the previous studies [] disclosed lower strengthening effect of reinforcements in Al-Zn-Mg-Cu alloys. In this study, 15 vol.%SiCp/7085Al composite and 7085Al alloy were fabricated by powder metallurgy (PM) method. The mechanical properties and microstructure evolution were investigated. The results showed that the as-extruded composites had 92 MPa enhancement in ultimate tensile strength (UTS) compared to the as-extruded unreinforced alloy. However, the strengthen effect disappeared after solution treatment and artificial ageing (T6 for short). UTS of the composite was 34 MPa lower than that of the T6 unreinforced alloy. Microstructural examination disclosed that typical precipitation phase MgZn2 depleted due to interface reaction between Mg and SiC particles. Compared to the unreinforced alloy, the composite had precipitates with lower density and larger size under T6 heat treatment. Based on the result, supplementary amount of Mg about 1.0 wt.% was added into the composite, the strengthening were recovered, thereby exhibiting superior strengthen compared to the present reports.

Keywords: Metal matrix composites, Interface, Ageing, Segregation, Powder metallurgy

Fig. 1 Tensile properties of SiCp/Al-Zn-Mg-Cu composite: (a) stress–strain curves and (b) strengthening capability after heat treatment.
An In Situ Formed TiCx Reinforced High Cr White Iron Composite with Improved Mechanical Properties and Wear Resistance

Jipeng Jiang, Shibo Li*, and Shujun Hu

Center of Materials Science and Engineering, School of Mechanical and Electronic Control Engineering, Beijing Jiaotong University, Beijing 100044, China.

*Email: shbli1@bjtu.edu.cn

Abstract

High chromium white irons (HCWIs) are a good abrasion resistant material used in machinery and metallurgy equipment, etc. However, the existence of large and coarse M7C3 ((M: Fe, Cr and other strong carbide formers) carbides is harmful to wear and mechanical properties of HCWIs. In order to modify the coarse microstructure and further improve the performance, an in situ formed TiCx reinforced HCWI composite has been prepared. The results showed that the in situ formed TiCx from the decomposition of Ti3AlC2 inhibited the growth of M7C3, effectively refining the M7C3 structure. The microstructure and phase composition were characterized, the hardness, strength, toughness and wear resistance of the composite were measured.

Keywords: High chromium white irons, Composite, TiCx, Microstructure, Performance

Fig. 1 Backscattered SEM micrographs of HCWI composites reinforced with 17.2 wt.% TiCx. The black particles are TiCx.
Improving Graphene Distribution and Mechanical Properties of GNP/Al Composites by Cold Drawing

Xuexi Zhang*, Jianchao Li, Lin Geng

School of Materials Science and Engineering, Harbin Institute of Technology, Harbin, China

*Email: xxzhang@hit.edu.cn

Abstract

Dispersion of graphene in aluminum matrix has been a key factor that affects the strengthening efficiency of graphene reinforced aluminum matrix composites. Here, GNP/Al composites reinforced with 0.4wt.% and 2.0wt.% graphene nano-platelets (GNP) were fabricated by powder metallurgy (PM) followed by a multi-pass cold drawing at ambient temperature in order to eliminate the GNP aggregates. The microstructure evolution and the mechanical properties of the GNP/Al composites were investigated. Results showed that GNP cracked into pieces along the drawing direction, leading to improved GNP distribution. GNP aggregates were eliminated in 0.4wt.% GNP/Al at an equivalent drawing strain of 6.00 compared with that in the as-extruded composite, while some still exist in the 2.0wt.% GNP/Al composite. The ultimate tensile strength (UTS) of as-drawn 0.4wt.% GNP/Al composites was ~52% higher than that of the Al alloy. While, the mechanical properties of 2.0wt.% GNP/Al composites deteriorated because of the existence of GNP aggregates. The dispersed GNP with strong interfacial bonding in 0.4wt.% GNP/Al composites exhibited significant load transfer strengthening effect, which contributed to the improvement in UTS. The strengthening efficiency (R) of graphene in the cold-drawn composite wires reached ~80%, which is comparable to that of the composites fabricated by wet chemistry method.

Keywords: Aluminum metal matrix composites, Graphene nano-platelets, Cold drawing, Mechanical properties.

Fig. 1 Mechanical properties of Al and GNP/Al composites: (a) Comparison of ultimate tensile strength (UTS) between the as-drawn and as-extruded Al and GNP/Al composites; (b) Stress-strain curves of the as-drawn Al and GNP/Al composites. The inset in (b) shows a fractured sample of the 0.4wt% GNP/Al composite.
Enhanced Mechanical Properties of Mg$_2$Si-Reinforced Aluminum Composites by Bi Addition

Fufa Wu*, Xiaofeng Wu*

School of Materials Science and Engineering, Liaoning University of Technology, Jinzhou, China

*Email: ffwooxy@163.com

Abstract

In the present work, the influence of Bi on the microstructures, tensile properties, and fracture behaviour of the cast Al-10 Mg$_2$Si composites have been systematically investigated. It was found that Bi addition caused a significant modification and refinement efficiency on the eutectic Mg$_2$Si in the cast Al-10 Mg$_2$Si alloys. The morphology of the eutectic Mg$_2$Si in the cast alloys was turned from plate-like structure to a thin coral-like and fibrous one, and the mean size and aspect ratio sharply decrease with the increase of Bi content. Bi addition changed the mode of fracture from brittle to ductile due to the presence of a large number of deep and well-distributed dimples and fine Mg$_2$Si particles embedded in the Al-matrix, which leading to the significantly improved tensile properties of the cast Al-10Mg$_2$Si composites.

Keywords: Hypoeutectic Al-Mg$_2$Si composites, Bi addition, Eutectic Mg$_2$Si, Tensile properties

Fig. 1 Microstructure of cast Al-10Mg$_2$Si composites (a) before and (b) after Bi addition.
Studies of Application of the Fiber Reinforced Composite Material for Stern Tube System

Iwao Matsuoka¹,², *, Motoaki Osawa¹ and Hiroyuki Saito¹

¹Graduate School, Tokyo Denki University,
²Eagle Industries Co., Ltd. Marine division
*Email: iwao.matsuoka@kemel.com

Abstract

We study about application of the fiber reinforced composite material for the stern tube system on ocean going marine vessels using line shaft propeller propulsion concerning lightweight, lower heat generation, anti-wear and anti-corrosion. Tungsten wire reinforced Al composites, W/Al composites were fabricated by vacuum hot pressing¹-³ and their mechanical properties were measured. W/Al interface formed harder reaction layer and gave influences to the bonding. In order to improve the bonding performance in the W/Al interface by controlling the formation of reaction layer, chemical deposition of Ti was applied between boundaries. The tensile strength of the reinforced composite was improved 3 times comparing with that of Al by forming reaction layer of Al/Ti, Ti/W. The corrosion performance of W/Al composites under 3% NaCl and ester based lubricant were also checked by using Scanning electrochemical microscopy (SECM). The corrosion rate⁴ under 3% NaCl was 20-40 times firster than that of original material (FC) and galvanic corrosion occurred at the W/Al interface. On the other hand, the corrosion rate under Ester based lubricant was very slow and can be longer than lifetime of the vessels.

Keywords: Marine vessel, Hot press, SECM, Corrosion rate

Fig. 1 Section view of W/Al active composite.
Sintering and Bulk Consolidation of Milled Al-MWCNTS Composite Using Vacuum Powder Metallurgy

AR Othman¹*, S. Kamaruddin¹, and Alzakri Ekhwan²

¹Mechanical Engineering Department, Universiti Teknologi PETRONAS, Perak, MALAYSIA
²Custodian Engineer Static Unfired, Engineering Department, Group Technical Solution T&E Division, PETRONAS, Menara Dayabumi, 50050 Kuala Lumpur, MALAYSIA

*Email: rahim.othman@utp.edu.my

Abstract

As in composites, the orientation of the CNTs, homogeneity of the reinforcement distribution, nanotube matrix adhesion, its aspect ratio and the volume fraction of nanotubes are expected to have significant influences on the properties of nanocomposites. Consolidation of the ball milled powders into bulk, full density compaction while retaining nanoscale grain size and uniform particle diffusion proved a major challenge. In this work, bulk sintering of Al-MWCNTs composites was produced by first dispersing 2wt% MWCNTs with 10-20 nm diameters and 5–15µm length into 31µm, 99% pure Al powders and 7.5, 15, 30 and 40 hours milled aluminum powders with particle distribution of 8.93µm to 19.8µm. The dispersion was achieved through milling at 15 and 30 hours, before consolidating the Al-CNTs composite powders through hot vacuum hot pressing at optimized compaction parameters. The process provided the minimized condition of undesirable reactions between the aluminium and oxygen, CNTs and the aluminium matrix, rather than hot or cold press, due to controlled atmosphere working environment and avoiding any interfacial reaction. The effect of varied sintering temperatures and milling times were investigated. Morphology micrograph has indicated the start of diffusion between particles after 470°C and was completed at 594°C. MWCNTs in the grain boundary played a pinning effect in restraining the grain growth. Raman spectroscopy of Al-CNTs pellets established the well-dispersed MWCNTs in 15-30 hours milled Al-CNTs solid samples at 4 different randomly chosen locations of analysis. 90% of densification was apparent for 15 and 30 hours of milling based on the results of densimeter at 2.57 g.cm-3. Microhardness was increased from 34.63Hv for unmilled aluminum powder and reached 126.33Hv for 15 hours milled Al-CNTs (3.64 times higher). The optimum consolidation was achieved at 594°C at 15 hours of dispersing milling time.

Keywords: Al-MWCNTs nanocomposites, vacuum powder metallurgy, morphology analysis, mechanical properties.
Session: Metal Matrix Composites
Comp-10-2-I1

Enhancement of Thermal Properties of Silver-CNT/Copper Composites by Friction Stir Processing
Jae-Ha Kim¹, Yeo-Reum Lee¹, Seung-Boo Jung² and Hyo-Soo Lee¹,*
¹Korea Institute of Industrial Technology, South Korea
²Sungkyunkwan Univ., South Korea
*Email: todd3367@kitech.re.kr

Abstract
It has been well known that the friction stir processing has much merit on refining microstructures and excellent mechanical properties without distortion of body and any consumable parts. The friction stir processing was applied for enhancing thermal diffusivity of silver-CNT reinforced copper matrix composites in this study. It was observed that silver was decorated homogeneously on CNT as shown in Fig 1(a), which was manufactured by synthesizing silver nitrate on the surface of CNT through acid treatment. And the silver-CNT composite powders were filled up into the groove region on copper matrix and were subjected to high strain that modified their grain pattern by plastic deformation with a stirring motion of tool laterally during 1~4 cycles. The refining microstructure was shown in Fig 1(b). The thermal diffusivities of silver-CNT/copper composites were measured as ranging from 102mm²/s to 113mm²/s at room temperature, which was 14~15% higher than those of pure copper as shown in Fig 1(c), and evaluated as maximally 118mm²/s at 100°C and 2cycles that 20% higher than that of pure copper. The improvement of thermal diffusivity of silver-CNT/copper composites was deduced to the enhancement of interfaces between silver-CNT composite powders and copper matrix induced by a forcible deformation. It could be obviously presented from this study that thermal diffusivities of silver-CNT/copper composites were remarkably increased due to the refined and homogeneous microstructures of silver-CNT/copper composites by the friction stir processing.

Keywords: Thermal Properties, Silver-Carbon, Copper, Composite, Friction Stir Processing

Fig. 1 Microstructure and thermal diffusivity of silver-CNT/copper composites. (a) Silver-CNT composite powder, (b) Silver-CNT/copper composite by friction stir processing, (c) variation of thermal diffusivity.
The Effect of Hybrid Graphene-Carbon Nanotube Reinforcements on Mechanical Properties of AZ31 Alloy Nano-Composites

Mingyang Zhou¹,², Lingling Fan¹,², Yuwenxi Zhang¹,², and Gaofeng Quan¹,²*
¹Key Laboratory of Advanced Technologies of Materials, Ministry of Education, Sichuan, China
²School of Materials Science and Engineering, Southwest Jiaotong University, Sichuan, China
*Email: quangf@home.swjtu.edu.cn

Abstract

Carbon nanotubes (CNTs) and/or graphenes (GNPs) reinforced AZ31 matrix composites were successfully fabricated by powder metallurgy method followed by hot extrusion. The nano-reinforcements on the microstructure and mechanical properties of the matrix were investigated by optical microscopy (OM), X-ray diffraction (XRD), scanning electron microscopy (SEM), microhardness and tensile test. The XRD results revealed that the addition of the carbonaceous nano-reinforcements would weaken basal texture of the AZ31. And it was found that adding the hybrid CNTs and GNP could inhibit the agglomeration of the nano-reinforcements, which might be caused by the formation of 3D hybrid network structure due to CNTs intercalating into GNPs layers. A striking synergistic effect was achieved by using this hybrid nano-reinforcements and compared to the matrix, the microhardness, yield strength, ultimate tensile strength, ductility and work of fracture of the composites were significantly enhanced up to +9.4%, +23.9%, +12.5%, +28.5%, +41.7%, respectively. The load transfer mechanism, Orowan mechanism, and thermal mismatch hardening played the important roles in the improvement of the mechanical properties. Our investigation may provide a novel method to fabricate composites stronger and tougher by using hybrid nano-reinforcements.

Keywords: Hybrid CNTs-GNPs, Synergistic effects, Basal texture weaken, Strengthening mechanisms, Toughening

Table 1 Mechanical properties of the as-extruded AZ31 and its nanocomposites.

<table>
<thead>
<tr>
<th>Material</th>
<th>YS (MPa)</th>
<th>UTS (MPa)</th>
<th>Elongation (%)</th>
<th>WOF (MJ/m³)</th>
<th>Microhardness (HV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZ31</td>
<td>188±5.2</td>
<td>280±4.5</td>
<td>14.4±1.2</td>
<td>36±2.2</td>
<td>81.1±1.1</td>
</tr>
<tr>
<td>AZ31-1wt.%CNTs</td>
<td>235±4.8</td>
<td>293±5.5</td>
<td>10.9±1.1</td>
<td>26±2.5</td>
<td>87.2±1.8</td>
</tr>
<tr>
<td>AZ31-1wt.%GNPs</td>
<td>232±3.5</td>
<td>292±4.7</td>
<td>12.4±0.8</td>
<td>32±1.8</td>
<td>85.7±1.5</td>
</tr>
<tr>
<td>AZ31-1wt.%Hybrid</td>
<td>233±4.2</td>
<td>315±5.0</td>
<td>18.5±1.0</td>
<td>51±2.0</td>
<td>88.7±1.7</td>
</tr>
</tbody>
</table>
Enhanced Strength-Ductility of CNT/Al-Cu-Mg Composites through Bimodal Grain Structure Design

Zhenyu Liu, Bolv Xiao*, and Zongyi Ma

Shenyang National Laboratory for Materials Science, Institute of Metal Research, Chinese Academy of Sciences, 72 Wenhua Road, Shenyang 110016, China

*Email: Blxiao@imr.ac.cn

Abstract

Carbon nanotube (CNT) reinforced Al-Cu-Mg composites, with a bimodal grain structure consisting of CNT-free coarse grain (CG) bands and CNT-rich ultrafine grain zones, were fabricated by high energy ball milling combined with powder metallurgy. Experiment results indicated that a narrow CG band and medium CG content were beneficial to increasing the strength-ductility. In the optimized condition, the bimodal composite with 3 vol.% CNT exhibited an elongation of 4.5% and an ultimate tensile strength of 728 MPa, achieving much higher strength-ductility compared to previous reported uniform CNT/Al composites. The yield strength was in accordance with that predicted by the rule-of-mixtures. However, the ultimate tensile strength were much higher than that predicted by the rule-of-mixtures. The enhanced strength-ductility was attributed to the extra back stress strengthening and micro-crack blunting. Constructing a bimodal grain structure provides an effective strategy for preparing CNT/Al composites with high strength-ductility.

Keywords: Metal-matrix composites (MMCs), Carbon nanotubes, Mechanical properties, Powder processing

Fig. 1 (a) Engineering stress-strain curves of uniform and bimodal 3 vol.% CNT/2009Al composites and (b) strength-ductility of CNT/Al composites and alloys fabricated by HEBM.
Abstract

It is known that the thick oxide makes the wetting of solder weaken1-2, though tin is a well-known solder composition. We measured the mass gain of tin oxides formed on pure tin plated on gold/quartz. The measurement is carried out with the method of quartz crystal microbalance (QCM). Exposed indoor sample shows logarithmic law as shown in Fig.1. On the other hand, exposed 100% humidity sample shows that the mass changed little until hundreds-hour exposure and that the corrosion rate behaves logarithmic law after then. In many cases, corrosion of metals is controlled the diffusion of ions thorough oxidation films according to Wagner theory3 and the corrosion rate shows parabolic low. The behaviour of those results, however, shows the rate control stage is not diffusion of ions in this system. According to quantum mechanics, logarithmic behaviour is obtained when the electron tunnelling shown in Fig.2 controls the total oxidation rate3-5. Since water molecules absorption prevent the tunnelling, the mass gain of 100% humidity in early stage must be lower than that of indoor condition.

Keywords: Solder, QCM, Oxidation, Rate controlling stage
Low Volume Fraction In Situ \((\text{Al}_3\text{Zr} + \text{Al}_2\text{O}_3) / \text{6061Al}\) Hybrid Composites with Network Microstructure Fabricated by Reaction Hot Pressing of Al–ZrO\(_2\) System

Wang, G.S. *, Li, A.B., Geng, L., Fang, S.

School of Materials Science and Engineering, Harbin Institute of Technology, Harbin, China

*Email: wangguisong@hit.edu.cn

Abstract

In situ hybrid \((\text{Al}_3\text{Zr} + \text{Al}_2\text{O}_3) / \text{6061Al}\) composites with volume fraction of 1%, 3% and 5% and a network microstructure were fabricated by low energy ball milling and reaction hot pressing in an 6061Al–ZrO\(_2\) system. In order to obtain network microstructure, 6061Al powder with large size and fine ZrO\(_2\) powder were selected. \text{Al}_3\text{Zr} rods and fine \text{Al}_2\text{O}_3\) particles were in-situ synthesized by the reactions between Al and ZrO\(_2\) during hot pressing. \text{Al}_3\text{Zr} rods and fine \text{Al}_2\text{O}_3\) particles were distributed around the surface of 6061Al powder forming a network microstructure. The tensile strength of 5vol.% \((\text{Al}_3\text{Zr} + \text{Al}_2\text{O}_3) / \text{6061Al}\) composites with network microstructure increased by 45% compared with that of unreinforced 6061Al. The network microstructure of \text{Al}_3\text{Zr} rods and fine \text{Al}_2\text{O}_3\) particles like a “skeleton” bearing load, matrix grain refinement and hybrid reinforcements of \text{Al}_3\text{Zr} and \text{Al}_2\text{O}_3\). Furthermore, with increasing volume fraction from 1% to 3% and 5%, the tensile strength of composites increased from 147.2MPa to 154.7MPa and 170.6MPa, while the ductility decreased from 7.3% to 7.1% and 6.6% slightly.

**Keywords:** Al hybrid composites, Low volume fraction, Network microstructure

Fig. 1 The room tensile stress–strain curves of \((\text{Al}_2\text{O}_3 + \text{Al}_3\text{Zr}) / \text{6061 Al}\) hybrid composites with network microstructure.
Microstructure and Reaction Properties of Ni/Al Composite Prepared by Accumulative Roll Bonding  
Xinyi Luo*, Sha Liao, Jie Tao  
College of Materials Science and Technology, Nanjing University of Aeronautics and Astronautics, China  
*Email: xinyiluo@nuaa.edu.cn  

Abstract  
Ni/Al energetic material has attracted much attention due to its high reaction heat triggered by an external impulse. In this paper, a certain thickness of nickel coating was obtained on the pure aluminum foil by electroless plating process. Then Ni/Al multilayer composite was prepared by hot pressing and accumulative roll bonding (ARB). It was observed that the interlaminar thickness of the Ni/Al composite decreased and nickle layers gradually necked and fractured with the increase of rolling pass. After seven rolling passes, cracked nickel fragments were distributed homogeneously in the aluminum matrix. The fabricated Ni/Al composite had good thermal stability without the formation of intermetallic compound. During the subsequent DSC test, the exothermic reaction occurred and Al3Ni2, Al3Ni and AlNi compounds formed. Moreover, with the increase of the accumulative rolling pass, the initial reaction temperature of intermetallic compounds decreased and the heat released increased obviously. After seven rolling passes, the exothermic peak reached to 1203.4J/g which was about 87 % of the theoretical value. Furthermore, the Ni/Al composite had good mechanical properties.  

Keywords: Ni/Al energetic composite, Accumulative roll bonding, Microstructure, Reaction property, Mechanical property  

Fig. 1 XRD patterns of Ni/Al composites in different processes (a) after the seventh cycle of ARB; (b) after DSC test.
Length-Scale Flow Strength of Ti/Cu Nanolaminates

Haoruo Zhou\textsuperscript{1}, Li Chang\textsuperscript{1,*}, Kunkun Fu\textsuperscript{1}, Leigh Sheppard\textsuperscript{2}, and Laurel George\textsuperscript{2}

\textsuperscript{1}School of Aerospace, Mechanical and Mechatronic Engineering, the University of Sydney, Australia
\textsuperscript{2}School of Computing, Engineering and Mathematics, Western Sydney University, Australia

*Email: li.chang@sydney.edu.au

Abstract

Ti/Cu nanolaminates exhibit high optical reflectivity, which endows them with great potentials in soft X-ray mirrors. In this study, a direct current magnetron sputtering method was used to fabricate Ti/Cu metallic nanolaminates with various individual layer thicknesses and modulation ratios. Then, the nanoindentation tests were performed to examine the flow strength of the nanolaminates. Fig. 1 showed that the flow strength and individual layer thickness $h$ of the Ti/Cu nanolaminates with the same modulation ratio deviate from Hall-Petch relation when the $h$ is less than 100 nm, controlled by a confined layer slip mechanism\textsuperscript{1}. A peak strength was found in the Ti/Cu nanolaminate with $h=5$ nm, which was approximately 1.45 times higher than the strength of the nanolaminate with $h=250$ nm. In addition, it was found that the flow strength of the Ti/Cu nanolaminates was also depended on the modulation ratio, and the strengthening mechanism of the nanolaminates was discussed.

Keywords: Length-scale strength, Ti/Cu nanolaminates, Confined layer slip, Nanoindentation

\begin{figure}
\centering
\includegraphics[width=\textwidth]{flow_strength_graph.png}
\caption{Flow strength as a function of $h^{1/2}$.}
\end{figure}
Microstructure and Mechanical Properties of Abow and Nickel-Coated MWCNTs Reinforced 2024 Al Hybrid Composite Fabricated by Squeeze Casting

Mingfang Qian*, Xuexi Zhang*, and Lin Geng

School of Materials Science and Engineering, Harbin Institute of Technology, Harbin, China

*Email: mingfang.qian@hit.edu.cn, xxzhang@hit.edu.cn

Abstract

Multi-wall carbon nanotubes (MWCNTs) have been considered as an ideal reinforcement for composites. Here, in order to improve the wettability and interfacial bonding between MWCNTs and aluminum matrix, a uniform layer of nickel was introduced on the surface of the MWCNTs by electroless plating. Hybrid preforms comprised of aluminum borate whisker (ABOw) and MWCNTs with/without nickel coating were prepared. The morphologies of the preform fractures indicated that the nickel coatings improved the MWCNTs distribution and the homogeneity of the hybrid perform. The polished surface of as-fabricated composites were investigated and showed that the nickel coating reduced the porosity of the composites remarkably. Compared with ABOw / 2024Al and ABOw + MWCNTs / 2024Al composites, significant improvement in hardness, modulus and ultimate tensile strength were obtained in ABOw + MWCNTs(Ni) / 2024Al composites and the mechanisms were analyzed. The fracture surface observation revealed that ABOw break and pulled out was the main fracture mechanism of both composites. While the improved mechanical properties of the latter can be ascribed to stronger interfacial bonding between MWCNTs/Al matrix and crack deflection caused by MWCNTs.

Keywords: Hybrid composites, Carbon nanotube, Interfacial bonding, Mechanical properties, Failure mechanism

Fig. 1 SEM image showing the fracture of 20vol.% ABOw/2024Al (a) and 20vol.% ABOw + MWCNTs(Ni)/2024Al hybrid composites.
Electrochemistry Corrosion Resistance and Biocompatibility of Ti-35Nb-2.5Sn/10HA Composites in Simulated Body Fluid

Wang Xiaopeng*, Kong Fantao, Chen Yuyon

National Key Laboratory for Precision Hot Processing of Metals, Harbin Institute of Technology, China

*Email: wangxiaopeng@hit.edu.cn

Abstract

Ti-Nb-Sn-hydroxyapatite (HA) composites were prepared by mechanical alloying for different times (unmilled, 4 8 and 12 h), followed by pulse current activated sintering. The effects of the milling time on the electrochemical corrosion resistance and bioactivity of the sintered Ti-35Nb-2.5Sn-15HA composites were investigated. Potentiodynamic polarization test results indicated that the sintered Ti-35Nb-2.5Sn-15HA composites exhibited higher corrosion resistance with increasing milling time. The corrosion potential and current of the Ti-35Nb-2.5Sn-15HA composite sintered by 12 h milled powders were −0.261 V and 0.18 μA/cm², respectively. This sintered composite showed a stable and wide passivation region. The hemolysis rate of the sintered Ti-35Nb-2.5Sn-15HA composites reduced with increasing milling time and the lowest hemolytic rate of the composites was 0.87%. In addition, the in vitro cell culture results indicated that the composite sintered by 12 h milled powders had good biocompatibility. These results indicate the significant potential of Ti-35Nb-2.5Sn/xHA composites for biomedical implant applications.

Keywords: Corrosion resistance, Biocompatibility, Ti-Nb-Sn/HA composites, Sintering

Table 1 Corrosion parameter of Ti-35Nb-2.5Sn-15HA sintered composites in Hank’s solution (PH=7.3)

<table>
<thead>
<tr>
<th>Composites samples</th>
<th>Corrosion potential $E_{corr}$ (V vs. SCE)</th>
<th>Corrosion current densities $I_{corr}$ (μA/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNS/HA0</td>
<td>-0.642</td>
<td>6.34</td>
</tr>
<tr>
<td>TNS/HA4</td>
<td>-0.586</td>
<td>4.05</td>
</tr>
<tr>
<td>TNS/HA8</td>
<td>-0.498</td>
<td>1.42</td>
</tr>
<tr>
<td>TNS/HA12</td>
<td>-0.261</td>
<td>0.18</td>
</tr>
</tbody>
</table>
Super-Aligned Carbon Nanotubes in Metal Matrix via Mechanical Pulling Method

Jong Gil Park* and Young Hee Lee

Center for Integrated Nanostructure Physics (CINAP) Institute for Basic Science (IBS), Department of Energy Science (DOES) Sungkyunkwan University (SKKU), South Korea

*Email: parkjg84@skku.edu

Abstract

Although carbon nanotube (CNT) has superb mechanical properties and high aspect ratio, its application as a reinforcement to the metal matrix composites (MMCs) is limited owing to the difficult handling of CNTs in the matrix. Moreover, the direction of alignment of CNTs strongly influences the mechanical properties of MMCs. The conventional micro-scale deformation such as rolling and extrusion is not sufficient to align nanoscale CNTs. Herein, we provide a new approach of achieving uniaxially aligned CNTs in the matrix without any plastic deformation, which consists of five steps: 1) CNT alignment via mechanical pulling method, 2) transfer on the metal foil, 3) metal deposition via sputtering, 4) repeating the stacking, and 5) sintering. The vertical grown CNT forest was mechanically drawing as a sheet form, which led to the uniaxially aligned CNTs, as shown in Figure 1. Also, the oxygen-free metal deposition process enhances the inter-diffusion, which led to the strong interface bond. As a result, the tensile strength of MMC enhanced by 20% with the adding of 0.02wt% CNTs at iso-strain state (parallel between the alignment of CNTs and the loading direction), as shown in Figure 2, resulting in a high strengthening efficiency (~1,000).

Keywords: Metal matrix composite, Carbon nanotube composite, Super-aligned carbon nanotube, Strengthening efficiency

Fig. 1 Mechanical properties of raw Al and Al-CNT composite. Angular dependence of tensile strength; (a) absolute values, (b) relative improvement.
CM6 Potential of Nano Materials Applied into Ceramic Composites: Structural and Functional

Hui Mei*

Science and Technology on Thermostructural Composite Materials Laboratory, Northwestern Polytechnical University, Xi’an Shaanxi 710072, PR China

*Email: bfocker@126.com

Abstract

Silicon carbide ceramic matrix composites (SiC-CMCs) reinforced by carbon nanotubes (CNT), silicon carbide nanowires (SiCnw) and silicon carbide whisker (SiCw) were prepared by chemical vapor infiltration (CVI) or polymer impregnation pyrolysis (PIP). Microstructures, mechanical and functional properties of the prepared SiC-CMCs were investigated. CNT-C/SiC composites were prepared via chemical vapor infiltration combined with electrophoretic deposition (EPD) methodology which enables CNT-coating of reinforcing fibers at varying load fractions. It was found that as increase of CNT quantity during electrodeposition, tensile strength of CNT-C/SiC increased substantially by 10.7%, 39.3%, and 45.2% corresponding to the CNT deposition times of 5, 8, and 10 minutes, respectively. For the same EPD periods, work of fracture increased by 49.4%, 82.7%, 120.8%. The electromagnetic interference absorption shielding effectiveness of the CNT-C/SiC composites was found to increase significantly with EPD duration, and it reached a maximum of 38.2 dB at an EPD duration of 10 min, an increase of 56.5% over C/SiC composites. SiCN ceramic matrix composites impregnated with multi-walled carbon nanotubes buckpapers (BP) were prepared by PIP. With 3 times PIP cycles, composite density reached to 2.15 g/cm3, which indicated complete and successful impregnation. The obtained buckypaper/SiCN composites showed excellent electrical conductivity of 185 S/cm. CNT film (CNTf) prepared by floating catalyst method was used to prepare CNTf/SiC composite by CVI method. The CNTf/SiC composite possess wonderful mechanical and electrical properties. Test of mechanical properties shows that CNTf/SiC composite showed greatest tensile strength of 646 MPa with 2 CVI cycles, about 9 times higher than that of pure CNTf. Conductivity of CNTf/SiC composite with 1 CVI cycle was about 576 S/cm, which was much higher than that of pure SiC ceramic matrix. An ice-segregation-induced self-assembly technique was employed to prepare CNT aerogel with well-defined macroporous architectures which was subsequently infiltrated with SiC matrix by 5 CVI cycles, as shown in Fig 1. The density of as-fabricated CNT aerogel/SiC composites was about 2.57 g/cm3 and the specimens exhibited lamellar structure with parallel lamellae intersected at discrete angles. By observing, there are in fact five different representative anisotropic macrostructures of the composite. The compressive strengths of these five different loading modes with respect to lamella orientation were 933, 619, 200, 199, and 297 MPa, respectively, and the failure mechanisms were attributed to the anisotropic nature of the macrostructures. Porous SiCnw/SiC ceramic matrix composite with macroscopic unidirectionally aligned channels (as shown in Fig 2) was also prepared by ice-segregation-induced self-assembly combined with CVI method. After 3, 5, and 7 CVI cycles, the porosity of the composite were 32.23, 23.44, 9.23%, respectively, and the specimens exhibited typical brittle fracture behaviors with flexural strengths of 122, 180 and 270 MPa. Compressive test indicated anisotropy of the SiCnw/SiC composite with transverse compression strengths of 54, 65, 110 MPa, and much higher longitudinal compression strengths of 249, 401, 496 MPa for 3, 5 and 7 CVI cycles, respectively. SiC-CMCs reinforced by the aligned CNTs with good oxidation resistance were found to be denser and to dissipate energy in the form of CNT pull-outs opposed to their bulk CNT-reinforced counterparts. The strength of C/SiC reinforced with 5 wt% and 15 wt% SiCw brushed on the carbon fiber cloth increased by 98.5% and 64.3%, respectively. The major strengthening and toughening mechanism of nano- and micro- reinforcement ceramic composite materials are related to the reinforcement bridging and pull-outs.

Keywords: Ceramic matrix composites, CNT assemblies, Chemical vapor infiltration, Mechanical properties, Functional properties
Eutectic Ceramic Composites for Thermal Barrier Coatings
Wei Pan*
Tsinghua University, China
*Email: panw@mail.tsinghua.edu.cn

Abstract
Increasing thermal efficiency and lower emissions require gas turbine designers to further increase the combustion temperature that leads to the high temperature components such as combustion chambers, blade and vanes surfaces face more rigorous conditions. Therefore, there is urgent demand to develop new ceramic coatings with even lower thermal conductivity, higher stability and durability than currently used YSZ thermal barrier coatings coating on the surface of high temperature alloy components.

In this presentation, we introduce the promising candidate ceramic composite system with high eutectic temperature that shows low thermal conductivity, high strength and toughness that could be used in next generation gas turbine and jet engines. The eutectic ceramic composite also demonstrates high temperature stability with depressed the grain growth and sintering at operation conditions. The presentation will introduce the design and selection of high eutectic oxide ceramic system from phase diagrams, the preparation and property cartelization of the composites.

Keywords: ceramic composit, eutectic ceramics, Thermal Barrier Coatings, strength, toughness
Mechanical Properties, Thermal Shock and Ablation Behavior of a ZrC/Cr2AlC Composite

Shujun Hu, and Shibo Li*

Center of Materials Science and Engineering, School of Mechanical and Electronic Control Engineering, Beijing Jiaotong University, Beijing 100044, China

*Email: shbli1@bjtu.edu.cn

Abstract

Cr$_2$AlC is a potential candidate for high-temperature applications due to its combination of good oxidation resistance, nonsusceptibility to thermal shock, damage tolerance, high thermal conductivity and crack healing capability. For high-temperature applications, it is necessary to further improve the mechanical properties of Cr$_2$AlC so that it can withstand thermal and mechanical loadings.

In this work, a ZrC/Cr$_2$AlC composite has been prepared by hot pressing a mixture of ZrC and Cr$_2$AlC powders at 1300 ºC under 20 MPa for 1 h. The results showed that the ZrC particles homogeneously distributed in the Cr$_2$AlC matrix (see Fig 1). The mechanical properties of the ZrC/Cr$_2$AlC composite were improved as compared with monolithic Cr$_2$AlC. In addition, the abnormal thermal shock behavior was investigated using the water-quenching method, and the ultra-high temperature ablation behavior of the ZrC/Cr$_2$AlC composite was studied using the oxyacetylene torch ablation test. Microstructure and phase composition were characterized with scanning electron microscopy and X-ray diffractometry techniques.

Keywords: Ceramic matrix composite, ZrC/Cr$_2$AlC, Mechanical properties, Thermal shock behavior, Ablation behavior

![Fig. 1 Back-scattered SEM image of the ZrC/Cr2AlC composite. The grey particles with a layered structure are Cr2AlC, and the white particles are ZrC.](image-url)
Characterizations of Microstructures and Damages in C/SiC Composite by using Three-Dimensional Visualizations

Long Wang¹,*, Kai Yuan¹, Xingang Luan², Jianguo Wu¹, and Haibo Li¹,*

¹Science and Technology on Reliability and Environmental Engineering Laboratory, Beijing Institute of Structure and Environment Engineering, Beijing, China.
²Science and Technology on Thermostructural Composite Materials Laboratory, School of Materials Science and Engineering, Northwestern Polytechnical University, Xi’an, Shanxi, China.

*Email: wlzx10@163.com

Abstract

Thanks to its excellent mechanical/thermal/thermal-mechanical property, C/SiC composite is being widely used in the field of aerospace, astronautics, automotive, nuclear engineering, et al. Characterizations of its microstructures and damages are crucial for the improvement of fabrication process and life predictions. C/SiC composite has a complex structural architecture, thus it is necessary to understand the microstructures and damages through three-dimensional visualizations. X-ray Computed Tomography (CT), which is an attractive 3D tool to visualize the microstructures in the bulk of material non-destructively, has been used to characterize the microstructures and damages in C/SiC composite.

An undamaged specimen is used for the characterizations of microstructures (Fig. 1): The holes and pores form a highly interconnected plain networks inside SiC matrix between laminates and even connect through several laminates to form a 3D interconnected network architecture. The damaged specimens after thermal-mechanical tests are used for the characterizations of damages (Fig. 2): Fiber breaks and matrix breaks are both identified in the fractured area, while delaminations and matrix breaks are also observed in the bulk outside the fracture area.

The tensile tests with in-situ observations by using X-CT have already been performed to visualize the damage evolutions in the bulk of C/SiC composite. The results are being analyzed.

Keywords: C/SiC composite, X-ray Computed Tomography, Three-dimensional characterizations, damage, Microstructure

Fig. 1 damages in a damaged C/SiC specimen after thermal-mechanical fatigue test.
Creep Behavior of C/SiC Under High Temperature and Its Mechanism

Jianguo Wu¹*, Fei Su², Haibo Li¹, Long Wang¹, and Xue Feng¹,*

¹Science and Technology on Reliability and Environmental Engineering Laboratory, Beijing Institute of Structure and Environment Engineering, Beijing 100076, China
²School of Aeronautic Science and Engineering, Beihang University, Beijing 100191, China
*Email: bhubowywjg@163.com

Abstract

C/SiC composite is widely used in the field of space technology, automotive, power technology, chemical and nuclear engineering, for its excellent mechanical/thermal/thermal-mechanical property. When C/SiC composite work under high temperature, the creep behaviour is occurred. To evaluate the service life of C/SiC composite under harsh environment, we need to investigate its creep behavior and obtain its creep model, furthermore, if creep mechanism of this material is investigated, high reliability material design can be realized. Although some investigations have revealed some unknowns about the creep behavior of C/SiC composite¹–⁵, more efforts should be made to make this issue more clear. we will explore the creep model that can be used to predict the service life of C/SiC composite under harsh environment, and the influence of oxidation and oxidation protective layer on the creep behavior of C/SiC composite will be systematically and quantitatively evaluated. Based on the equivalent steady state strain rates from these tests, phenomenological creep models were developed. Moreover, the micro-mechanism of creep of C/SiC material were investigated. By correlating all these experimental findings, we conclude that the creep mechanism of C/SiC composite in hot oxidizing atmosphere is due to and controlled by the oxidation/ablation of carbon fibers.

Keywords: C/SiC composite, T300 carbon fiber, Creep, Oxidation

Fig. 1 Typical creep test results of the specimen without oxidation protective layer.
In-Plane Shear Behavior and Failure Mechanisms of 2D C/SiC Composite under Off-Axis Loading

Yi Zhang*, Litong Zhang, and Laifei Cheng

Science and Technology on Thermostructural Composite Materials Laboratory, Northwestern Polytechnical University, West Youyi Rd., No. 127, Xi’an, Shaanxi 710072, PR China

*Email: yit.zhang@outlook.com

Abstract

In this study, plain woven carbon fiber reinforced silicon carbide matrix composite (2D C/SiC) is prepared by chemical vapor infiltration (CVI) process, and its in-plane shear behavior is investigated under off-axis loading. The results show that the in-plane shear modulus and strength increase with the increase of the angle between the fiber orientation and the loading direction, while the shear strain is in inverse proportion to the angle. It may be ascribe to that the shear crack is always perpendicular to the fiber orientation, and fiber bridging mechanism controls the in-plane shear behavior no matter how the fiber orientation changes. Different from tensile matrix cracking, the matrix is under shear stress and failed via an inclined periodical cracking mode, just like the formation of “shear bands” in metals manufacturing processes. Same as tensile fiber bridging, the fibers are bended under shear stress so as to bridge the matrix cracks, instead of breaking up. From that view of point, a relationship could be built between tension and shear strength based on the fiber bridging mechanism.

Keywords: Ceramic matrix composites, Mechanical behavior, Failure mechanisms, Crack

Fig. 1 Crack deflection of 2D C/SiC composite under 45° shear loading.
Synthesis and Characterization of SiBNC Ceramic Fibers for Ceramic Matrix Composites
Chenyu Zhang¹, Chao Cheng², Yong Liu³*, and Muhuo Yu⁴*

Donghua University
*Email: liuyong@dhu.edu.cn; yumuhuo@dhu.edu.cn

Abstract
A new approach for the synthesis of polymer precursor for quaternary SiBNC fibers is presented. The inexpensive, commercially available reactants n-propylamine (C₃H₇NH₂), trichlorosilane (SiHCl₃) and boron trichloride (BCl₃) were used in a simple one-step reaction. The reaction mainly involved the co-polymerization between Si-Cl, B-Cl and N-CH₂CH₂CH₃ with C₃H₇NH₂ evaporation. Characterization of synthesized polymer was performed by FT-IR and NMR. The polymer has a relatively linear-chain chemical structure, and could be easily converted into flexible green fibers by melt-spun with diameter of 24µm. Pyrolysis of the green fibers to 800°C under nitrogen atmosphere resulted in ceramic fibers with a diameter of 19µm, a tensile strength of 1.05 GPa and it remained in the amorphous state up to 1600°C, which made them as the promising candidates for reinforcements in ceramic matrix composites for high-temperature application.

Keywords: Polymer precursor, SiBNC ceramic fibers, Co-polymerization, Pyrolysis

Fig. 1 TGA curves of polymer precursor to 900°C (10°C/min, nitrogen flow).
Silicon Carbide Fibre Reinforced Ceramic Matrix Composites Development

Seyoung Kim\(^1\), Ji-Yeon Park\(^2\), Sea-Hoon Lee\(^3\), Sang-Kuk Woo\(^1\), In-Sub Han\(^1\)

\(^1\)Korea Institute of Energy Research
\(^2\)Korea Atomic Energy Research Institute
\(^3\)Korea Institute of Materials Science

*Email: saykim@kier.re.kr

Abstract

Silicon carbide fibre reinforced silicon carbide composites material (SiC\textsubscript{f}/SiC) has been widely applied to gas turbine parts and aerospace since it has excellent heat resistance and mechanical strength. In this study, we applied CVI (chemical vapour infiltration), LMI (liquid melt infiltration), PIP (polymer infiltration and pyrolysis) and EPD (electrophoretic deposition) methods to fabricate SiC\textsubscript{f}/SiC and evaluate the properties of composite materials with improving their performance. In CVI process, performed a study for uniform infiltration inside and outside using a multi-nozzle and attained a proportional limit strength of 170 MPa. In the case of LMI, Cr alloy infiltration process was applied to improve the fracture toughness, and 1.7 times improvement was achieved. In addition, excellent fracture toughness results of 13.5 MPa\cdot m^{1/2} were obtained through precursor research for high purity PIP process and CVI-PIP hybrid process. Furthermore, the EBC (environmental barrier coating) for preventing the recession of the material that may occur in the steam atmosphere was also studied, and the stability was secured at 1200°C (\(\Delta 1000 ^\circ C\) in air) for 5,000 cycles of thermal fatigue. Through various test procedures developed for these materials, various physical property evaluations were performed. The obtained physical property results were categorized into data bases.

Keywords: SiC\textsubscript{f}/SiC, Ceramic matrix composites, SiC fibre, CMC

Fig. 1 SiC\textsubscript{f}/SiC composites (a) whisker CVI processed, (b) Cr alloy LMI processed, (c) EBC layer and liner parts.
Silicon Carbide Composites with Particle Dispersion in Matrix

Tatsuya Hinoki*

Kyoto University, Japan

*Email: hinoki@iae.kyoto-u.ac.jp

Abstract

Silicon carbide (SiC) is one of very attractive engineering ceramics in particular for severe environment. Silicon carbide composites basically require weak fiber/matrix interphase like carbon (C) or boron nitride (BN). The interphase material and its thickness are keys to determine mechanical properties. However precise control is the critical issue in terms of large scale production and material cost. The interphase is the weakest link for the environmental effects. The objective of this work is to develop SiC composites without fiber/matrix interphase by applying particle dispersion in SiC matrix for industrial use.

Silicon carbide composites reinforced with Hi-Nicalon type-S and Tyranno SA fibers were fabricated by liquid phase sintering (LPS) method. Silicon carbide matrix with BN was formed by mixture of SiC powder and BN powder. Mechanical properties were characterized by tensile test and fatigue test. Microstructures and fracture surfaces were characterized by FE-SEM.

The BN particle dispersion SiC composites have uniform microstructure through thickness. No significant degradation of tensile strength wasn’t observed following exposure up to 1500°C in air. Oxidation of the composites were limited to near surface in particular for the fiber bundle region up to 1500°C. The composites reinforced with satin weave fibers didn’t break following over 1 million cycles applying 140 MPa at 1150°C in air. The specimens had no oxidation resistant coating like CVD SiC.

Keywords: Silicon carbide composites, Oxidation resistance, Interphase, High temperature mechanical properties
Study and Improve the Behaviour of Cylinder-Shape Component based on A 2D-SiC-CMCS

Fufa Wu, Xiaofeng Wu*
Xiaochong Liu*, Laifei Cheng, Xiaoying Liu, Chidong Liu, and Xiaokun Sun
*Email: liuchong@nwpu.edu.cn

Abstract

Cylinder-shape parts, such as pins, bolts or bearings, are commonly used as connector for engineering structure of SiC-CMCs, whose performance play a key role in structural reliability and functional achievement for the whole component. This paper systematically investigates the shearing properties of the pins made of 2D-SiC-CMCs, and reveals the dispersibility of its shear properties, hence proposes approach to improving the performance of the cylinder-shape connector made of SiC-CMCs.

Keywords: Ceramic matrix composites, Cylinder-shape component, Shearing property

Fig. 1 The test method for 2D-pin specimens.
Mechanical Behaviors and Failure Mechanisms of 2D C/SiC Z-Pinned Joints Prepared by Chemical Vapor Infiltration

Xiaoying Liu*, Chidong Liu, Yi Zhang

Science and Technology on Thermostructural Composite Materials Laboratory, Northwestern Polytechnical University, West Youyi Rd., No. 127, Xi’an, Shaanxi 710072, PR China

*Email: 412203971@qq.com

Abstract

In this study, the 2D C/SiC z-pin joints with a single pin or multiple pins were prepared by the online z-pinning method via chemical vapor infiltration. The tensile behaviors and the failure mechanisms of the z-pin joints were investigated from the mesomechanics view, it is found that the 2D C/SiC z-pin is sheared off under the coupled shear and bending stress, and the interface sliding and fiber bridging mechanisms control the fracture process of z-pin. The shear strength of 2D C/SiC z-pin joint with a single pin equals the in-plane shear strength of 2D C/SiC composite plus the bending stress component of the fiber bridging stress. The load distributions of 2D C/SiC z-pin joint with multiple 2D C/SiC z-pins were studied via their load-displacement curves and corresponding strain-displacement curves. Results showed that: (a) The joints with multiple pins in longitudinal array and the joint with two pins in transverse array shows uniform load distribution ability due to the same shear strength as the joint with a single pin. (b) The joint with three pins in transverse array, the joint with three pins in triangle array and the joint with four pins in rectangle array show nonuniform load distribution among their z-pins due to their shear strengths are lower than the joint with a single pin.

Keywords: Z-pin joint, Mechanical behavior, Failure mechanisms, Ceramic matrix composite

Fig. 1 Calculated secondary bending effects of 2D C/SiC z-pin joint with a single pin of a total porosity 27.3% by finite element model.
Multi-Functional Properties of Ceramic Matrix Composites Containing Max Phases

Xiaomeng Fan*, Xiaowei Yin, Laifei Cheng, Litong Zhang

Science and Technology on Thermostructural Composite Materials Laboratory, Northwestern Polytechnical University, Xi’an, Shaanxi, 710072, PR China

*Email: fanxiaomeng@nwpu.edu.cn

Abstract
The integration of structural and functional properties are the future trends for the ceramic matrix composites (CMCs). In consideration of the unique properties of MAX phases, it will be an effective way to obtain multifunctional properties by combining CMCs and MAX phases. A new toughening mechanism, plastic deformation of MAX phases, is introduced into ceramic matrix composites besides the conventional toughening mechanisms, interphase debonding and fiber pullout, leading to the different damage mode for CMCs containing with MAX phases, so CMCs containing MAX phases have good strength and toughness.

Furthermore, besides good oxidation behavior and ablation resistance, the electromagnetic interference shielding effectiveness can be higher than 40 dB for CMCs containing MAX phases, revealing great potential as thermo-structural and functional materials. It will be an interesting and attractive research area to obtain multifunctional composites by combining the MAX phases with ceramic matrix composites.

Keywords: Ceramic matrix composites; MAX phases; Structural and functional properties; Multifunctional composites
Effects of Thermal Shock on the Mechanical Behavior of 2D C/SiC Channel Beam

Chidong Liu*, Laifei Cheng, Zonbei He, Yi Zhang

Science and Technology on Thermostructural Composite Materials Laboratory, Northwestern Polytechnical University, West Youyi Rd., No. 127, Xi’an, Shaanxi 710072, PR China
*Email: 14050401@qq.com

Abstract

The effects of thermal shock on the mechanical behavior of 2D C/SiC channel beam prepared by chemical vapor infiltration were investigated. Results showed: (1) In atmosphere, the thermal shock damages of 2D C/SiC channel beam included matrix thermal stress damages, fiber oxidation damages and matrix oxidation damages. At 700℃, the fiber oxidation damages were predominant, and the damage degree was increased with the thermal shock cycle increasing. At 1000℃, the thermal shock damages were related to the number of thermal shock cycles. (2) The thermal shock damage affected the bending response of 2D C/SiC channel beam. After thermal shocking at 700℃, the compressive nonlinearity emerged at the later stage of loading, and this nonlinearity was related to the thermal shock cycles. After thermal shocking at 1000℃, the tensile nonlinearity of 2D C/SiC channel beam which resulted from the matrix damages was obvious. (3) The bending failure modes of 2D C/SiC channel beam were affected by the damage modes resulted from thermal shock. Carbon fiber oxidation could lead to compressive failure of the channel beam, and matrix damages could lead to tensile failure of the channel beam.

Keywords: Thermal shock, 2D C/SiC, Channel beam, Mechanical behavior

Fig. 1 Distributions of temperature after heating 10min and the temperature rise curves (a) Distribution of temperature for 700℃; (b) Temperature rise curve for 700℃; (c) Distribution of temperature for 1000℃; (d) Temperature rise curve for 1000℃.
Flexible Fe/CNT-SiC Hybrid Nanofiber Mats with Effective EM Absorbing Performance

Yani Zhang*, Laifei Cheng, and Yi Hou

Northwestern Polytechnical University (NWPU), School of Materials Science, PO Box 547, No.127 Youyi Weston Road, Xi’an, China
*Email: zhangyani@nwpu.edu.cn

Abstract

Radar cross section (RCS) reduction is essential to design modern military platforms. Using electromagnetic (EM) wave absorbing materials is one of important means to achieve it. The materials are composites or hybrid made of EM lossy inclusions and of low loss binding media. To serve the high temperature and harsh environments which the platforms face, the ceramic based EM absorbing materials are desired. SiC is a low dielectric lossy material if without any doping or hybrid. As the lossy inclusions, flexible C-doped SiC and Fe/CNT-SiC hybrid nanofiber mats with tailored fiber morphology and distribution were successfully fabricated by co-electro spinning and high temperature pyrolysis afterwards, and their EM absorbing performance were also investigated. The C-doped SiC nanofiber mats exhibited fair EM absorption property in X band (8 ~ 12GHz). The addition of CNT effectively enhanced the electrical conductivity and permittivity of the SiC nanofiber. Furthermore, the EM absorption frequency and performance of the CNT-SiC nanofiber mat could be easily tuned by varying the concentration of CNT in SiC. By introducing Fe phase, both the permittivity and permeability values for the SiC nanofiber mat were increased. They showed great EM absorbing performance in the frequency range from S to C bands (2 ~ 8 GHz), and broadened the application frequency bands of the SiC ceramic nanofiber material. Therefore, by controlling the type and the concentration of functional composition phases in the C/Fe/CNT-SiC hybrid nanofiber mats, the performance and bandwidth of the absorbing materials can be effectively manipulated.

Keywords: Ceramic, Silicon carbide, Electromagnetic property, Nano-fiber
Abstract

Recently the oxygen transport membrane (OTM) using a ceramic composite membrane to obtain a high-purity oxygen with a low production cost have been widely studied. Because OTM membrane operates at a high temperature over 800°C and high pressure of 10 bars, the ceramic composite materials in membrane should have enough structural safety. However, the mechanical properties tests of ceramic composites have a limit of time and cost. Moreover, the material properties of porous ceramic composite material vary depending on the interior shape of the pores. Therefore it is necessary to predict the appropriate ceramic material properties in the preliminary design phase of OTM membrane and module design.

In this study, properties of LSCF/GDC composite material applied to OTM have been predicted by various structure analyses through CAE and compared with material test result. The internal structure modelling technique of the porous ceramic material was proposed to predict the material properties according to porosity and pore dispersion. A 3D finite element (FE) analysis model was constructed to reflect the pore shape factors such as pore size, porosity and dispersion based on the cross-sectional image of the actual porous layer. The mechanical properties of porous ceramic composites were stochastically predicted and compared with tensile test results, based on more than 50 randomly generated FE analysis models for the same pore shape factors.

Keywords: Oxygen transport membrane, Ceramic composite, Porous material, Structural analysis

Fig. 1 An array of wind turbines in rural countryside.
Ablation Mechanism of 3D-Needled C/SiC Composites in Combustion Chamber of Rocket Engine

Chao Chen¹,*, Jianzhang Li²,*, Xiaoying Liu¹, Bo Chen¹, Jiaming Wang², Laifei Cheng¹, and Litong Zhang¹

¹Science and Technology on Thermostructural Composite Materials Laboratory, Northwestern Polytechnical University
²Xi’an Golden Mountain Ceramic Composites Co., Ltd.
*Email: superchen@nwpu.edu.cn; lijianzhang@xaxinyao.com

Abstract

The test pieces made from 3D needled carbon fiber felts reinforced silicon carbide composites (3DN C/SiC) were prepared by chemical vapor infiltration processing (CVI) and then were evaluated for combustion chamber application in ground test bench of rocket engine. The cylindrical pieces kept the structural integrity after test. Their ablation characteristics behaved uniformly along circumferential directions and varied along axial direction from ablation severity to morphology. The front-end gas in-let part has obvious ablation degradation. However, the majority part, especially the rear part has near zero ablation and was covered by the melt. The composites’ damage originated from thermal chemical ablation of high-temperature rocket engine exhaust and thermal mechanical erosion of multiphase flow gas. The non-steady state and non-uniformity of the multiphase flow field made the partial material endure relatively severe ablation conditions and the introduced impurity elements aggravated such partial ablation of C/SiC.

Keywords: Ablation Mechanism, C/SiC, Composites, Combustion Chamber, Rocket Engine
3D Printing of Superelastic Conductive Matrix for Flexible Energy Storage Applications

Chuhong Zhang*, Wenbin Kang

State Key Laboratory of Polymer Materials Engineering, Polymer Research Institute, Sichuan University, Chengdu 610065, China
*Email: chuhong.zhang@scu.edu.cn

Abstract

Boasted as a prospective technique that facilitates the launch of the third industrial revolution that might potentially reform the current economical and sociological patterns, 3D printing hallmarked by additive manufacturing is currently under vigorous development. While some success has been witnessed for 3D printing of mechanical and structural materials, functional materials and devices especially for energy storage applications obtained from 3D printing are still at a most nascent stage. An innovative 3D printing by direct ink writing method is proposed wherein 3D printable inks constructed from conductive carbons and macro porous hydrogel scaffold with desired rheology properties suitable for consistent 3D printing is achieved. The conductive scaffold could be modulated into macro porous or cellular structures that, following covalent intermolecular functionalization to strengthen the integrity of the network, permit the realization of superelastic property. Finally, 3D supercapacitor printed in multiple layers with excellent gravimetric and aerial capacities could be realized. The excellent electrochemical property alongside the superelastic nature rendered possible by 3D printing provides an exciting solution that successfully addresses critical issues to the currently sluggishly progressing industry for 3D printing of functional materials and devices for energy storage applications.

Keywords: 3D printing, hydrogel, superelastic carbon, energy storage

Fig. 1 A SEM image of the conductive cellular matrix assembled by conductive carbons on a polymeric scaffold (left) and demonstration of its superelastic property (right.).
Influence of Structure on the Mechanical Properties of 3D Printed Nanocomposites

Lixin Wu¹, Zixiang Weng², and Jianlei Wang¹

¹Fujian Institute of Research on the Structure of Matter, Chinese Academy of Sciences, 155 West Yangqiao Rd, Fuzhou, China, 350002
²Western University 1151 Richmond Street London, Ontario, Canada, N6A 3K7

*Email: lxwu@fjirsm.ac.cn

Abstract

Organically modified nanofillers, including nano SiO₂, montmorillonite and attapulgite were incorporated with Acrylic resin and Acrylonitrile butadiene styrene (ABS) used for Stereolithography Apparatus (SLA) and Fused Deposition Modeling (FDM) 3D printing respectively. The 3D printed samples were evaluated by tensile, flexural, thermal expansion and dynamic mechanical tests. The morphology of nanocomposites were observed by TEM. It was found that addition of 5 wt% of nano SiO₂ increased the tensile strength and modulus of SAL 3D printed materials by 20.6% and 65.1% respectively. Addition of 5 wt% OMMT improved the tensile strength of FDM 3D printed ABS samples by 43% and significantly increased the tensile modulus, flexural strength, flexural modulus and dynamic mechanical storage modulus, and decreased the linear thermal expansion ratio and the weight loss of TGA. In addition, SilSesquioxanes (POSS) nanoparticles with varios sizes and crystal forms were incorporated into SLA resins. The significant improvement of mechanical properties of 3D printed objects were found. These nanocomposites with better mechanical properties are promising in 3D printing markets.

Keywords: 3D printing, Polymer nanocomposites, Mechanical property, Mophology, Structure and property

Fig. 1 SLA 3D printed objects with and without addition of nanoparticles
High Temperature Additive Manufacturing of Poly Aryl Ether Ketones (PaeK) Composites

Yuan Wang*

Sun Yat-Sen University, School of Materials Science and Engineering, Guangzhou, China

*Email: wangyuan5@mail.sysu.edu.cn

Abstract

Additive manufacturing has been making significant progress in the aerospace and automotive fields with new lightweight designs, cheaper costs and faster production time avoiding machining. Recently, the polymer powder bed fusion technology known also as laser sintering received a boost through the introduction of high temperature laser sintering (HT-LS) system, EOSINT P800 and high temperature powder materials PAEK. The PAEK polymer family has high temperature resistance, high strength, excellent mechanical resistance and high wear resistance. As with the majority of the additive manufacturing processes, one advantage offered by the HT-LS process is the design freedom, which allows fabrication of highly complex structures unachievable through any other subtractive manufacturing process.

This study presents recent developments in high temperature laser sintering of composites with focus on glass filled PEK (PEK/GB) and graphite platelet filled PEEK (PEEK/GP) materials. The hardness and thermal stability of the glass filled PEK structures has been improved without losing any of the tensile strength performance. The graphite filled PEEK powder shows an improvement in tensile strength and strain, graphite acting as reinforcement as well as a good energy absorbent agent which leads to enhanced sintering of parts without enhanced shrinkage or distortion of parts.

Keywords: Composite, Laser sintering, Glass beads, Graphite, PEEK
Dynamic Response of Additively-Manufactured Functionally Graded Ti-6Al-4V Lattice Structures

Lijun Xiao, Weidong Song*

State Key Laboratory of Explosion Science and Technology, Beijing Institute of Technology, China

*Email: swdgh@bit.edu.cn

Abstract

The rapid development of additive manufacturing method makes it more convenient to fabricate porous Ti-6Al-4V materials with high efficiency, which can be widely used in the field of aerospace and biological transplantation. In this study, Functionally graded Ti-6Al-4V lattice structures with step-wise gradient and continuous gradient were designed and fabricated by selective laser melting (SLM) method respectively. Compression experiments were conducted by electronic universal machine, Split Hopkinson Pressure Bar (SHPB) system and Direct Hopkinson Pressure Bar (DHPB) system to reveal the mechanical response of the material under different loading velocities. Digital imaging correlation (DIC) method was adopted to determine the deformation mechanism and stress wave propagation in the lattice structures, and the effect of different loading directions was taken into consideration. The results indicate that the functionally graded Ti-6Al-4V lattice structures exhibit different failure modes when subjected different loading velocities. The structures with continuous and negative gradient is found to exhibit better energy absorption abilities when loaded with high velocity. Besides, finite element (FE) analysis was conducted based on the 3D beam element to simulate the dynamic response of the graded lattice structures, which can be adopted to predict the failure mode and mechanical behaviour of the material.

Keywords: Functionally graded, Ti-6Al-4V lattice structure, Dynamic loading, Deformation mechanism

Fig. 1 Schematic of graded Ti-6Al-4V lattice structure: (a) with step-wise gradient; (b) with continuous gradient.
3D Printing Feed-Stock Filament Processing and Mechanical Properties of Milled Carbon Fiber Reinforced Poly(Lactic Acid) Composites

Kohji Suzuki¹*, and Yuan Wang²

¹Chiba Institute of Technology, Department of Mechanical Engineering
²Chiba Institute of Technology, Graduate School, Department of Mechanical Science and Engineering 2-17-1 Tsudanuma, Narashino-shi, Chiba 275-0016, Japan

*Email: kohji.suzuki@it-chiba.ac.jp

Abstract

Recently 3D printing of composites has been recognized as one of the promising composite manufacturing methods due to their extreme easiness and robust buildability of complicated three-dimensional forms and parts. In the present study, poly (lactic acid), PLA, thermoplastic composites which are reinforced with short or milled carbon fibers (milled-CF) of various volume fraction, were moulded by a single-screw melt mixing machine followed by filament extruding processes to make 1.75mm feedstock filaments for additive manufacturing or 3D printing purposes. From tensile test results of single monofilaments extruded from a FDM (fused deposition modelling) 3D printer with a nozzle of 1mm diameter, it was found that the milled carbon fibers were able to reinforce PLA matrix and tensile strengths (as shown in Fig.1) and modulus were respectively increased along with carbon fiber loadings. From the X-ray computed tomography (X-ray CT) and the scanning electron microscope (SEM) fractography (as shown in Fig.2) of the fractured surfaces in the present 3D printed thermoplastic composite monofilaments, voids and relatively poor interface imperfections between PLA matrix and reinforcing carbon fibers were observed, which implies that there may be a need for finding appropriate processing conditions of the present milled-CF/PLA thermoplastic composites to achieve their optimum mechanical performances.

Keywords: additive manufacturing, 3D printing, milled carbon fiber, poly(lactic acid), CFRT

Fig. 1 Tensile strengths of PLA and CF/PLA
Hemp Hurd/Polylactide Biocomposite for Fused Deposition Modelling: Printability and Morphology

Xianglian Xiao¹,², Venkata S. Chevali¹, Pingan Song¹, Dongning He¹ and Hao Wang¹,²*

¹University of Southern Queensland, Centre for Future Materials, Springfield, QLD 4300,Australia
²China-Australia Institute for Advanced Materials and Manufacturing, Jiaxing University, China.
*Email: Hao.Wang@usq.edu.au

Abstract

Printability and morphology analyses of hemp hurd/polylactic acid biocomposites for fused deposition modelling (FDM) are presented with respect to varying hemp hurd loading levels. 0-40 phr of hemp hurd were incorporated with polylactic acid with poly (butylene adipate-co-terephthalate), and ethylene glycidyl methacrylate used as toughening agents through melt-blending as filaments for FDM. Melt flow rate was determined to evaluate the processability of hemp hurd/polylactic acid biocomposites as FDM filament feedstock, along with mechanical and printability/morphology analyses. The melt flow rate of biocomposites decreased with increasing hemp hurd loading levels. The biocomposites were extruded to filaments, however with rougher filament surface, with increasing HH loading levels. The biocomposites exhibited decreases in toughness, including elongation-at-break and impact strength because of inadequate interfacial bonding between polylactic acid and hemp hurd as shown in Fig 1 (b). Overall, the hemp hurd/polylactic acid biocomposite filaments with up to 30 phr hemp hurd still possessed comparable toughness properties as polylactic acid. This research ultimately supports the application of hemp hurd biomass in 3D printing as cost-effective biocomposite filament feedstock.

Keywords: 3D printing, FDM, Biocomposite, Hemp hurd, Printability, Biomass

Fig. 1 FDM-printed product (a) toughness, and (b) electron microscopy image showing fibre pullout from polymer of biocomposite with 20 phr HH loading.
3D Printing Polyimides and Surface Functionalization
Xiaolong Wang1,2*

1State Key Laboratory of Solid Lubrication, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Lanzhou 730000, China. Email: wangxl@licp.cas.cn
2Yiwu R&D Center for Functional Materials, LICP, CAS, Yiwu, 322000, China.
*Email: wangxl@licp.cas.cn

Abstract

3D printing has attracted extensive attention from various fields due to its powerful capability of turning materials into devices in a completely different way with traditional ones. Nevertheless, compared to conventional materials, 3D printing materials are extremely short which is strongly restricting its practical applications. Developing novel 3D printing materials and new methods have thus become critical yet still remain challenges in additive manufacturing. To address, novel 3D printing polyimides and a new 3D printing surface functionalization approach have been developed. In the former, photo curing polyimide oligomers with good solubility in reactive diluents were prepared, which were then used to form solvent-free photocurable resins for DLP 3D printing (Fig 1). The 3D printing polyimides are believed to be promising in constructing parts and models with excellent mechanical and thermoresistant performance. The later approach is named initiator integrated 3D printing (i3DP). i3DP allows to prepare architectures with surface properties controllable by growing polymer brushes via surface-initiated polymerization. It is demonstrated that the method makes 3D printing technology more practical, especially where surface properties are critical, such as biomedical science, separation, and electronics.

Keywords: polyimide, surface modification, photo-curing 3D printing, direct ink writing

Fig. 1 3D printing of polyimides
i3DP, a versatile approach extending 3D printing to 4D printing

Jun Yang*

Western University (The University of Western Ontario), Canada

*Email: jyang@eng.uwo.ca

Abstract

3D printing has been leading to a new revolution in manufacturing and material engineering. The technology, with the capability of substantially changing the way in which materials are turned into devices, is becoming a powerful manufacturing technology for creating sophisticated and bespoke 3D objects. Several 3D printing techniques such as selective laser sintering, fused deposition modeling, polymer jet deposition, granular materials binding and stereolithography have been developed. However, these techniques are limited to few choices of materials. Therefore, printing structural materials along with a series of post-printing processes for material modification is a highly-desirable way for 3D printing. In this presentation, we will introduce a method, called i3DP (initiator integrated 3D printing), which is a robust yet simple approach enabling versatile material modification and functionalization, extending 3D printing to 4D printing.

Keywords: 3D printing, i3DP, functional materials
A Left-Handed Metacomposite Containing CNTS/Microwire Fibres

Y. Luo*, S.G. Wei, D. Estevez, F.X. Qin, and H.X. Peng

Institute for Composites Science Innovation (InCSI), College of Materials Science and Engineering, Zhejiang University, Hangzhou, 310027, China

*Email: yangluo@zju.edu.cn

Abstract

Metamaterials are featured with fascinating left-handed properties1,2 yet the intrinsic materials’ properties of building blocks are ignored. We have proposed a term of metacomposites whose eventual electromagnetic properties are manipulated by both dielectric/magnetic properties of building blocks and their topology. Preliminary work shows a typical left-handed EM response yet with rather limited tunable properties.3-5 The work takes a bold move to coat CNTs onto microwires and incorporate them into polymer matrix to realise a tunable metacomposite. The magnetoimpedance profiles of hybrid fibres reveal that applying a dc bias up to 25 mA is beneficial in enhancing the giant-magnetoimpedance ratios due to relaxed surface stresses between CNT/wire interfaces allowing for an increased volume of circular anisotropy (Fig. 1). The dielectric permittivity of wire-composites shows a non-plasmonic to plasmonic transition as the annealing current is increased. This is attributed to the discontinuous CNTs, which prevents microwires being as perfect electric conductors such that Pendry’s model does not apply.6 Nevertheless, increasing annealing temperature excites dipole-dipole polarisation among CNTs hence enhancing surface plasma. Subsequently, plasmonic behaviour appears as evidenced in Fig. 2. Above features provide insights to design and fabricate tunable left-handed composites that are of potential engineering interest for cloaking and sensing applications.

Keywords: Left-handed behaviour, Ferromagnetic microwires, Carbon nanotubes, Giant magnetoimpedance, Dielectric permittivity

Fig. 1 Frequencies and annealing current dependences of MI ratios of CNT-coated hybrid fibres.
Tribological Properties of 3D Printed Continuous Carbon Fiber Reinforced Polyamide Composites

Ziyan Man, Qinghao He, and Li Chang*

Centre for Advanced Materials Technology, School of Aerospace, Mechanical and Mechatronic Engineering, the University of Sydney, NSW 2006, Australia

*Email: li.chang@sydney.edu.au

Abstract

Three-dimensional (3D) printing has received increasing attention from both research and industrial communities. It is expected to revolutionize the manufacturing of components. Nevertheless, the mechanical properties of the printed products are normally poor, which is inherently limited by the properties of the used polymeric resins. Up to now, attempts have been made to develop high performance polymer composites by adding various fillers. In this work, a novel 3D printing technology was applied to manufacture continuous carbon fibre reinforced polyamide (PA) composites. The mechanical and tribological behaviour of the composites printed with different infill patterns were studied. The results showed that the mechanical properties of the composites can be effectively improved with the increase of fibre contents. In general, the wear resistance of PA can also be improved by carbon fibres, which was attributed to the mechanical enhancement and the lubricating function of fibres. However, there was no clear relationship between the tribological behaviour and fibre contents. Based on the observations of worn surfaces, it was found that the wear behaviour of the composites was greatly affected by the carbon fibre/matrix interfaces. In particular, when fibre contents are high, the wear resistance may be comprised by the relatively poor interfaces.

Keywords: 3D Printing, Continuous Carbon Fibres, Tribology

Fig. 1 SEM image of worn surfaces subjected to pin-on-disk test.
Characterisation and Improvement of 3D Printed Continuous Carbon Fibre Reinforced Composites

Qinghao He, Lin Ye*

School of Aerospace, Mechanical and Mechatronic Engineering, the University of Sydney, Australia

*Email: lin.ye@sydney.edu.au

Abstract

Pure polymer fabricated by fused filament fabrication (FFF) process can hardly be utilised in load-bearing applications due to its limited mechanical performance. Currently, continuous fibre reinforced thermoplastic composites (CFRTPCs) produced by FFF process have emerged as a promising solution due to its inherently excellent specific strength and stiffness. However, one major concern of 3D printed CFRTPCs is the week intralaminar or interlaminar bonding due to voids induced during a FFF process. This study hence begun with characterisation of materials quality by quantifying the void content in carbon fibre reinforced polyamide (CFRP) composites fabricated on a 3D printing platform (Mark Two, U.S.A), using Micro-CT and scanning electron microscopy. Apart from tensile and three-point bending tests, the study also evaluated the Mode I interlaminar fracture toughness (I) of CFRP composites manufactured by the FFF process. To investigate effects of voids on mechanical performance, characterisations were also conducted on the post-processed CFRP after further compression moulding.

Keywords: Fused filament fabrication, Continuous carbon fibre composites, Voids, Mechanical properties, Mode I fracture
Wave Propagation in Tunable Lightweight Tensegrity Metastructure

Yitian WANG, Rui ZHU*, Xiaoning LIU, and Gengkai HU

School Aerospace Engineering, Beijing Institute of Technology, Beijing 100081, China
*Email: ruizhu@bit.edu.cn

Abstract

In this presentation, lightweight metastructures are designed consisting of prismatic tensegrity building blocks which have excellent strength-to-weight ratio and also enable unique compression-torsion coupling. Theoretical models are first developed to study the band structures of different tensegrity metastructures. Broadband full-wave attenuation is found in the tensegrity metastructure with special opposite-chirality unit cells. Moreover, the unique coupled axial/torsional stiffness is investigated in the prismatic tensegrity structure and ‘small-on-large’ tunability is achieved in the tensegrity metastructure by harnessing the geometrically nonlinear deformation through an external control torque. Prestress adjustment in the cables for fine tuning of the band structure is also investigated. Finally, frequency response tests on the finite metastructures are performed to validate their wave attenuation ability as well as their wave propagation tunability. The proposed tensegrity metastructures could be very useful in various engineering applications where lightweight and tunable structures with broadband vibration suspension and wave attenuation ability are in high demand.

Keywords: Metastructure, Tensegrity, Compression-torsion coupling, Tunable
Elastic Waves: Negative Refraction by Cross-Section of A Laminate

Dengke Guo1, Ankit Srivastava2, and Gengkai Hu1,*

1 School of Aerospace Engineering, Beijing Institute of Technology, Beijing 100081, China
2 Department of Mechanical, Materials, and Aerospace Engineering, Illinois Institute of Technology, Chicago, IL 60616, USA

*Email: hugeng@bit.edu.cn

Abstract
Laminate materials are widely investigated considering optic1, ultrasonic2 transmission in laminated direction. However, relevant research in cross-section direction3 is rare, which is of crucial importance for wave transmit through periodic interface4,5. In this work, dispersion relation for in-plane wave in a laminate is obtained, which is capable for oblique incidence in both X1 and X2 directions. Orthogonality condition for in-plane wave is provided along interface between cross section of laminate and homogenous material for the first time. By considering the continuous condition, the refraction and reflection coefficient is calculated for oblique incidence. Negative refraction is observed at the laminate interface, which is a typical phenomenon in metamaterial with complicated micro-structures. Beyond the limit of 2-nd pass band, it can outperform higher dimensional crystals. Negative refraction can be realized in both low and high frequency domains with different mechanisms. Due to the universality of the mechanism, negative refraction may also emerge in surface waves by laminate material with similar arrangement.

Keywords: Laminate, In-Plane wave, Cross-section, Negative refraction

Fig. 1 The unit cell of two-phase laminate material.
Tunable Control of Guided Waves in a Soft Phononic Crystal with Line Defect

Yueting Wang¹,* , Yuxin Fu¹, Ronghao Bao², Weiqiu Chen², and Yuesheng Wang¹

¹Department of Mechanics, Beijing Jiao-tong University, Beijing 100044, China
²Department of Engineering Mechanics, Zhejiang University, Hangzhou 310027, China

*Email: 835384178@qq.com

Abstract

Highly tunable phononic crystals may be designed by harnessing multiple folding mechanisms in periodic elastomeric structures comprising a triangular array of circular holes1. Under the action of load, the structure buckles, and the change of configuration results in the change of energy bands, which affects the location and width of the band gap and the acoustic characteristics of the structure. However, the previous researches focused on the phononic crystals with perfect periodicity. The systems with defects have not been yet studied. In this paper, we consider a tunable line defect in a soft phononic crystal. The soft phononic crystal is made of rubber with periodic circular holes in a triangular lattice. Hard inclusions are inserted in every other holes. The line defect is generated by removing an array of hard inclusions. Pressure is applied to the sample and leading to buckling and thus tuning the configurations of both defect and unit cells outside the defect (see Fig.1).

Both numerical and experimental, results show that uniaxial loading and biaxial loading under different loading ratios will result in different buckling configurations, which will also affect the guided wave behaviours along the defect. In conclusion, the tunable waveguide is obtained by using the soft phononic crystal. There may be a variety of adjustment possibilities under different loading ratios.

Keywords: Soft material, Phononic crystal, Waveguide, Line Defect

Fig. 1 (a) A schematic diagram of a soft phononic crystals. (b) A schematic diagram of a soft phononic crystals with a line defect. (c) Change of configuration of the sample under uniaxial pressure.
Broadband Solid Cloak for Underwater Acoustics

Yi Chen*, Xiaoning Liu, and Gengkai Hu*

School of Aerospace Engineering, Beijing Institute of Technology, Beijing 100081, China

*Email: ChenYi221@gmail.com, hugeng@bit.edu.cn

Abstract

Inertial acoustic cloak requires metafluid with anisotropic density to deflect wave trajectory. However, conventional technique, like perforated plate, cannot offer sufficient anisotropy when implemented for water sound. To circumvent this difficulty, we report here the first acoustic cloak designed from pentamode material1-4. Pentamode materials are solids with vanishing shear modulus, and can mimic metafluid with extremely anisotropic modulus. Due to its broadband efficiency and solid feature, pentamode material is more promising for engineering applications.

Keywords: Pentamode Material, Acoustic Cloak, Experiment, Waveguide

Fig. 1 (a) Experiment setup; (b) Experiment test platform.
Layered Complementary Media for Impedance Match Design in Acoustic Meta-Materials

Han Zhang*, Jun Yang

*Email: zhanghan@mail.ioa.ac.cn

Abstract
Control of acoustic waves with acoustic meta-materials (AMMs) is of great topical interest and is fuelled by rapid progress in acoustic cloaking, nondestructive testing, medical imaging and therapy and so on. In these fields, AMMs with rather unusual values of densities and modulus have made progress in manipulating waves with unique transmission/reflection behavior. Nevertheless, acoustic impedance mismatch is extremely wave field and non-compensable energy loss. Therefore, it is necessary to give out a strategy of impedance match in the process of AMMs designs and applications.

In this paper, we propose a new recipe of AMMs with impedance match design using layered complementary media (LCM). The idea is based on combining the concept of complementary media (1) and transformation acoustics (2, 3). The properties of LCM depend on the properties of both the object to be hidden and its surrounding medium. So the LCM can restore the acoustic fields distorted by the object and can realize perfect acoustic impedances matched with the object and its surrounding medium.

Numerical example demonstrates that the LCM could hide the object in acoustic field, when placed adjacent to an object interface with strongly mismatched impedance of the surrounding medium. Compared with the transcranial ultrasonic imaging in Fig. 1 using phased arrays and phase-conjugate technique(5), our result in Fig. 2 of LCM approach significantly compensates for the larger energy loss due to avoiding the reflection caused by mismatched impedance and reconstruct images of small scatters in the surrounding medium behind the object with higher resolution.

Keywords: Acoustic complementary meta-materials, Coordinate transformation, Impedance match
3D Printing of Multifunctional Polymer Composites: an Application in Aerospace Engineering

Francesca Nanni1*, Marianna Rinaldi1, Lucia Pigliaru1 and Tommaso Ghidini2

1Dept of Enterprise Engineering, University of Rome “Tor Vergata”, via del Politecnico 1, Italy
2ESA/ESTEC European Space Agency European Space Agency NL-2200AG, The Netherlands

*Email: fnanni@ing.uniroma2.it

Abstract

Fused Deposition Modeling (FDM) is a polymeric additive layer manufacturing technology by which objects are created adding material layer after layer by starting from polymeric filaments, from three-dimensional digital CAD models [1,2]. The filament is melted through a nozzle and deposited in form of a thin layer onto a heated plate. It is a revolutionary technique as it allows for the production of complicated geometries, unthinkable when using traditional manufacturing process, making engineers and designers free to investigate new solutions. FDM of technoplyomers (i.e. polyetherimide PEI, and polyetheretherketone PEEK) is relatively complex and requires high (above 350-400°C) and carefully controlled temperature during the printing process. At present only few printers are available on the market. On the other hand, engineering polymers are most important for structural engineering applications, as they present good specific mechanical properties. Among engineering polymers, PEEK is an interesting semi-crystalline high performance thermoplastic polymer, with a molecular structure presenting aromatic groups and both ether and ketone group in the backbone, which give the polymer superior thermal (Tg between 143-148°C, Tm between 330°C-340°C and service temperatures up to 260°C), chemical (soluble only in sulphuric acid at 60°C) and mechanical (tensile strength ≈ 100 MPa, E ≈ 3.5GPa) properties [3]. PEEK is mostly used in biomedical applications (as bulk implant [4] orthopaedic implants, prosthesis systems, etc.) and it is very important in space applications due to the very low outgassing that makes it compliant with the ECSS requirements [5]. PEEK, however is not easy to be processed, particularly in ALM, due to its semicrystalline nature [6].

In this paper neat PEEK as well as PEEK composite filaments were prepared with the aim to obtain multifunctional materials, where the primary structural function is provided together with other properties as electrical conductivities (by adding carbon fillers) or magnetic properties (by adding metal fillers). Due to the interesting results obtained in FDM PEEK printing, a cubesat was printed, with the aim to present a possible application in aerospace engineering.

Keywords: 3d printing, multifunctional composites, aerospace applications
High Performance p-Type Half-Heusler Thermoelectric Materials
Tiejun Zhu*, Chenguang Fu, Dongsheng Li, and Xinbing Zhao

State Key Laboratory of Silicon Materials and School of Materials Science and Engineering, Zhejiang University, Hangzhou 310027, China
*Email: zhutj@zju.edu.cn

Abstract
Half-Heusler (HH) compounds are important high temperature thermoelectric (TE) materials having attracted considerable attention in the recent years. High figure of merit zT values of 0.8~1.0 have been obtained in n-type ZrNiSn based HH compounds. However, developing high performance p-type HH compounds with low cost is a big challenge. In this talk, we first show that a new p-type HH solid solutions with a high band degeneracy, Ti doped FeV0.6Nb0.4Sb, can achieve a high zT of 0.81. Further investigation shows that increasing Nb content in the Fe(V1-yNby)Sb solid solutions can achieve lower valence band effective mass and consequently higher carrier mobility. Moreover, the decrease in band effective mass can lead to the decrease in optimal carrier concentration, which is favorable for p-type Fe(V,Nb)1-xTixSb due to the limited solubility of Ti. In addition, FeNbSb has larger band gap Eg than that of FeVSb, and increasing Nb content in Fe(V1-yNby)1-xTixSb will prevent the degradation of the TE performance at high temperatures due to the bipolar conduction. Thus we obtain a high zT of 1.1 at 1100K for FeNb1-xTixSb without V substitution2. More recently, we found that Hf doped FeNbSb exhibits a record high zT of 1.5 at 1200K due to simultaneously optimized electrical power factors and reduced lattice thermal conductivity3. In view of abundantly available elements, good stability and high zT, FeNb1-xTixSb alloys can be great promising for high temperature power generation.

Keywords: Thermoelectric materials, Half-Heusler compounds, NbFeSb, Figure of merit
High Performance Oxide Thermoelectric Materials

Sean Li*

UNSW, Australia

*Email: sean.li@unsw.edu.au

Abstract

Efficient and ecological friendly high temperature conversion of thermal to electric energy needs not only materials with optimized energetic efficiency but also demands high chemical stability and lower toxicity. This leads to an importance of the development of oxide based thermoelectric materials. However, the current lack of a material with high thermoelectric conversion efficiency has impeded the exploitation of their applications, but our research finding in the development of oxide thermoelectric materials with specific sited defect engineering has demonstrated a well-founded hope that this problem can be solved. Here we present an experimental approach to realize the Einstein-mode rattling through the localized phononic structure engineering, thus significantly suppressing the thermal conductivity with an enhancement of the electrical conductivity in calcium cobaltate.

Keywords: Thermoelectric oxides, Phononic structure, Defect engineering
Abstract

The very basic Ag2Q (Q=S, Se, Te) compounds constitute an important class of versatile materials with applications in thermoelectrics, optics, spintronics, magnetotransport, and solid-state ionicics. Yet it is surprising that they are not fully understood partly because they present synthetic challenges in yielding high quality samples with repeatable properties. Simultaneous control of the stoichiometry, microstructure, and compositional homogeneity is a prerequisite for the fundamental and technological studies of Ag2Q, but is hard to attain by traditional methods (e.g., growth-from-the-melt, wet chemistry approaches) in view of the volatile nature of Q, and highly mobile Ag+ ions above the superionic phase transition at very low temperatures (e.g. 407 K for Ag2Se, 420 K for Ag2Te). In this work, we report a room-temperature self-sustaining synthesis method of Ag2Q that occurs at room temperature and requires no solvent. Technically, this method has minimum requirement of energy input, instrument and atmosphere control, yet creates rich microstructures, outstanding stoichiometry and compositional homogeneity. It is hard to find methods simpler than this. Scientifically the new procedure is based on the dissociative adsorption of Q by Ag and the reaction kinetics in line with Hard-Soft-Acid-Base (HSAB) scheme (rate order Ag2Te > Ag2Se > Ag2S). For Ag2Se compound, the low carrier concentration achieved ~1018 cm-3 and the optimized weighted majority-to-minority carrier mobility ratio observed in the samples as corroborated by the state-of-the-art thermoelectric performance of ZT ~1.2 at 390 K attest to the superiority of the synthesis route in yielding highly stoichiometric Ag2Se samples.

Keywords: Ag2Q (Q=S, Se, Te), dissociative adsorption reaction, HSAB scheme, thermoelectric performance
Preparation and Thermoelectric Properties of Ag2Te/PEDOT:PSS core/shell nanostructure composite Films

Haijun Song, Kefeng Cai*

Key Laboratory of Advanced Civil Engineering Materials (Tongji University), Ministry of Education; School of Materials Science & Engineering, Tongji University, China

*Email: kfcai@tongji.edu.cn

Abstract

First, Te/PEDOT:PSS core/shell nanowires were prepared, then Ag2Te/PEDOT:PSS core/shell structures were prepared by introducing Ag+ into the Te/PEDOT:PSS core/shell nanowires in different fabrication processes. One approach was to prepare Te/PEDOT:PSS core/shell nanowire films firstly, then the film was soaked into AgNO3 solutions with different concentrations to prepare Ag2Te/PEDOT:PSS core/shell nanostructures. Another approach was to add AgNO3 solution to the reaction solution for preparing Te/PEDOT:PSS core/shell nanowires. Ag2Te/PEDOT:PSS core/shell structures were successfully prepared by both the methods; however, the different reaction mechanisms resulted in the composites with a significant difference in the composition, morphology and the thermoelectric properties. The reaction mechanisms were studied. Also, the thermoelectric properties of the Ag2Te/PEDOT:PSS core/shell structure films as a function of AgNO3 concentration were measured. The composites showed n-type conduction. The composite synthesized via the later process showed a much higher power factor due to a more thoroughly reaction and the existence of elemental silver. H2SO4 treatment was used to further tune the thermoelectric properties of the composite films. Finally, the H2SO4 treated composite film showed a power factor of 40.3 μV/mK2, which is much higher than that of the most reported n-type organic thermoelectric materials. A power generator based on the film was designed.

Keywords: PEDOT, Ag2Te, composite film, thermoelectric
High-Performance Germanium Telluride Thermoelectric Materials
Min Hong, and Zhi-Gang Chen*
University of Southern Queensland, Australia
*Email: Zhigang.Chen@usq.edu.au

Abstract
Thermoelectric materials have attracted worldwide attention for applications in power generation, waste heat recovery, and refrigeration. Thermoelectric performance, quantified by figure-of-merit, is proportional to the power-factor and the reciprocal of thermal conductivity. Generally, multi sub-bands warrant a higher power-factor, and strong anharmonic phonon-phonon interactions ensure a low thermal conductivity. Herein, theoretical studies reveal that cubic GeTe has superior thermoelectric behaviour which is linked to (1) the two valence bands to enhance the electronic transport coefficients and (2) stronger enharmonic phonon-phonon interactions to ensure a lower intrinsic thermal conductivity. Experimentally, based on Ge1-xSbxTe with optimized carrier concentration, a record-high figure-of-merit of 2.3 is achieved via further doping with In, which induces the distortion of the density of states near the Fermi level (Fig 1). Moreover, Sb and In co-doping reduces the phase-transition temperature to extend the better thermoelectric behaviour of cubic GeTe to low temperature. Additionally, electronic microscopy characterization demonstrates grain boundaries, a high-density of stacking faults, and nanoscale precipitates, which together with the inevitable point defects result in a dramatically decreased thermal conductivity. The fundamental investigation and experimental demonstration provide important direction for the development of high-performance Pb-free thermoelectric materials.

Keywords: GeTe alloys, Thermoelectric, Phase transition, Density-functional-theory calculations, Phonon dynamics

Fig. 1 Crystal structure (a) and Fermi surface (b) of GeTe. (c) Comparison of temperature-dependent peak zT of Ge0.89Sb0.1In0.01Te in this study with the reported state-of-the-art thermoelectric materials.
Ultra-high figure-of-merit in carbon doped Cu2Se thermoelectric materials

Xiaolin Wang*

*Email: xiaolin@uow.edu.au

University of Wollongong, Australia

Keywords: Figure of merit, Thermoelectric materials, Carbon doping
Design and Preparation of High Energy Density Dielectric Capacitors: From bulk to thin film

Y.-H Lin*, H Pan, X Zhang
Tsinghua University, China
*Email: Linyh@tsinghua.edu.cn

Abstract
Developing high-performance film dielectrics for capacitive energy storage has been a great challenge for modern electrical devices. Exploring dielectric capacitors with high energy density, i.e., high dielectric permittivity, high breakdown electric field, and low dielectric loss, has recently aroused considerable interest. We designed a sandwich-structured PVDF-based composite film with both of BaTiO3-nf and TiO2-np as the nano fillers fabricated by a layer-by-layer casting process, and obtained a high energy density ~20 J cm\(^{-3}\) is achieved at 646 kV mm\(^{-1}\). Recently, we demonstrate that giant energy densities of ~ 70 J cm\(^{-3}\) is achieved at 646 kV mm\(^{-1}\). It is revealed that the SrTiO3 incorporation can transform the ferroelectric micro-domains of BiFeO3 into highly-dynamic polar nano-regions, resulting in a ferroelectric to relaxor-ferroelectric transition with concurrently improved energy density and efficiency. Such structure and domain engineering are effective in improving the breakdown strength and the electric displacement for developing dielectric film capacitors with high energy density.

Keywords: High energy density, Capacitor, Domain engineering, BaTiO3, BiFeO3-SrTiO3
Individual Adjustment of Electrical Conductivity and Thermopower Enabled by Multiple Interfaces in Polyaniline -based Ternary Hybrid Nanomaterials for High Thermoelectric Performances

Yao Wang, Chao Yu, and Yuan Deng*

School of Materials Science and Engineering, Beihang University, Beijing 100191, China

Abstract

Recent developed conducting polymer based hybrid thermoelectric (TE) materials provide a promising alternative route for energy conversion on a large scale. However, high thermopower largely relies on high content of low abundance elements, such as tellurium, which impedes the mass production of these materials. To optimize the compositions of the hybrids and further improve the TE properties, interfacial engineering is therefore employed to modulate the carrier transport properties in rationally designed multiwalled carbon nanotubes (MWCNTs)-Te nanorod/polyaniline (PANI) ternary hybrid nanomaterials considering the similar π-π conjugated interactions among these constituents. The effects of MWCNTs and Te nanorods, especially the multiple interfaces formed between the constituents, on the TE performances and carrier transport behavior are studied in depth. Due to simultaneous increase in both electrical conductivity and thermopower, an optimal power factor of 54.4 μW m−1K−2 is obtained in 52%Te-16% MWCNT/PANI film, which is almost twice the value of binary Te/PANI film at the same Te content and comparable to that of 60% Te/PANI film. Moreover, the ternary hybrid film shows good mechanical stability. This study demonstrates an effective strategy to improve TE performances of conducting polymer based hybrids and has great potential for cost-effective flexible energy conversion devices.

Keywords: Energy filtering, Hybrid nanomaterials, Interface, Polyaniline thermoelectric

Table 1 Comparison in transport parameters of 50% Te/PANI, 9% MWCNT-55% Te/PANI, and 16% MWCNT-52% Te/PANI hybrid films.

<table>
<thead>
<tr>
<th>Transport parameters</th>
<th>50% Te/PANI</th>
<th>9% MWCNT-55% Te/PANI</th>
<th>16% MWCNT-52% Te/PANI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical conductivity (S cm⁻¹)</td>
<td>88 ± 8</td>
<td>106 ± 6</td>
<td>137 ± 5</td>
</tr>
<tr>
<td>Thermopower (μV K⁻¹)</td>
<td>56 ± 2</td>
<td>55 ± 2</td>
<td>63 ± 2</td>
</tr>
<tr>
<td>Power Factor (μW m⁻¹ K⁻²)</td>
<td>27.9 ± 2.8</td>
<td>29.8 ± 1.6</td>
<td>54.4 ± 2.6</td>
</tr>
<tr>
<td>Carrier concentration (10²² cm⁻³)</td>
<td>1.06 ± 0.2</td>
<td>3.22 ± 0.4</td>
<td>3.31 ± 0.8</td>
</tr>
<tr>
<td>Carrier mobility (m² V⁻¹ s⁻¹)</td>
<td>5.03 ± 0.8</td>
<td>3.47 ± 0.3</td>
<td>3.85 ± 0.7</td>
</tr>
<tr>
<td>Effective mass (m* kg⁻¹)</td>
<td>0.61</td>
<td>1.28</td>
<td>1.47</td>
</tr>
<tr>
<td>Work function barrier (eV)</td>
<td>0.22</td>
<td>0.22/0.05</td>
<td>0.22/0.05</td>
</tr>
</tbody>
</table>
Physical Mechanism under the New Criterion for Self-Propagating High-Temperature Synthesis and Its Universality

Xiaoming Tan, Xianli Su, Wei Liu, Yonggao Yan, Xinfeng Tang

State Key Laboratory of Advanced Technology for Materials Synthesis and Processing, Wuhan University of Technology, Wuhan 430070, China.
*Email: tangxf@whut.edu.cn

Abstract

Self-propagating high temperature synthesis (SHS) is a technique for rapid preparation of compounds utilizing the heat released by the exothermic chemical reaction itself. Empirical criterion [1] states that the combustion wave of SHS could only sustain when the adiabatic temperature $T_{ad}$ is over 1800 K. Recently, our group [2] proposed a new criterion for sustainability of the combustion reaction, in which the adiabatic temperature must be higher than the melting point of the elemental component with the least melting point, i.e. $T_{ad}/T_m > 1$. In order to uncover the physical mechanism underling the new criterion and its universality, we carried out a survey research including 138 binary compounds with the experimental observation and theoretical calculations. Results indicate that, besides the requirement of the new criterion, the enthalpy of the reaction must be larger than the heat needed to raise the reactants to the melting point $T_m$, $L$. For vast majority of reactions, SHS can take place only when the melting process occurs during the reaction, which is consistent with the new criterion. On the other hand, SHS processes can be sustainable when preheating is adopted in certain less-exothermic systems, such as Sb$_2$Te$_3$ and Cu$_2$Te. This phenomenon further implies the correctness of the new criterion and its universality. Our work helps to broaden the application fields of SHS reaction and provides a highly efficient and economical preparation method for a large number of materials.

Keywords: SHS, Adiabatic temperature, New criterion, Melting point
Metal Oxides Nanostructures for Energy Applications
Ziqi Sun*

School of Chemistry, Physics and Mechanical Engineering, Queensland University of Technology, Brisbane, QLD 4000, Australia
*Email: ziqi.sun@qut.edu.au

Abstract
Metal oxides are known to possess unique functionalities that are absent or inferior in other solid materials. Their nanostructures have emerged as an important class of materials with a rich collection of properties and general potential for energy applications. In this presentation, we will show our recent results on the rational design of the diverse morphologies of the typical metal oxides, like TiO2, ZnO, WO3, etc, with 1D, 2D, and 3D architectures, based on the precise controlling of the starting solutions, to meet the materials requirements for high-performance energy harvesting, storage and conversion devices. These metal oxide nanostructured materials offer huge surface to volume ratios, favourable transport properties, altered physical properties, and confined quantum size effects, and thus boost the performance of energy devices.

Keywords: Metal oxide, nanostructures, energy devices, solar cells, batteries
Significant Enhancement of Thermoelectric Performance in Boron Doped Copper Selenide

Sheik Md. Kazi Nazrul Islam¹, Meng Li¹, Umut Aydemir³, Xun Shi⁴, Lidong Chen⁴, G Jeffrey Snyder⁵, and Xiaolin Wang¹,² *

¹Institute for Superconducting and Electronic Materials, Australian Institute for Innovative Materials, University of Wollongong North Wollongong, NSW 2500, Australia
²ARC Centre of Excellence in Future Low-Energy Electronics Technologies, University of Wollongong, Australia
³Department of Chemistry, Koc University, Sariyer, Istanbul, 34450, Turkey
⁴State Key Laboratory of High Performance Ceramics and Superfine Microstructures Shanghai Institute of Ceramics, Chinese Academy of Sciences, 1295 Dingxi Road, Shanghai, China, 200050
⁵Northwestern University, 2220 Campus Drive, Cook Hall, Evanston, IL 60208-3109, USA

*Email: xiaolin@uow.edu.au

Abstract

The superionic conductors in the chalcogenide-based family have been considered as promising class of thermoelectric materials, which offer great prospects for converting ubiquitous waste heat into highly demanded electrical energy. Further improvement of the thermoelectric figure-of-merit, \( zT \), for the Cu2Se is much desirable for its practical applications. In this work, we demonstrate that insulating-boron nano-particles inclusion in Cu2Se has little effect on overall power factor, but can significantly reduce the thermal conductivity, resulting in great improvement in \( zT \), by a factor of 1.6-2.6 compared to undoped samples. Microstructure studies by high resolution transmission electron microscopy revealed that boron nanostructures interspaced between Cu2Se microscale grains are responsible for the great reduction in thermal conductivity and, in turn, the significantly enhanced \( zT \). Synchrotron X-ray diffraction experiments show change for the lattice parameters due to nano-boron doping (Figure 1). The enhancement of thermal boundary resistance ascribed to the strong acoustic mismatch between Cu2Se and boron is responsible for the low thermal conductivity of the microstructured composite (Figure 2). Our findings offer an effective approach of using insulating nano-particles to significantly improve Seebeck coefficient and significantly reduce lattice thermal conductivity for achieving high \( zT \) in Cu2Se and many other similar thermoelectric composites.

Keywords: Thermoelectricity, Copper selenide, Doping
Session: Energy and thermoelectric materials
Comp-5-3-O2

Flexible Thermoelectric Materials: Progress and Challenge
Yuan Wang, and Zhi-Gang Chen*

*University of Southern Queensland, Australia

*Email: Zhigang.Chen@usq.edu.au

Abstract
Advancements in miniaturization and integration of electronics have stimulated the explosive developments of medical implantable and wearable devices, and their potential market values are estimated to reach 115.8 billion U.S. dollars in 2020 and 5.8 billion U.S. dollars in 2018, respectively. In spite of this, current power supply for most of these devices relies on batteries, which require frequent replacement and maintenance. In this situation, developments of maintenance-free and energy-autonomous power sources can be of vital significance for implantable and wearable devices applications. Flexible thermoelectric (F-TE) energy generator can achieve the direct conversion from heat to electricity through Seebeck effect, and act as a maintenance-free and energy-autonomous power source to various electronic devices. Compared with other power methods, F-TE can harvest human body heat as the energy source. The novel flexibility can not only effectively improve customer experience, but also maximally prevent heat losses during transfer by realizing the conformal contact with heat sources. Therefore, high-performance F-TE energy generator holds full potential to power implantable and wearable devices. Here, recent progresses in developments of F-TE materials are summarized and zT values of typical F-TE systems are revealed from Figure 1.

Keywords: Review, Flexible, Thermoelectric

Fig. 1 zT values of typical F-TE systems studied in recent years.
Piezoelectric Composites for Energy Harvesting
Hairong Chen¹, Hong Xia², and Qing-Qing Ni²*

¹ Interdisciplinary Graduate School of Science and Technology, Shinshu University, Japan
² Department of Mechanical Engineering & Robotics, Shinshu University, Japan
*Email: niqq@shinshu-u.ac.jp

Abstract
Piezoelectric materials have been already applied to energy harvesting because of the ability to transform mechanical energy into electric energy, so lead zirconate titanate (PZT) particles, a famous kind of piezoelectric materials, and shape memory polyurethane (SMPU) are employed to develop a kind of readily applicable piezoelectric composites. The resultant composites, PZT/SMPU films, with interdigitated electrodes are able to produce continuous sine wave voltages in response to applied sinusoidal vibrations. The produced voltages increase with the frequency of applied vibrations, and the peak-to-peak amplitude reaches to about 2.36 V at the frequency of 2000 Hz. PZT/SMPU films actually show a good potential for energy harvesting.

Keywords: Energy harvesting, Interdigital electrodes, Piezoelectricity, Composites

Fig. 1 Output voltages of PZT/SMPU composites in response to applied sinusoidal vibrations. (a) Peak-to-peak values of output voltages at the frequency from 10 to 2000Hz, (b) Sine wave output voltage at 100Hz, (c) Sine wave output voltage at 2000Hz.
Ultra-high Thermoelectric Performance in Graphene-Doped Cu$_2$Se: Role of Mismatching Phonon Modes

Meng Li$^1$, David L. Cortie$^1$, Jixing Liu$^{1,2,3}$, Dehong Yu$^4$, Sheik Md. Kazi Nazrul Islam$^1$, Lanling Zhao$^{1,5}$, David R G. Mitchell$^6$, Richard A. Mole$^4$, Michael B. Cortie$^7$, Shixue Dou$^1$, Xiaolin Wang$^1,*$

$^1$ Institute for Superconducting and Electronic Materials, Australian Institute for Innovative Materials, University of Wollongong, North Wollongong, NSW 2500, Australia
$^2$ School of Material Science and Engineering, Northeastern University, Shenyang, 110819, China
$^3$ Superconducting Materials Research Center, Northwest Institute for Nonferrous Metal Research, Xian, China
$^4$ Australian Nuclear Science and Technology Organization, Lucas Heights, Menai, NSW
$^5$ School of Physics, Shandong University, Jinan, Shandong 250100, P. R. China
$^6$ Electron Microscopy Centre, Australian Institute for Innovative Materials, University of Wollongong, Australia
$^7$ School of Mathematical and Physical Sciences, University of Technology Sydney, NSW 2007, Australia

*Email: xiaolin@uow.edu.au

Abstract

Thermoelectric nanocomposite consisting of Cu$_2$Se incorporated by graphene nano platelets is successfully synthesized and characterized. The carbon-reinforced Cu$_2$Se exhibits boosting thermoelectric figure-of-merit of $zT=2.44\pm0.25$ at 870 K. Microstructural study reveals dense, nanostructured grains of Cu$_2$Se with multilayer-graphene and graphite agglomerations located at grain boundaries. Synchrotron powder diffraction shows that the graphene-incorporated Cu$_2$Se matrix retains a cubic structure and the composite microstructure is chemically stable at elevating temperature. Based on the experimental structure, density functional theory was used to calculate the formation energy of carbon point defects and the associated phonon density of states. The isolated carbon dopant is shown to have high formation energy in Cu$_2$Se whereas graphene and graphite phases are enthalpically stable relative to the solid solution. Neutron spectroscopy proves that there is a frequency mismatch in the phonon density of states between the carbon honeycomb phases and cubic Cu$_2$Se. This provides a mechanism for the strong scattering of phonons at the composite interfaces, which significantly impede the conduction of heat and enhances thermoelectric performance.

Keywords: Thermoelectric, Cu$_2$Se/graphene nanocomposite, Interfacial thermal resistance, Density functional theory.
Effect of Nano-Al on Thermal Decomposition Characteristics and Sensitivities of 1,1-diamino-2,2-dinitroethene based plastic-bonded explosive

Jialin Cai*

Institute of Chemical Materials, China Academy of Engineering Physics, China

*Email: jialin.cai@163.com

Abstract

To study the effect of nano-Al on thermal decomposition characteristics and sensitivities of 1,1-diamino-2,2-dinitroethene (FOX-7) based plastic-bonded explosive (PBX), Two kinds of FOX-7 based PBX were prepared containing micro-Al and nano-Al respectively. Kinetic parameters of decomposition for two kinds of FOX-7 based PBX were analyzed by a TG-DSC simultaneous thermal analyzer, and their impact sensitivity and friction sensitivity were tested according to GJB772A—1997. Results show that the thermal decomposition initial temperature is 226 ℃ and activation energy is 412.5 kJ•mol⁻¹ for the PBX containing micro-Al, and the thermal decomposition initial temperature is 222 ℃ and activation energy is 327.4 kJ•mol⁻¹ for the PBX containing nano-Al. Impact sensitivity H50 of PBX containing nano-Al is 75.7 cm, decreasing by 36.8 cm comparing with the PBX containing micro-Al. Friction sensitivity of PBX containing nano-Al has an increase of 8 % compared to PBX containing micro-Al.

Keywords: Nano-Al, FOX-7 based Plastic bond explosive, Thermal decomposition characteristics, Sensitivities
Session: Energy and thermoelectric materials
Comp-5-4-O1

Framework Derived Hierarchical Co-Cu-S Nanosheet as an Advanced Electrode for Supercapacitors
Ahmed Bahaa1, Jayaraman Balamurugan1, Yazan Al Haj1, Nam Hoon Kim1*, Joong Hee Lee1,2*

1Advanced Materials Institute of BIN Convergence (BK plus Global) & Department of BIN Convergence Technology, Chonbuk National University
2Center for Carbon Composite Materials, Department of Polymer & Nano Science and Technology, Chonbuk National University, Jeonju, Jeonbuk, 54896, Republic of Korea
*Email: jhl@chonbuk.ac.kr, nhk@chonbuk.ac.kr

Abstract
Metal-organic frameworks (MOFs) are emerging as a promising candidate for the development of numerous nanoarchitecture with extraordinary surface area, which can enhance the electrochemical performance of the energy related devices. 1 Herein, novel cobalt copper sulfide nanosheet (Co-Cu-S NS) with high specific surface area and unique porous architecture have successfully synthesized using MOFs. When evaluated as an electrode material for SCs, the MOF derived Co-Cu-S NS arrays exhibit a remarkable electrochemical performance with an excellent rate capability and ultra-long cycling stability. It delivers an ultra-high areal capacity of 0.97 mA h cm-2 (specific capacity of 358.1 mA h g-1) at a current density of 1 mA cm-2, with an exceptional rate capability (≈245.7 mA h g-1 at a current density of 10 mA cm-2) and outstanding cycling stability (≈91.8 % of capacity retention after 10000 cycles). Such excellent electrochemical performance is due to their high catalytic activity, rich active sites, high surface area and long void space. This general strategy provides an alternative to design the other MOF derived ternary metal sulfides, making it scalable, free-standing, binder-free, and cost-effective electrodes for large-scale applications in modern electronics.

Keywords: Metal-organic frameworks, Ternary metal sulfide, Nanosheets, Hierarchical, Supercapacitors.
Session: Energy and thermoelectric materials
Comp-5-4-O2

Decoupling Electrical and Thermal Transport to Enhance the Thermoelectric Performance of Polycrystalline SnSe via Doping carbon
Guangsai Yang, Xiaolin Wang*, Meng Li, Sheik Nazrul Islam
University of Wollongong, Australia
*Email: xiaolin@uow.edu.au

Abstract
Thermoelectric (TE) materials are of current interest and great importance due to their ability to provide green and reliable energy by direct conversion of heat into electricity. The record-breaking figure of merit SnSe single crystal have stimulated related research on its polycrystalline. Boosting the thermoelectric conversion efficiency requires to improve thermal power factor and lower thermal conductivity. However, it is still a big challenge to optimize the above parameters independently due to their complex interrelationships. Herein we proposed an innovative approach to decoupling of electrical transport from thermal transport by incorporating conductive nanocarbon within SnSe polycrystalline. It is found that carbon doped sample exhibits enhanced electrical conductivity compared with undoped SnSe polycrystalline and an ultralow thermal conductivity of $\approx 0.14$ W m$^{-1}$ K$^{-1}$ at 800K, leading a record high ZT=1.3. The results indicate the dispersion of conductive nanocarbon can be a good way to decouple the electrical transport from thermal transport. Additionally, SnSe samples incorporated with nanocarbon feature good thermostability and superior mechanical properties, which are favorable for device fabrication applications.

Keywords: SnSe, Thermoelectric materials, Electrical conductivity, Seebeck, Thermal conductivity
Thermal Properties of Polymers Filled by Graphene Oxide Beads Absorbed with Phase Change Materials

Jinliang Zhao, and Jinglei Yang*

Department of Mechanical and Aerospace Engineering, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong 999077, China

*Email: maeyang@ust.hk

Abstract

Graphene oxide beads (GOB) are novel carbon-based macrostructures with graphene oxide (GO) foam inside and GO membrane outside. GOBs can be used as carriers to absorb phase change material (PCM) and contain the solid-liquid transition inside without adding high weight or volume, which provides a better solution to the technology challenge of PCMs being incompatible with the matrix or being unstable at a high temperature. In this study, GOBs and reduced GOBs (rGOBs) which were annealed at 1100°C under nitrogen atmosphere for 1 hour were submerged into liquid-state PCM for absorption. Scanning electron microscopic images of GOB and rGOB before/after absorption of PCM are shown in Fig 1. An IR radiation model was built up to investigate the thermal properties of the samples. PCM-contained rGOBs were added into a film made of polydimethylsiloxane (PDMS), with a mass ratio of PDMS : PCM : rGOB = 27g : 3g : 0.05g. The temperature distributions of the radiation model for PDMS/PCM/rGOB sample and pure PDMS reference sample are as shown in Fig 2. This report reveals the roles that GOB plays as both carrier and thermal management filler, as well as the remarkable performance it offers.

Keywords: Graphene oxide bead, Phase change material, Thermal management, Energy economics

Fig. 1 SEM images of GOB (a) before and (b) after absorption of octadecane and rGOB (c) before and (d) after absorption of octadecane.
A Modified Sulfur Cathode from Recycling Fly Ash Towards Advanced Li-S Batteries

Gang Wu*, Zhao-Yan Zhu, and Yu-Zhong Wang*

College of Chemistry, National Engineering Laboratory of Eco-Friendly Polymeric Materials (Sichuan), Sichuan University, China

*Email: gangwu@scu.edu.cn; yzwang@scu.edu.cn

Abstract

Generally, in order to overcome the major drawbacks of lithium-sulfur batteries, e.g. inherently low electronic conductivity of sulfur, dissolution of polysulfides in electrolyte, and volume expansion of sulfur during discharge, great efforts had been made to develop the advanced Li-S batteries with outstanding performances. However, most of the preparation technologies often involve tedious, complicated, and expensive procedures, which are not facile for the practically commercial application. In addition, the fly ash as a main solid waste contains various oxides, such as SiO2, Al2O3, Fe2O3, etc., which are from coal-fired power plants. It is harmful for human beings and other organisms when the fly ash is discarded into environment at random. Thus, to explore the recycling of fly ash is of great significance. It has been found that most of metal oxide can effectively inhibit the shuttle effect of polysulfides. Herein, we present a modified sulfur cathode based on the fly ash by a facile, simple, and low-cost method. The results show that, for the fly ash-modified sulfur cathode, the shuttle effect of polysulfides can be restrained, and the performances of the Li-S battery, especially cycling stability, are improved remarkably as showed in Fig 1.

Keywords: Fly ash, Lithium-sulfur battery, Rate performance, Cycling stability

Fig. 1 Cycling performance and coulombic efficiency of Li-S battery at 0.2C.
Improved Compatibility between Squaraines and Pc71bm by Dicyanomethylation on Squaraines

Jianglin Wu¹, Zhiyun Lu¹,*, and Yuan Yuan²

¹College of Chemistry, Sichuan University, Chengdu 610064, P. R. China
²College of Management, Southwest University for Nationalities, Chengdu 610041, P. R. China

*Email: luzhiyun@scu.edu.cn

Abstract

By dicyanomethylation on the central squaric acceptor core, three unsymmetrical squaraines (USQ), namely diCN-USQ-1~3, were synthesized, and in-depth comparative studies between them and their reference compounds (USQ-1~3) were carried out. The results indicate that the presence of dicyanomethylene groups on the central squaric ring will lead to distinctly altered properties on the entire π-conjugated system of the fluorophore, and the better compatibility between USQ and [6,6]-phenyl-C71butyric acid methyl ester (PC71BM). Consequently, solution-processed bulk-heterojunction small molecule organic solar cells (BHJ-SMOSCs) using these diCN-USQs as electron donor materials could show simultaneously much enhanced open-circuit voltage and significantly increased short-circuit current density, hence drastically higher power conversion efficiencies (PCEs) than their corresponding USQ-based reference devices (PCE: 1.46%, 1.91%, and 4.58% for diCN-USQ-1~3, and 0.45%, 0.77%, and 3.05% for USQ-1~3 in sequence). Note that the diCN-USQ-3-based device shows a PCE of 4.58%, which is the highest value among all the reported organic solar cells based on centrally substituted squaraines.

Keywords: Solar cells, Organic photovoltaic, Squaraine, Compatibility, Morphology

Fig. 1 The TEM images of the USQ:PC71BM (1:3) active layers.
Effect of Process Variability on the Permeability of Automated Dry Fibre Placed (ADFP) Preforms

R. Umer1, *, X. Zeng1, M.A. Ali2, P. Schubel1

1Centre for Future Materials (CFM), University of Southern Queensland, Toowoomba, Australia
2Department of Aerospace Engineering, Khalifa University of Science and Technology (KUST), Abu Dhabi, UAE

*Email: rehan.umer@usq.edu.au

Abstract

This work presents the findings of a research study based on process variability of automated dry fiber placed (ADFP) preforms and their effect on resin flow properties. In this study, a numerical analysis of a dry tape preform model, with the focus on the in-plane and through-thickness permeability has been undertaken. Geometrical models, containing flow channels of the dry tape carbon preform with two different widths have been created using the TexGen modeller. Computational fluid dynamics (CFD) simulations have also been undertaken, to obtain the predicted principal permeability values of the dry tape preform. An in-situ compaction study carried out in an XCT machine revealed that the gap sizes are irregular throughout the preforms. In addition, an experimental investigation of the in-plane and through-thickness permeability, which is based on a transient and saturated flow condition respectively at a thickness representing full vacuum pressure, is presented. Finally, the CFD predictions for the permeability of the XCT re-generated model preforms are compared with the experimental data.

Keywords: Automated fibre placement, Permeability, Preforms, Modelling

Fig. 1 (a) Solid model of a dry fiber preform, (b) The representation of the boundary conditions, (c) 3D slice of the X-ray scanned preform RVE, (d) Micro XCT of the RVE, showing gaps.
Non-Destructive Analysis of CFRP Laminates Manufactured Using Automated Fibre Placement

Ebrahim Oromiehie¹, *, Ji-Youn Arns²,³, Ulf Garbe⁴, Christoph Arns¹, *, B. Gangadhara Prusty¹, *

¹School of Mechanical and Manufacturing Engineering, UNSW Sydney, NSW 2052, Australia
²School of Petroleum Engineering, UNSW Sydney, NSW 2052, Australia
³Research School of Physics and Engineering, ANU, Canberra, ACT 2601, Australia
⁴Australian Nuclear Science and Technology Organization (ANSTO), NSW 2234, Australia
*Email: e.oromiehie@unsw.edu.au, c.arns@unsw.edu.au, g.prusty@unsw.edu.au

Abstract

Laminated composites are being extensively used in aerospace and automotive industries. Due to the high demand, there is a growing trend towards high volume, high rate and error-free manufacturing. Automated fibre placement-based manufacturing can meet the current demand elegantly.

The AFP technology merges several manufacturing stages like cutting, curing and consolidation. Therefore, manufacturing of composites using AFP is a complex, high-dimensional nonlinear multivariable process that involves large number of variables and parameters. Since AFP manufactured laminates are prone to internal flaws, due to the improper selection of process parameters, detecting these defects becomes an imperative to ensure the quality of final product.

The quality and integrity of the structure is critically dependent on the choice of these parameters. Thus, AFP manufactured laminates are prone to internal flaws due to the improper selection of process parameters. Identifying them at earlier stages is critical to ensure the quality of final product.

In order to inspect these possible flaws, 3D X-ray computerized tomographic (CT) and neutron imaging techniques were performed to achieve a multi-scale quality assessment of CFRP laminates made using AFP. This study assesses the capabilities and limitations of these techniques for characterization of internal flaws, including delamination, micro-cracking and porosity in AFP manufactured laminates made under different processing conditions.

Keywords: Automated fibre placement, CFRP laminates, 3D X-ray CT tomography, Neutron imaging, Porosity

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Fabrication of Complex 3D Composites by Fusing Automated Fibre Placement (AFP) and Additive Manufacturing (AM) Technologies

Felix Raspall*, Rajkumar Velu*, and Nahaad Vaheed*

Digital Manufacturing and Design Centre, Singapore University of Technology and Design, Singapore.

*Email: felix_raspall@sutd.edu.sg, rajkumarvelu@sutd.edu.sg, nahaad@sutd.edu.sg

Abstract

Automated fibre placement (AFP) is emerging as one of the advanced methods towards fabrication of polymer matrix based composite structures. This automated technique focuses on polymer composite manufacturing for use in a wide range of applications, predominantly in the automotive and aerospace industries1. The AFP process offers an elevated level of customization through the possibility of placing each individual ply at custom-designed trajectories. Additive manufacturing (AM) method, on the other hand, has the potential to fabricate functional end user parts of complex geometries, thus eliminating the need for costly tooling, multi-step processing and the use of fasteners or joints2. This paper will highlight the potential of fusing AFP and AM processes, converging the fabrication of complex 3D polymer based composite parts. A combination of these two processes (AFP and AM) suggests a promising option for composite materials development, improving composite structures in terms of complexity and customizability. However, the adaptation and integration of AM to the AFP requirements is challenging and requires a thorough research and development process (initial printing and reinforcing sequence is explained in Figure 1). The paper will present the adopted research methodology, background research, the design, development and setup of an experimental workcell that fuses AM and AFP (see Figure 2) and the design methodology which is required to design complex composite parts using the proposed manufacturing process. Main challenges and opportunities will be discussed such as how restrictions of conventional composite production can be eased, and additional freedoms of design can be achieved.

Keywords: Automated fibre placement, Additive manufacturing, Polymer composites, Design methodology
Effects of Processing Parameter of Unidirectional CFRTP Rod using Compression and Pultrusion Method

Daiki Tanabe*, Kazuki Kurima and Kazuaki Nishiyabu

National Institute of Technology, Wakayama College, Japan.

*Email: tanabe@wakayama-nct.ac.jp
Abstract

Precise fabrication of microholes in advanced manufacturing field has a broad range of applications, from aeroengine turbines to automotive fuel filters. However, conventional micro-hole manufacturing techniques are usually time/labour consuming, non-controllable, and most significantly, not compatible with plastic materials. Due to their attractive properties, plastic materials incorporated with accurate micro-holes have garnered increasing attentions in many areas, such as flexible electronics and biomedical devices. Considering these appealing applications, there is growing demands for the development of feasible manufacturing techniques producing precise micro-holes in plastic materials.

Since the mid-1970s, pulsed solid-state lasers have proven to be an efficient tool for reliably preparing micro-hole structures. Inspired by this discovery, we here report a brand-new type of 3-dimensional (3D) femtosecond laser manufacturing process that enables precise fabrication of micro-hole structures in plastic materials operating in air (Fig 1). To accurately prepare these micro-holes in plastics, laser parameters (pulse energy, scanning speed), material aspects (substrate thickness, substrate type), and micro-hole features (hole size, geometric shape) governing the ablation processes, were systematically investigated. In sum, our 3D laser ablation technique developed provides a significant insight into fields of precise micro-manufacturing using plastic materials, and offers the possibility of creating tailored plastic microhole structures for customized applications.

Keywords: Plastic Materials, Micro-Manufacturing, 3D Ablation, Maskless, Femtosecond Laser
Intelligent Manufacturing of Composites - A New Sensor for High-Volume Manufacturing

A. Chaloupka¹, M. Zier¹,* , S. Knappe¹,* , A. Gillen²,* , and T. Denner¹,*

¹NETZSCH-Geaetebau GmbH, Germany
²NETZSCH Australia Pty Ltd, Australia

*Email: macro.zier@netzsch.com, stephan.knappe@netzsch.com, andrew.gillen@netzsch.com, thomas.denner@netzsch.com

Abstract

Current curing processes in composite production are set to predefined cycle times and cannot be adapted without considerable effort. Material, temperature and humidity fluctuations cannot be compensated and there is a risk of waste production. A newly developed sensor provides the possibility to characterize the material behavior in the invisible and critical curing process in the tool, to communicate with the superordinated machine control and thus to implement dynamic manufacturing processes. This brings robust processes, cost savings and higher productivity.

Composites have already proven their potential as the main material in the mobility of the future. Nevertheless, their use in high-volume applications fails due to the high cost of the raw material and the leak in the robustness of the manufacturing processes. In particular, the uncertainty of the invisible but critical curing processes in tools is in the foreground. A new sensor system for material characterization in the mold and thus process control will change the composite production of the future and thus make a major contribution on the way to large-scale production. This makes processes dynamic and robust, saves process time and increases productivity.

The new sensor is the first of its kind that is able to deal with carbon fibers without the necessity to shield the sensor against the fibers, as it has to be done with commonly used dielectric systems or related measuring techniques. The proof of concept has already been done by the German funded and AVK awarded project “OPTO-Light” with the partners BMW, KraussMaffei, the AZL Aachen and others. Through communication with the process control system, the new sensor technology controlled the process in such a way that an optimal adhesion of dissimilar materials in a cascaded process could be achieved.

Keywords: Cure monitoring, Composites, High-volume, Manufacturing, Process control
Real-Time Prediction of Composite Property Development during Variable Cure Conditions

Nigel A. St John and Gary I. Mathys

*Maritime Division, Defence Science and Technology Group 506 Lorimer St, Fishermans Bend VIC 3165, Australia

*Email: nigel.stjohn@dst.defence.gov.au

Abstract

Unidirectional glass fibre prepreg tape is used for producing the pretensioned armature bands used on large direct current (DC) motors. Achieving full cure is important to enable the bands to function reliably under the operating conditions. Challenges arise when these armature bands need to be replaced on a motor. Due to the thermal mass of the windings of a large DC motor and a need to preserve the winding insulation, the cure of new armature bands is conducted over several days, taking a day just to reach the target cure temperature. It is thus important to be able to predict the changes in degree of cure with time and temperature as the planned temperature profiles may not be achieved or be interrupted such that a decision needs to be made when to end the cure operation. To this end, an approach has been developed to allow real-time calculation of the degree of cure of a commercial banding tape based on incremental time steps covering varying temperatures during the cure process (Fig 1). The relationships between the degree of cure and the glass transition temperature (Fig 2) and the tensile failure strength have also been derived.

Keywords: Cure, Glass transition, Tensile strength

Fig. 1 Measured percent degree of cure of banding tape for different cure temperatures and times plotted on master curve using 90 percent cure representing 100 percent process time and derived curve from empirical model.
Characteristics of Thermoplastic CFRP Auto Tape Laying Using Near Infrared Heating
Naoki NAKATA¹, Daiki TANABE², *, and Kazuaki NISHIYABU¹

¹ Kindai University, 3-4-1 Kowakae, Higashiosaka, Osaka 577-8502, Japan
² National Institute of Technology, Wakayama College, Wakayama, Japan
*Email: tanabe@wakayama-nct.ac.jp

Abstract
Auto Tape Laying (ATL) in which carbon fiber reinforced thermoplastic (CFRTP) prepreg tape is heated to the vicinity of the melting point and lamination molding is performed in an arbitrary direction have attracted attention in aircraft and automobile applications. The near infrared heater has a high start-up speed and a short wavelength, so it has a high absorptivity to the carbon fiber, and it is suitable for heating the CFRTP. However, there are few research and development examples of ATL for CFRTP using near infrared heating. This study aims to develop the auto tape layup device for unidirectional carbon fiber reinforced polyamide 6 prepreg tape using near infrared heating. The effects of the tension of prepreg tape and the number of lamination on the molded article thickness of CFRTP were investigated.

Keywords: Thermoplastic composites, Auto tape laying, Near infrared heating, Pulsed flash lamp, CF/PA6

Fig. 1 Temperature distribution images of CF/PA6 prepreg tape in ATL process.
Manufacturing of Structural SMC Composite
Mohammad Rouhi\textsuperscript{1, *}, Krister Svensson\textsuperscript{2}
\textsuperscript{1}Swerea SICOMP, P.O. Box 104, 431 22 Mölndal, Sweden
\textsuperscript{2}Swerea IVF, Vällaregatan 30, 293 38 Olofström
*Email: mohammad.rouhi@swerea.se

Abstract
Compression moulding is a popular manufacturing technique for composite parts. In particular, the development of high-strength sheet moulding compounds is driving the adoption of compression moulding processes in automotive applications. SMC manufacturing benefits range from very high volume production ability, good part reproducibility, cost effectiveness and lower industrial scrap. Other advantages such as weight reduction, due to lower dimensional requirements and also because of the ability to consolidate many parts into one, are of importance. One can achieve higher fibre content and longer fibres with SMC compare to other similar processes. Therefore, mouldings made from SMC have higher mechanical properties.

In this work, the study of different type of SMC materials for compression moulding technique was suggested. Few choices of commercial materials were selected and manufacturing of a demonstration case study was exercised and the manufactured samples were tested for three-point-bending, CT-Scan and Warpage measurement by project partners. Fig 1 below shows the sample manufactured geometry and the warpage measurement.

Keywords: SMC Composites, Manufacturing, Testing

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{(a) The demonstrator, (b) a manufactured sample.}
\end{figure}
Cost Analysis of the Manufacturing Processes of Composite Railway Sleepers

Joshua Peauril*, Allan Manalo, and Peter Schubel

University of Southern Queensland, Australia

*Email: joshua.peauril@usq.edu.au

Abstract

Technical Cost Analysis was conducted for the manufacture of commercially available composite railway sleepers with the aim to find the most economical method depending on unknown future production rates. Three sleeper designs of similar structural performance were compared along with their corresponding manufacturing methods, including those based on geopolymer concrete filled pultruded sections, glue laminated sandwich panels and fibre reinforced urethane foam. This multi-variable problem was modelled by combining parametric and process flow simulations.

Keywords: Cost analysis, Manufacturing, Composite, Sleeper
Abstract
The goal of the present work was to create a better understanding of the possibility of forming specific geometric structures from plywood. The current work describes the formability of a 3-ply laminate, prepared from the commercially available radiata pine (Pinus radiata D. Don) veneer, under a 4-point bending rig. Previous studies on single-curvature vee-bending had exposed the possibility of the initial spring-forward, experienced during forming, to have significant interaction effects for multiple bends in the same plane. These aspects were studied, for a pre-softened plywood, to observe the effects and interactions due to varying span lengths. Real-time strain measurements, using strain gauges, were carried out to ensure that the deformation lengths essentially depend only on the geometric parameters and are independent of the material’s mechanical properties. Finally, kinematic analysis of the macroscopic deformation of the plywood was carried out through a grid strain analysis. Furthermore, a geometric conformance study was also carried out to ensure the desired profile is achieved, for quality assessment and error calculation.

Keywords: 3-ply laminate, Forming of plywood, 4-point bending, Grid strain analysis
Fabrication of Super-Strong Carbon Nanotube Bundles with Tensile Strength over 80 GPA

Yunxiang Bai and Fei Wei*

Beijing Key Laboratory of Green Chemical Reaction Engineering and Technology, Tsinghua University, Beijing, 100084, China

*Email: wf-dce@mail.tsinghua.edu.cn

Abstract

Carbon nanotubes (CNTs) are the most promising materials to help us realize the space elevator dream. When CNTs assemble into fibers, however, the strength of fibers are usually impaired by defects, impurities, random orientations and discontinuous lengths of CNTs. Fabricating CNT fibers with strength reaching that of single CNTs has been a challenge for decades. Herein, centimeters long CNT bundles (CNTBs) with defect-free, neat, uniform oriented and continuous structure were in-situ synthesized. It was revealed that the tensile strength of CNTBs was controlled by the Daniels effect due to the nonuniformity of the initial strains in the components. A synchronous tightening and relaxing (STR) strategy is proposed to release the nonuniform initial strains of the CNTB components. Consequently, the tensile strength of the bundles can be improved to over 80 GPa, which is far higher than that of any other strong fibers ever fabricated. According to our study, the strength of CNTBs consisting of a large number of components with parallel alignment, defect-free structures, continuous lengths and uniform initial strains won’t change much with the number of components increasing. Our results provide a new approach for fabricating ultrahigh-strength CNT-based materials.

Keywords: Carbon nanotube bundles, Super-strong fibres, Daniels effect, Initial stress
Session: Advanced Manufacturing
Manuf-2-3-O2

CFRTP Molding by Using Direct Resistance Heating to Carbon Nanotube Grafted Carbon Fibers
Kazuto Tanaka*, Ririko Habe, Masayoshi Tanaka, and Tsutao Katayama
Dept. of Biomed. Eng., Doshisha Univ., Japan
*Email: ktanaka@mail.doshisha.ac.jp

Abstract
In order to apply Carbon Fiber Reinforced Thermoplastics (CFRTP) to mass-produced automobile parts, it is necessary to develop the impregnation method for the thermoplastic resin, which has relatively high viscosity, into the carbon fiber bundles (CF). Although the conventional hot press molding heated materials using the heat transfer from the mold, novel molding method using the heat generation of CF itself is expected to be developed for CFRTP molding. We have developed resistance welding methods, in which CNT grafted carbon fibers (CNT-CF) are used for the heating elements and revealed that the higher welded strength is obtained by using CNT-CF instead of CF1. The direct resistance heating method to CNT-CF can be applied to the CFRTP molding. In this study, in order to develop the CFRTP molding method by using direct resistance heating to CNT-CF in the hot press molding. CFRTP ([0°]10s) with the volume fractions (Vf) of 40% is molded by conventional hot press and hot press with direct resistance heating to reinforcing fibers as shown in Fig.1. CF or CNT-CF is used for reinforcement. As shown in Fig.2, CFRTP molded with the direct resistance heating to CNT-CF (CNT-CFRTPDRH-HP) indicated lower void content than CFRTP molded with the direct resistance heating to CF (CF-CFRTPDRH-HP). CNT-CFRTPDRH-HP had lower void content than CFRTP molded by only the hot press using CNT-CF (CNT-CFRTPHP). It is possible to mold CFRTP with low void content by using direct resistance heating to CNT-CF for hot press molding.

Keywords: CFRTP, Direct Resistance heating, CNT grafted carbon fibers, Impregnation, Void content

Fig. 1 Schematic drawing of CFRTP molding by using direct resistance heating.
The Design and Development of A Novel In Situ Manufacturing Method for Producing Fibre-Reinforced Polymer Confined Concrete Columns

Peter Turner*, Michael Heitzmann

UQ Composites, Australia

*Email: peter.turner@uqconnect.edu.au

Abstract

Fibre-Reinforced Polymer (FRP) confined concrete columns are increasingly being used in the initial design stage of construction projects due to their improved structural performance, and their improved resistance to corrosion when compared to conventional concrete columns. There are currently two main methods of manufacturing FRP confined columns:

i) Pouring of concrete into pre-fabricated FRP tubulars, or

ii) Wet-layup of FRP sheets onto pre-existing concrete columns.

Both of these methods are very limited when it comes to the efficient manufacture of complex shapes such as curved structures or structures with varying diameters. The aim of the overarching research project is to develop an alternative manufacturing method that addresses these limitations. This method produces both the exterior FRP confinement jacket, and the interior concrete column on site and in their final position.

The process starts with the extrusion of a rapid cure cement to form a hollow structure. This structure is then used as a stay-in-place mandrel for the in situ filament winding of the external FRP confinement jacket, and as a stay-in-place formwork for the pouring of the concrete, producing the final FRP confined concrete column.

This paper will present the current state of progress for this project. This will include the conceptual design of the manufacturing system, initial research on suitable material choices, and current progress on the in situ manufacture of both the FRP and cement materials.

Keywords: In situ, Automation, Filament winding, Rapid cure
A Study on the Processability of Megastructured Shipbuilding Composite Structures using Resin Infusion Process

Jong-Rok Ha¹, Sung-Won Yoon¹, Sung-Hoon Kim¹, Jae-Hyung Cho¹, and Dong-Gi Seong²*  

¹Department of Ocean ICT & Advanced Materials Technology Research Division, Research Institute of Medium & Small Shipbuilding, Busan, South Korea.  
²Department of Polymer Science and Engineering, Pusan National University, Korea.  
*Email: dgseong@pusan.ac.kr

Abstract

It is difficult to apply polymer composite materials for the shipbuilding products due to their large sizes. Resin infusion process is often applied for the effective production of the large sized products in shipbuilding industry. It has various process parameters to be controlled for successful fabrication of the large sized composite structures, which are also used to simulate the resin infusion process. In this study, the essential process parameters such as viscosity of resin and permeability coefficient of fiber preform to simulate the liquid molding process for a 39 ft grade power boat hull. Dynamic and isothermal scanning tests of resin viscosity were conducted to investigate the temperature and time dependence of resin in the processing conditions. The pot life of 60 min was predicted by the result of viscosity. Permeability coefficient was measured by the radial flow method, by which two principal permeabilities, K1, K2, were determined. The process simulation of 39ft grade power boat was conducted as shown in the Fig. 1 by the commercial software, RTMWORKS from Polyworks by using the measured process parameters. The predicted filling time was 45 min and the result will be compared with the experimental ones for the huge composite structure.

Keywords: Resin infusion process, Composites process simulation, Boat hull

Fig. 1 Simulation of resin infusion process for the 39 ft grade power boat hull.
Session: Composite Machining and Joining  
Manuf-3-2-O1

Improvement in Bearing Performance of Composite Bolted Joint Using Defense Hole System: Experimental Investigation  
Alzakri Ekhwan¹, A R Othman², and Khudhayer J. Jadee³

¹Custadian Engineer Static Unfired, Engineering Department, Group Technical Solution T&E Division, PETRONAS, Kuala Lumpur, Malaysia  
²Mechanical Engineering Department, Universiti Teknologi PETRONAS, Perak, Malaysia  
³Technical Engineering College-Baghdad, Middle Technical University, Baghdad, Iraq  
*Email: rahim.othman@utp.edu.my

Abstract

Stress concentration around the bolt-hole region is critical in the design of part assembly, as it affects the failure load, thus bearing strength of the composite bolted joint. A defense hole technique (DHS) has been introduced to alleviate the maximum stress at the bolt-hole, in an effort to improve the bearing strength of the bolted joint. However, the questions remain indecisive, particularly on how much the technique could improve the failure loads and bearing strength. Therefore, this study presents an experimental analysis on the effect of DHS on the bearing strength of the single-bolt, double-lap reinforced composite bolted joint under tensile loading. A series of bearing tests were conducted on 5.2 mm-thick plain weave glass fibre composite, at different configurations of width-to-bolt diameter (W/D) and edge-to-bolt diameter (E/D). Two DHS parameters; hole diameter (DHD) and bolt-hole distance (DS), were also included for DHD=0.625D and 0.75D, and DS=1.5D, 2D and 2.5D, respectively. Experimental results tabulated in Table 1, indicates that the maximum load increment was achieved for DHD=0.625D at DS=2.5D, with the increment varied from 15% (for W/D=5, E/D=4) to 34.81% (for W/D=3, E/D=5. In addition, the maximum bearing strength increment for the respective W/D and E/D configurations varied between 19% and 46% as shown in Fig 2. As the edge distance increased, the use of DHS at a larger distance from the main hole provided the most effective in the load increment and bearing strength.

Keywords: Glass fiber composites, Composite joining, Bolted joint, Defence hole system

Fig. 1 Single-bolted composite laminates with defence hole system.
Effect of CNT Deposition Time to the Surface of Carbon Fibers on Flexural Strength of Resistance Welded CFRTP Using CNT Grafted Carbon Fiber as Heating Element

Kazuto Tanaka, Takanobu Nishikawa, Kazuhiro Aoto, and Tsutao Katayama

*Email: bmo0078@mail4.doshisha.ac.jp

Department of Biomedical Engineering, Doshisha University, Kyoto Prefecture, Japan

Abstract

In recent years, Carbon Fiber Reinforced Thermoplastics (CFRTP) is expected to be used as lightweight structural materials for mass-produced vehicles. CFRTP with thermoplastics as matrix allows us to weld them using melting of matrix by heating. We have been developing a direct resistance heating method, which uses carbon fibers as the resistance heating elements. Further improvement of welding strength is needed to reduce the welding area where materials overlap. Carbon nanotube (CNT) is expected to be used as additive to FRP, and we reported that the fiber/matrix interfacial shear strength was improved by grafting CNT on the surface of carbon fibers and tensile lap-shear strength was improved by using CNT grafted carbon fiber as heating elements for welding (Fig 1). For the practical use of CFRTP for structural parts, flexural strength is also necessary to be evaluated. In this study, flexural test was carried out to clarify the effect of CNT deposition time to the surface of carbon fibers on flexural strength of resistance welded CFRTP using CNT grafted carbon fiber as heating element. As shown in Fig 2, the highest flexural strength was obtained when CNT10, for which CNT is grafted on the carbon fibers for deposition time of 10 min, was used for heating element of resistance welding. In the case of CNT deposition time of 60 min, the lowest flexural strength was obtained because of the poor impregnation of the resin into the carbon fiber due to the excess CNT on the carbon fibers.

Keywords: CFRTP, Resistance welding, Carbon nanotube (CNT), CNT grafted carbon fiber, Flexural test
A Study on Machining Performance of Al-Si-Tib2 In-Situ Metal Matrix Composites

Jimmy Karloopia*, Shaik Mozammil, and Pradeep Kumar Jha*

Department of Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee, Roorkee, India

*Email: jimmykarloopia@gmail.com, and pkjhafme@iitr.ac.in

Abstract

In this study, an attempt has been made to investigate the machining performances of the Al-12%Si matrix alloy which was subsequently reinforced with in-situ TiB2 using mixed salt route method. A series of dry turning experiments were conducted on cylindrical specimens to measure the influence by varying machining process parameters such as depth of cut, cutting speed and feed rate on output measures e.g. cutting force, surface roughness and the orientation of the chips obtained during operation. SEM images reveal major insert tool wear due to excessive friction between the flank face of the tool and the machined surface. The length of the chip and the formation of curls of the chip increases with an increase in cutting speed at given feed rate and depth of cut. The optimization of machining parameters was conducted by designing a full factorial matrix using MINITAB. The analysis of variance (ANOVA) was used to investigate the effect of used parameters on Cutting force and surface roughness (Ra).

Keywords: Metal matrix composites, TiB2, Turning, Cutting force, Surface roughness

Fig. 1 Schematic view of experimental setup.
Boundary and Thickness Effects on the Free Vibration Behaviour of Functionally Graded GPL Reinforced Composite Plates

Rasappagari Muni Rami Reddy, Warna Karunasena and Weena Lokuge

University of Southern Queensland

*Email: karu.karunasena@usq.edu.au

Abstract

A first order shear deformation theory based finite element approach is used in this paper to investigate the boundary and thickness effects on the free vibration behaviour of functionally graded multi-layer composite plates reinforced with graphene nanoplatelets (GPLs). Four different layer-wise variations of GPL distribution along the thickness direction are considered. For each layer and GPL distribution type, the effective Young's modulus in all directions is determined using the modified Halpin-Tsai model. The rule of mixture is used to calculate the density and Poisson’s ratio of each GPL reinforced layer. The natural vibration frequencies from the presented method are verified by comparing with reported results in the literature for specific cases. Thereafter, the method is used to conduct a parametric study, focusing on the different length to thickness ratios and all possible plate edge boundary condition combinations. The parametric study shows that even a small percentage of GPL (like 1%) has a significant effect on the vibration response for certain thicknesses and boundary conditions

Keywords: Vibration, Natural frequency, Functionally graded material, Graphene nanoplatelets, Nanocomposite, Boundary conditions
Evaluation on Welding Behaviour of Metal and CFRTP by Fusion Joining Methods

Daiki Tanabe*1, Kota Tamura2, and Kazuaki Nishiyabu2

1National Institute of Technology, Wakayama College, Wakayama, Japan
2Kindai university, Osaka, Japan
*Email: tanabe@wakayama-nct.ac.jp

Abstract
This study aims to reveal the multi-material welding behaviour of metal and carbon fiber reinforced thermoplastics (CFRTP) by fusion joining methods. Fig. 1 shows the fusion joining method of CFRTP and metal. The material used for experiment was woven CF/PPS laminates and aluminium plate and steel plate. In order to improve the joining strength, polishing, plasma treatment, discharge treatment and surface-modified polymer coating were performed on the joining surface of the metal plates. In this study, CFRTP and metal plates were bonded by the resistance welding method using carbon fiber heating element. The effects of processing conditions such as applied current, oscillation frequency, pressing force and surface treatment methods were investigated to improve the joining strength.

Keywords: Multi-material, CFRTP, Welding, Surface treatment, Joining strength

Fig. 1 Appearance of resistance welding method for different kind of materials.
Microwave Drilling of Glass and Polymeric Composite
Apurbba Kumar Sharma*, Gaurav Kumar, and Inderdeep Singh

*Email: akshafme@iitr.ac.in

Indian Institute of Technology Roorkee, India

Abstract
Microwave drilling is a thermal energy based process in which a metallic concentrator is used to concentrate the electromagnetic energy at the tip of the tool. Due to high strength of electric field around tool tip, dielectric media at the tool tip gets ionised which results in plasma formation. The plasma ablates the material from the surface of the workpiece just beneath the tool tip. In the present research work, micro-hole drilling of borosilicate glass and two different composites using microwave energy in air and transformer oil has been investigated. The drilling characteristics have been assessed in terms of heat affected zone (thermal damage) and overcut; a comparison has been made while drilling in air and transformer oil. The study revealed that drilling in presence of dielectric like transformer oil reduces the defects significantly. Higher feed rate also helped in minimizing the defects around the hole.

Keywords: Microwave drilling, Glass, Composite, Overcut, Thermal damage

Fig. 1 Schematic diagram of the microwave drilling set up (inset: enlarged view of the cavity).
Abstract
The rapid increase in the number of multi-material transportation structures has led to an increased demand for suitable joining technologies to join these dissimilar materials. In the current work a fastener-less adhesive design concept is described for use with composite-metal joints. The design employs interlocking surface geometries on metal (male) and composite (female) adherends in an effort to combine the advantages of both the mechanical and adhesive joining technologies currently employed in the industry. Finite element damage modelling has been used to investigate the potential improvements of the interlocking concept over standard adhesively bonded joints, while experiments were carried out on miniature lap shear specimens using a microtester. The numerical and experimental results indicate that improvements in both joint strength and work to failure can be achieved, which are largely dependent on the geometry of the male and female profiles. Details are also provided regarding the manufacture of the female profiles on the composite adherends. Mound-in manufacturing using stretch-broken carbon fibre-polyamide produced specimens with accurate dimensions and increased damage tolerance. Samples were also manufactured by laser-machining the profiles on cured aerospace-grade prepreg material, where optical microscopy and nanoindentation testing indicated a minimal heat affected zone (HAZ) near the cut edges.

Keywords: Adhesive Joints, Finite Element Analysis (FEA), Damage Mechanics, Laser Machining, Nanoindentation

Fig. 1 (a) Deben Microtensile Tester, (b) Modified Plane Strain version of Joint W and (c) Crack propagation observed from SEM imaging.
Static Strength of Composite Single-Lap Joint by New Stitching Method

Woo-Jin An, Cheol-Hwan Kim, and Jin-Ho Choi*

School of Mechanical, Aerospace and Information Engineering, ReCAPT, Gyeongsang National University, Jinju-Daero, South Korea

*Email: Choi@gnu.ac.kr

Abstract

Composite lap joints are widely used in composite structures. Inter-laminar delamination is a typical form of failure composite joints because the strength in the through-thickness direction is weak. Therefore, several reinforcing methods have been developed to improve through-thickness directional material property, and stitching method is generally used. However, the conventional stitching method has a disadvantage in that it is not only complex in equipment but also can not use highly elastic brittle fibers such as carbon fiber. Recently, we proposed new 1-thread stitching method to minimize bending of carbon fibers and prevent their fracture. In this paper, a composite single-lap joint specimens using a new stitching method were fabricated by a vacuum bag process and their strengths were evaluated. The strengths of composite joint specimens fabricated with different stitching intervals and patterns were compared with those of specimens without stitching process.

Keywords: Stitching, Single-lap, Composite, Vacuum Bag

Fig. 1 Schematic diagram.
Session: Composite Machining and Joining  
Manuf-3-2-O3

Evaluation on Joining Strength of Woven CF/PPS Laminates Bonded by Continuous High-Frequency Induction Heating  
Kazuki Kurima¹, Daiki Tanabe²*, and Kazuaki Nishiyabu¹  
¹Kindai University, Osaka, Japan  
²National Institute of Technology, Wakayama College, Wakayama, Japan  
*Email: tanabe@wakayama-nct.ac.jp

Abstract
A joining technology is necessary for the manufacturing process of CFRTP composite structures. This study aims to reveal the induction welding behavior of CFRTP composites by high-frequency induction heating method. The material used is woven-CF/PPS. The effects of roller and coil distance, coil moving speed and high-frequency power on heating behavior, the cooling method and the influence of CFRTP composites in induction heating were investigated. The experimental results revealed that the surface temperature of woven-CF/PPS laminates was increased with increasing the high-frequency power, and decreased as the coil moving speed increased. Moreover, the surface treatment could be suppressed with the cooling method. The effects of high-frequency-power and coil moving speed, and cooling method were investigated, the optimum condition was obtained to improve. The results of single lap tensile test, the strength was obtained at 42MPa when the high-frequency power was 500-550W.

Keywords: Thermoplastic composites, CF/PPS, Induction heating, Joining strength

Fig. 1 Appearance of continuous high-frequency induction welding equipment.
Effects of Pressure and Cooling Rate of Woven CF/PPS Laminates on Joining Strength Using Resistance Welding Method

Kota Tamura¹, Daiki Tanabe²*, and Kazuaki Nishiyabu¹

¹Kindai University, Osaka, Japan
²National Institute of Technology, Wakayama College, Wakayama, Japan

*Email: tanabe@wakayama-nct.ac.jp

Abstract

This study aims to reveal the effects of pressure and cooling rate of continuous fiber reinforced thermoplastic (CFRTP) composites using carbon fiber resistance heating element on joining strength. The woven-CF was inserted between the woven CF/PPS laminates as a resistance heating element. The thermocouples were stucked on the laminates to evaluate the welding temperature. The contents for evaluation were electric conducting behavior, pressure fluctuation, surface condition of joint section peeled off after applying current, welding area obtained from those images and single lap shear strength. The effects of processing conditions such as applied current, conducting time, pressure and cooling rate were investigated to obtain the optimum condition for resistance welding. From the experimental result, the cooling rate was increased with decreasing the applied current. It was also found that the cooling rate and pressure have influence on joining strength.

Keywords: CF/PPS, Resistance welding, Pressure, Cooling rate, Single lap shear strength

Fig. 1 Schematic diagram of melting behavior of resistance welding part.
Development of Magnetorheological Elastomers Based Tuned Mass Damper for Building Protection from Seismic Events

Weihua Li*, Shuaishuai Sun, and Matthew Christie

School of Mechanical, Materials and Mechatronic Engineering, University of Wollongong, NSW, Australia

*Email: weihuali@uow.edu.au

Abstract

This study investigated and evaluated a semi-active tuned mass damper which incorporated four multi-layered structures, fabricated using magnetorheological elastomers. The four magnetorheological elastomer structures formed a square layout and provided the tuned mass damper variable stiffness in order to track the excitation frequencies. This design not only increases the stability of the tuned mass damper but more importantly eliminates the magnetic circuit gap in our prior design because all four of the magnetic circuits used to control the magnetorheological elastomer isolators are closed circuits. A wide frequency shift range from 3 Hz to 7.5 Hz proved that this new design is feasible and controllable. In order to verify the capability of the magnetorheological elastomer based tuned mass damper to protect a building from earthquake, extensive simulation and experimental testing were conducted. The swept sinusoidal signal was used to excite a scaled three story building. The experimental results have verified that the magnetorheological elastomer based tuned mass damper outperformed all other passive tuned mass dampers.

Keywords: Tuned mass damper, Building protection, Magnetorheological elastomers, Vibration control

Fig. 1 The structure and prototype of the MRE TMD.
Comparison of Soft Extensile and Contractile Bending Pneumatic Artificial Muscles

Yanju Liu¹, Qinghua Guan², Jian Sun², and Jinsong Leng²*  

Department of Astronautical Science and Mechanics, Harbin Institute of Technology (HIT), Harbin, China  
Centre for Composite Materials and Structures, Science Park of Harbin Institute of Technology (HIT), Harbin, China  
*Email: lengjs@hit.edu.cn

Abstract

Soft Bending actuators are widely used in robotic and rehabilitation applications due to the lightweight, excellent compliance and simple design1, 2, 3. And the Pneumatic Artificial Muscles (PAMs) as one type of earliest soft actuators have consistently attracted the attention from researchers 4, 5, which usually consist of a bladder tubes, a braided sleeve and end fittings. In this study, two types of soft bending actuators based on extensile and contractile PAMs were proposed. These actuator was tested and compared to characterize its performance and mechanical properties. The extensile/contractile bending PAM consists of two 3-D-printed end fittings, an elastic tube, a braid tube and an embedded elastic frame. As the axial driving extensile and contractile PAMs, when the initial braid angle is lower than 35.26 degree, the actuator would act as an extensible bending PAM, on the contrary, it would work as a contractile bending PAM, as Fig 1. Then the free-bending tests were conducted to evaluate the bending capability. And the tests of output-force were implemented to assess its driving capability. The test results above were compared and discussed to comprehend their merits and demerits. Moreover a tandem Multi-degree manipulator was built to demonstrate its potential applications for soft robotics.

Keywords: Soft robotics, pneumatic artificial muscle, Contractile, Extensile, Comparison

Fig. 1 The designs of bending pneumatic artificial muscles (BPAMs), (a): contractile bending pneumatic artificial muscles, (b): extensile bending pneumatic artificial muscles.
Conductive Graphene-Silicone Rubber Composites For Intelligent Monitoring
Xuefeng Yao*, Heng Yang and Linhui Gong
Department of Engineering Mechanics, Tsinghua University, Beijing, China
*Email: yxf@mail.tsinghua.edu.cn

Abstract
Flexible strain sensors based on conductive elastomer composites have attracted increasing attention.
In this paper, the graphene was added into silicone rubber to prepare the conductive composites by co-coagulation. The conductive graphene-silicone rubber composites show a lower percolation threshold with 1.9 wt. %. And the SEM analysis indicate the graphene disperses well in the silicone rubber, significantly enhancing the mechanical and conductive properties. In the meanwhile, the strain-resistance behaviors for different contents graphene composites under uniaxial and cycle loading tension have been investigated carefully. The experimental results show that the graphene-silicone rubber composites exhibited a very high sensitivity (gauge factor > 149) and a wide range of strain (>160%). What’s more, the good recoverability and reproducibility were found in the loading-unloading cycle, which represent great potential for application in the continuous and long-term strain collection, such as structure health monitoring and biological motion monitor. In addition, the analytical model based on the connectivity of the graphene nanosheets and the viscoelasticity of the rubber matrix was used to describe the electromechanical properties of conductive graphene-silicone rubber composites. And the ‘shoulder peak’ phenomenon during cyclic loading-unloading test has been explained by schematic illustration and numerical simulation in detail. Finally, the conductive graphene-silicone rubber composites were applied to monitor the stress state of the rubber seals.

Keywords: Graphene-silicone rubber composites, Electromechanical properties, Intelligent monitoring

Fig. 1 The fractional resistance change ($\Delta R/R_0$) as a function of applied strain for graphene-rubber nanocomposites with different graphene contents.
Flexible Strain Sensors Based on Three Dimensional Carbon/Silicone Composites for Human Health and Motion Detection

Yuanqing Li*, Xiaoguang Yu, Pei Huang, and Shaoyun Fu

College of Aerospace Engineering, Chongqing University, Chongqing, China

*Email: yqli@cqu.edu.cn

Abstract

Large-scale fabrication of highly sensitive and flexible strain sensors with low-cost and facile techniques is significant to meet the need in the next-generation of wearable electronics. In recent years, series of flexible strain sensor based on low cost piezo-resistive composites have been developed by our group. As shown in Fig 1, these flexible piezo-resistive composites are fabricated with three dimensional (3D) carbons from biomass, such as cotton, waste paper and bamboo, as piezo-resistive strain-sensing material and silicone resin as flexible elastomer matrix 1, 2. The as-fabricated flexible strain sensors are highly sensitive to strain with a maximum gauge factor of 18.42. The flexible strain sensors fabricated exhibit fast and repeatable response to dynamic loading, and excellent durability within the strain range of 0-20% and the working frequency of 0.01-10 Hz. In addition, these flexible sensors as wearable device for human motion detection including joint motion, eye blinking, blood pulse and breathing are demonstrated by attaching the sensor to corresponding part of human body. In consideration of the simple fabrication technique, low material cost and excellent strain sensing performance, the strain sensor based on 3D carbon/silicone composites is believed to have great potential in the next-generation of wearable devices for human health and motion detection.

Keywords: Strain sensor, 3D Carbon, Piezo-resistive composite, Flexible, Wearable

Fig. 1 Flexible strain sensor based 3D carbon/silicone composite with cotton (a) and waste paper (b) as raw materials.
Session: Smart Composites/Structural Health Monitoring
Struc-4-1-O3

Smart Composite for off-Shore Large Dimensions Windblades. Numerical & Analytical Modeling
Monssef Drissi-Habti* and Venkadesh Raman
PRES LUNAM IFSTTAR, Bouguenais, France
*Email: monssef.drissi-habti@ifsttar.fr

Abstract
Offshore wind energy is one of the main sources of renewable energy that can benefit from smart composite materials that exhibit good oxidation resistance and mechanical reliability. Composite materials are the best consideration for harsh environment and deep-sea wind turbine manufacturing. Numerical simulation was implemented to predict the stress distribution over a wind turbine blade and to determine areas with high stress concentration. Finite Element Analysis (FEA) was used to find optimal material and bonding techniques to construct the blade which dimensions are expected to exceed 100m. Appropriate SHM sensors were designed and their placement numerically modeled to ensure the best use.

Keywords: Numerical modeling, Analytical modeling, Smart composite, Fatigue, Sensors, SHM
Smart Composite High-Voltage Cables For Off-Shore Applications. Numerical & Analytical Modeling

Monssef Drissi-Habti\textsuperscript{1*}, Fouad Ech-Cheikh, and Abdelghani Matine\textsuperscript{1}

\textsuperscript{1}PRES LUNAM IFSTTAR, Bouguenais, France
\textsuperscript{2}CEA TECH, , France

*Email: monssef.drissi-habti@ifsttar.fr

**Abstract**

High voltage cables for offshore wind farms are structures that have to carry electrical power for several tens of kilometers from wind turbines to onshore power stations. Therefore, they must be very reliable not only from the mechanical point of view, but also multiphysics. In this article, we propose an analytical and numerical modeling of some multiphysical aspects of the behavior of their constitutive phases. We also propose some solutions to instrumentalize them effectively, in the optics of the control of their structural integrity (SHM).

**Keywords:** Mechanical modeling, Multiphysics modeling, SHM, Sensors, Fatigue
Erosion-Corrosion Behavior of Typical Electric Submersible Pump (ESP) Stage Materials

Hejun Du*, Yuefan Wei, Zeqing Sun, and Wenfei Wu

School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore

*Email: mhdu@ntu.edu.sg

Abstract

Electrical submersible pumps (ESP) are widely used in the extraction of oil and gas underground as well as deep in the sea. In the extraction process, the ESP pump system is subjected to many corrosive elements, especially the sea water (chloride) and sands, resulting in severe erosion-corrosion and finally functional failure. Erosion-corrosion is a global issue, which costs economic loss of trillions of dollars annually, around 6.2% of global GDP, of most industrialized nations. It is a complex degradation mechanism, including electrochemical, mechanical and interactive/synergistic processes between materials and their environment. Total loss in a slurry environment can be significantly higher than the sum of individual loss due to pure erosion and corrosion. Therefore, in this work, the erosion corrosion behaviours of some typical ESP materials, such as nickel-aluminum-bronze (NAB), Ni-resist alloys and super duplex stainless steel (DSS) were investigated. The effects of different working conditions, including temperature, sands concentration, chloride concentration and impact angle, on their erosion corrosion.

Keywords: Erosion-corrosion behavior, Electrical submersible pumps (ESP), Characterization

Fig. 1 Tafel plots obtained from potentiodynamic testing results. (a) (b) and (c) Duplex stainless steel (DSS), nickel aluminium bronze (NAB) and Ni-resist alloys tested in 3.5 wt% sodium chloride (NaCl) solution at room temperature, respectively. (d) DSS, NAB and Ni-resist alloys tested in 7 wt% NaCl solution at room temperature.
Detection of Laminar Damage in Composites Using the Nonlinear Vibro-Ultrasonic Technique

Mitch Dunn*, Alessandro Carcione, Philippe Blanloeuil, and Martin Veidt

School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore
*Email: m.dunn1@uq.edu.au

Abstract
Nonlinear ultrasonics has been recognised as a promising field of nondestructive testing for early damage detection in the context of structural health monitoring. This paper reports on the detection of laminar damage in composites using the nonlinear vibro-ultrasonic technique, in which a high-frequency ultrasonic probing wave interacts with a low-frequency pumping vibration. Carbon/epoxy composite laminate beam specimens are produced containing laminar damage; one set of specimens with artificial delamination damage and a second set with damage created through low-velocity impact tests. Deliberate selection of experimental instrumentation, signal processing techniques and input excitation parameters leads to a low noise floor in measurements, and the sideband frequency components in the output signal that are used to quantify nonlinearity are clearly resolved as a result. The results of this study demonstrate that gross laminar defects cause an increase in nonlinearity as to be confidently differentiated from intact specimens. A strong dependence of nonlinear wave interaction on the amplitude of the pumping wave in the presence of the nonlinearity is observed, for pumping frequencies deliberately selected to be away from resonance.

Keywords: Nonlinear vibro-ultrasonics, Nonlinear acoustics, Delamination, Impact damage
A Broadband Vibration Energy Harvester with a Soft Magnetorheological Elastomer-Piezoelectric

Shuaishuai Sun*, Jian Yang, and Weihua Li*

School of Mechanical, Materials and Mechatronic Engineering, University of Wollongong, NSW, Australia

*Email: ss886@uowmail.edu.au and weihuali@uow.edu.au

Abstract

Vibration energy harvesters have the ability to convert ambient kinetic energy into electrical energy; however, the problem of narrow bandwidth and power generated is a prominent issue in this field. To achieve a broad frequency bandwidth, many techniques have been analysed and investigated, such as, multimodal, resonance tuning and non-linear techniques. This paper presents an innovative hybrid nonlinear vibration energy harvester consisting of a magnetorheological elastomer (MRE) layer, piezoelectric sheet and a tip mass. The newly proposed energy harvester makes use of the stiffness controllable characteristics of MRE to develop a nonlinear energy harvester. The multi-layered MRE-piezoelectric beam is enclosed by permanent magnets to close the magnetic circuit around the MRE and induce a nonlinear stiffness. The high flexibility of the soft magnetorheological elastomer-piezoelectric hybrid beam enables the energy harvester to have higher vibration amplitude compared to an equal thickness aluminium based harvester. Experimental investigation has been performed to analyse the performance of the hybrid energy harvester; specifically, the effective bandwidth and generated power. Additionally, a linear energy harvester has been tested for comparison; furthermore, comparisons between the linear energy harvester and the hybrid energy harvester demonstrated that the hybrid nonlinear energy harvester has a wider effective frequency bandwidth and generated more power.

Keywords: Hybrid vibration energy harvester, Magnetorheological elastomer, Piezoelectric

Fig. 1 Schematic and experimental photos of the proposed hybrid VEH.
Session: Smart Composites/Structural Health Monitoring
Struc-4-2-O3

Load Sensing in Ridft-Fabricated Composite Blades Using Triboluminescent Sensor
Md Abu Shohag* and Okenwa Okoli

High-Performance Materials Institute, FAMU-FSU College of Engineering, Florida, Unit States
*Email: mss14d@my.fsu.edu

Abstract
As wind blades become larger and are located in remote areas as well as offshore, there is a growing need to monitor the various loads acting on these composite structures. This article proposed a novel sensor system based on the proprietary in situ triboluminescent optical fiber (ITOF) sensor for dynamic load monitoring in wind blades. The new triboluminescent sensor, C-shaped ITOFPress, consists of an ITOF sensor network with micro-exciter integrated within a polymer matrix. The C-shaped ITOFPress was subjected to repeat mechanical loading and produced TL emissions due to the friction between micro-excitiors and ITOF sensors corresponding to each loading cycle. The authors present ongoing research on load sensing triboluminescent sensor in composite lab-sized wind blade for load monitoring of the structure. The lab-sized wind blades were fabricated with an innovative composite fabrication process called Resin Infusion between Double Flexible Tooling (RIDFT). Several defect-free blades were fabricated with this novel process and instrumented with C-shaped ITOFPress. The preliminary results show that the sensor can sense applied loads on the sensor itself as well as generates signals with the applied loads on the blades. The C-shaped ITOFPress has the ability to monitor dynamic continuous applied loads over cycles.

Keywords: Composite wind blades, Load sensing, RIDFT, Sensor, Triboluminescence

Fig. 1 Composite blade fabrication process using RIDFT technique.
A Modelling Approach to Compute the Through Thickness Resistance of a Multifunctional Composite in a Three Point Bending Experiment

Subhasis Chakraborty\textsuperscript{1,*}, Holger Göbel\textsuperscript{1}, Felix Heinrich\textsuperscript{1,*}, Rolf Lammering\textsuperscript{1}, Taha Genco\textsuperscript{1}, Till Augustin\textsuperscript{2,*}, and Bodo Fiedler\textsuperscript{2}

\textit{Institute of Electronics, Helmut-Schmidt-University/University of the Federal Armed Forces Hamburg, Holstenhofweg 85, D-22043 Hamburg, Germany}

\textit{Institute of Polymer and Composites, Hamburg University of Technology, Denickestraße 15, D-21073 Hamburg, Germany}

*Email: s.chakraborty@hsu-hh.de, felix.heinrich@hsu-hh.de, and till.augustin@tuhh.de

Abstract

A two-dimensional model is created in a multiphysics simulator (COMSOL) to evaluate the through-thickness resistance of a multifunctional composite under increasing mechanical load and validated against experimental data. The multifunctional composite system consists of carbon fiber reinforced plastics (CFRP), which have printed conductive paths. For the experimental part of this work, CFRP samples with inkjet-printed silver nanoparticle paths on top and a printed silver layer on the entire bottom side were used in a test setup for a three-point bending experiment and the resulting fracture progression was monitored in an optical microscope. The images provided an insight into damage development occurring under mechanical load. A model was developed to encompass the changing mechanical and electrical properties of the multifunctional composite. It had been previously investigated that a differently oriented system of printed electronics provided accurate information on the interlaminar delamination occurring in a CFRP sample. A qualitative correlation was found between our experimental results, the experimental results from previous work as mentioned and simulation results from the model. The numerical model, experimental results and simulated values of resistance changes for various damage states in CFRP in the context of structural health monitoring are presented in this paper.

Keywords: Three-point bending experiment, Through thickness resistance, Discrete damage states, Printed electronics, Structural health monitoring
The Effect of Glass Fibre Reinforcement on the Shape Programming And Stress Recovery Behaviours of The Smpcs

Wessam Al Azzawi¹*, Jayantha Epaarachchi¹*, Mainul Islam¹, and Jinsong Leng²*

¹Centre for Future Materials, University of Southern Queensland, Toowoomba, Queensland, Australia
²Centre of composite materials and structures, Harbin institute of technology, Harbin, China

*Email: wessam.al-azzawi@usq.edu.au, Jayantha.Epaarachchi@usq.edu.au, and lengjs@hit.edu.cn

Abstract

Shape memory polymers (SMPs) have emerged recently due to their ability of recovering original shape. However, the significantly lowe recovery stress have implied a few critical limitations on their applications in engineering applications. As a consequence SMPs were limited to use in non-structural engineering applications. However, it has been shown that the inclusion of fibre reinforcements to SMP have significantly increased the SMP’s mechanical properties. This study presents the effects of glass fibre reinforcement on the Styrene-based SMPs programming and recovery stresses. Different fibre volume fraction samples have been prepared, and tested on Dynamic Mechanical Analyser to investigate the fibre impacts. Results revealed that the fibre reinforcement has significantly improved the recovery stress. Further, it has increased the programming stress, and reduced the stress drop happened due to relaxation in the shape programming stage.

Keywords: SMPC, Shape programming, Stress recovery

Fig. 1 Shape programming and stress-free strain recovery processes and their associated heating and cooling steps for (a) neat SMP, (b) 20% SMPC and (c) 25% SMPC samples.
Tunable Negative Permittivity of Metacomposites with Nanocarbon/Amorphous Wire Hybrid Fibers

Diana Estevez, Faxiang Qin*, and Hua-Xin Peng

Institute for Composites Science Innovation, School of Materials Science and Engineering, Zhejiang University, Hangzhou, China
*Email: faxiangqin@zju.edu.cn

Abstract

Metacomposites based on Co-based amorphous wires (AW) arranged in a periodical manner create a double negative (DNG) medium due to the plasma–like feature and natural ferromagnetic resonance properties of the wire fillers. However, the characteristic plasma frequency is merely controlled by mesostructural aspects, e.g. wire arrangement. Herein, we propose alternative building blocks based on nanocarbon/amorphous wire hybrid fibers to enable tuning of negative permittivity through carbon nanotube (CNT) thickness and sequential removal of oxygen-functional groups from graphene oxide (GO). Figure 1 shows the preparation of the hybrid fibers by electrophoretic deposition (EPD) process and their composites. As the CNT content and the reduction of GO increased, a change from resonance-induced (Lorentz-type) to plasma-like behavior (Drude-type) was observed. The resonance-induced negative permittivity for low CNT thickness and 300°C-annealed GO/microwire fiber, was ascribed respectively to the induced electric dipole generated from the isolated CNT islands and from the abundant functional groups in GO. The plasma-like behavior was explained by the low frequency plasmonic state generated from conductive nanotube network and the structural changes induced during GO reduction. These results have profound implications for exploring the generation and regulation mechanism of negative permittivity behavior in amorphous wires enabled multifunctional composites.

Keywords: Amorphous wires, Carbon nanotube, Graphene oxide, Negative permittivity
Cure Process Monitoring and Optimization of FRP Using Optical Fiber Sensors
Tatsuro Kosaka¹, Genko Fujioka²*, and Kazuhiro Kusukawa¹*

School of Systems Engineering, Kochi University of Technology, Kami, Japan
Graduate School, Kochi University of Technology, Kami, Japan

*Email: 215028z@gs.kochi-tech.ac.jp, and kusukawa.kazuhiro@kochi-tech.ac.jp

Abstract
In the present paper, in-situ cure process monitoring and optimization of FRP with non-uniform temperature distribution was conducted. First, distribution of degree-of-cure of GFRP with partial heating was measured by embedded three optical fiber Fresnel-reflection sensors. Here, thermocouples were also embedded in the FRP for temperature measurement. The experimental results of temperature and degree-of-cure were compared with the analytical distribution obtained by FEM analysis. From the results, it appeared that the experimental curves had good agreement with analytical ones. Next, optimization of cure temperature of the step-wise GFRP laminate where the step-wise thicknesses were 3 and 6 mm. Two heaters A and B were attached on the thinner and thicker surfaces, respectively. The heating rate of the heater A on the thicker surface was 5 degrees/min. The heating rate of the heater B and the maximum temperature of the both heaters were design parameters. The multi-objective function was a combination of responses of processing time, heating energy and unevenness of distribution of degree-of-cure. The Pareto solutions were obtained and the optimized heating condition to minimize the three objectives was obtained successfully.

Keywords: Cure monitoring, Process optimization, Optical fiber sensor, Degree of cure

Fig. 1 Experimental set-up of cure monitoring of FRP with partial heating.
Monitoring Tip of Embedded Mixed Mode Delamination Crack Propagation Using TSA Technique
Ayad Kakei\textsuperscript{1,2*} and J.A Epaarachchi\textsuperscript{1*}

Centre of Excellence in Engineered Fibre Composites, University of Southern Queensland, Toowoomba, Queensland, Australia
College of engineering, University of Kirkuk, Kirkuk, Iraq
*Email: ayadkakei78@gmail.com, and Jayantha.Epaarachchi@usq.edu.au

Abstract
The composite material can be used in light-weight structure for aerospace. However the applications of composite are limited by the lack of adequate techniques to monitor internal damage during service. In this work TSA Technique has been used to monitoring delamination crack tip development and strain distribution due to delamination damage along single shear specimen. The delamination damage was both experimentally and numerically studies at woven laminated composite specimen. The result show that delamination damage propagates due to tensile loading at the single shear specimen. The simulations and measurement showed good agree for the delamination damage monitoring. Non-destructive TSA method has shown a capability to estimate damage in composite structures. Many recent studies have shown that the TSA based techniques are powerful tools for estimating damage in fibre reinforced polymeric materials. In this study MITE system has been used to evaluate delamination crack tip. A TSA system called MITE© was developed by Defence Science Technology Organisation (DSTO) of Commonwealth of Australia. The complete details can be found in 2.1. These references details MITE© system’s capabilities and has shown that the low-cost microbolometer device is more affordable and better suited for in-service applications. The major advantage of the MITE© system is capability of using for a wider range of applications in civil, maritime and aerospace sectors because of microbolometers are, small size, have a good tolerance to shock and vibration and consume less power than their photon counterparts.

Keywords: Delamination, Structural health monitoring, TSA, Cohesive element

Fig. 1 Delamination crack front propagation (θ-component). Red dotted line outlines the boundary of the initial delamination. Delamination zone is seen to increase as a function of mean load.
Temperature Effects on Rheological and Impact Behaviour of Polymer-Based Shear Thickening Fluid

Kunkun Fu¹*, Y.X. Zhang², Hongxu Wang², Juan Escobedo², Lin Ye¹

¹School of Aerospace, The University of Sydney, Sydney, NSW 2006, Australia
²School of Engineering and Information Technology, The University of New South Wales, Canberra, The Australian Defence Force Academy, ACT 2600, Australia

*Email: kunkun.fu@sydney.edu.au

Abstract

Concentrated colloidal suspensions exhibit shear thickening behaviour, i.e. a steep rise in viscosity of up to three orders of magnitude at a critical shear rate for a given stress level, affecting by the working environment such as temperature. This reversible transition from a low-viscosity state to a high-viscosity state is regarded as one of the main contributors to the total energy absorption during an impact. This study aims to examine temperature effect on the rheological and impact behaviour of a concentrated polymer-based shear thickening fluid (STF). The STF consists of 58 vol% styrene/acrylate particles prepared using an aqueous emulsion polymerisation technique. First, the steady-state rheological behaviour of the STF was conducted at temperatures ranging from 0 °C-50 °C, and the result is shown in Fig. 1. It indicates that the STF shows non-Newtonian fluid behaviour. Interestingly, the shear-thinning behaviour is not observed in the STF at 0 °C. In addition, the semi-confined low-velocity and high-velocity impact behaviours of the STF were studied at various temperatures, respectively. The results show that the energy absorption of the STF was controlled by the temperature.

Keywords: Shear thickening fluid, Temperature effect, Rheological behaviour, Energy absorption

Fig. 1 Microstructure of the styrene/acrylate particles.
Abstract

Graphene based nanotechnology has offered a variety of novel strategies for enabling self-sensing and diagnosing functionalities for next-generation composites. In comparison to traditional methods with complicated procedures and limited scalability, a new process is impending for graphene sensor fabrication with designable shape and controllable performance. Toward this goal, this paper combined multiple computer-aided processes for designing graphene thin film sensors and arrays on composites, including spray-coating, laser-scribing and ink-dispensing. The processing-structure-property relationship was systematically investigated for understanding the piezoresistive performance of sensors. It is determined that by increasing the laser rastering time, the gauge factor could be tailored up to 3 orders of magnitude from ~450 to ~0.6. The accumulated bump-shaped area caused by higher leveled gas liberation and thermal reduction is believed to disrupt the efficiency of load-transfer and the resulting sensing performance. With the optimized recipe, versatility of graphene sensor and array deployed with ink-printed flexible circuits were further explored for monitoring and mapping large-scale deformation and strain distribution of composites.

Keywords: Graphene, Laser scribed graphene, Piezoresistive sensor, Polymeric composites, Structural health monitoring

Fig. 1 Laser scribed Graphene Sensor Array on Polymeric Composites.
Fabrication of Bioinspired Structured Hydroxyapatite Composites with Enhanced Fracture Toughness

Jingyu Liu and Cheng Yan*

School of Chemistry, Queensland University of Technology, Brisbane, Queensland, Australia.

*Email: c2.yan@qut.edu.au

Abstract

Strength and toughness have been generally deemed as two incompatible properties in many materials. However, balanced toughness and strength have been observed in biomaterials, whose hard and soft phases are arranged into a unique and hierarchical architecture. Therefore, it is essential to develop processing technologies that can mimic the structures observed in biomaterials. In this work, hierarchical structures were achieved in hydroxyapatite (HA) via freeze casting. The suspension solid load changes from 5% to 20% and cooling rate from 1°C/min to 5°C/min were adopted to achieve different microstructures. A ductile phase (PMMA) was also introduced to the HA matrix by in-situ polymerization. In addition, the bonding strength between HA and PMMA was investigated. The fracture toughness was evaluated by a three-point bending test. Based on these, the role of microstructures and interfacial strength in dictating the overall mechanical behavior were discussed.

Keywords: Bioinspired materials, Hierarchical structure, Materials testing, Composites

Fig. 1 Scanning electron micrographs of horizontal cross-section images of freeze casted Alumina scaffold with varying content of dispersant: a) 4 wt% Darvan811; b) 8 wt% Darvan811; c) 12 wt% Darvan 811.
Design Optimization for Manufacturing of Composite Wing Structures Considering PLY Material Types

Jong-Cheon Lee*, Min-Sung Kim and Chan-Yik Park

*Email: jongcheon@add.re.kr

Aeronautical Technology Directorate, Agency for Defense Development

Abstract

The advantages of carbon composite materials are high specific stiffness and high specific strength. Therefore, the percentage of composite materials in aircraft structures is increasing recently due to structural weight reduction. While metallic materials are isotropic, composite materials are anisotropic or orthotropic. Furthermore, composite materials have many design parameters including stacking sequence, ply angle, etc. The design optimization methodology, conducting design iteration, is used to solve these problems. In this paper, design optimization was conducted for the composite wing structures of small and middle aircraft using commercial software. Three types of ply materials used in the optimization are unidirectional tape only, fabric only and hybrid (tape and fabric). Design requirements of structures such as load, geometry and criteria were decided. Fig. 1 shows two-dimensional FE (finite element) models of composite wings. The design optimization has two steps. The first is effective laminates step applying equivalent properties and the second is discrete laminates step determining lay-up. For small aircraft, hybrid type is the best solution of the optimization because its weight is minimum and its manufacturability is maximum. For middle aircraft, the amount of weight reduction with composite material is 38.3%.

Keywords: Design optimization, Composite wing, Composite structure, Manufacturability

Fig. 1 FE models of composite wing structures.
**A Novel Structural of Three-Dimensional Hollow Fabric Reinforced Composite**

Wei Guo, Zhengliang Zhou, Shouyu Zhang*, and Tonghai Chen*

*Sinoma Science & Technology Co., Ltd., China.*

*Email: zsyscu2010@126.com, and chentonghai@fiberglasschina.com*

**Abstract**

The three-dimensional hollow fabric is a new type of sandwich structure, which is made of high performance fibre through the weaving process. This structure consists of two deck layers formed by warp and weft direction and Z direction fibers. Z direction fibers interconnect both layers and improve the stability of mechanics property. The thickness between two deck layers (Z direction) can be designed from 2mm to 20mm in order to meet different needs. The typical structure of vertical piles can be recognized by the 8-shape piles in warp direction, ensuring the stability of mechanics property and surface evenness. Based on the special structural characteristics of hollow fabrics, hollow fabric composites have excellent electrical properties (low dielectric constant, low loss tangent, high broadband transmission rate), light weight, high strength, sound insulation, heat insulation, design, filling and embedment. Hollow fabric and its composite materials show wide application prospects in communication base stations, radome, aerospace, rail transit, marine vessels, building materials and double wall storage tanks. The application of hollow fabric composites in the field of radome was mainly reviewed, including analysis and comparison of the advantages and disadvantages of glass fiber, quartz fiber, Kevlar fiber and high modulus polyethylene fiber as reinforcement, the superiority of hollow radome composite over traditional sandwich materials and solid FRP radome materials in structure and properties and the applications of traditional resin and new-type high temperature resistant resin in radome wave transmitting composites. Finally, the development trend of radome materials in the future was pointed out.

**Keywords:** Three-dimensional hollow fabric, Composite, Mechanics property, Electrical properties

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*Fig. 1 FE models of composite wing structures.*
Session: Composites Structure Design
Struc-1-1-O3

Evaluation of Fiber Orientation Analysis Methods in Fiber-Reinforced Composites for QA Purpose
Rémi Blanc¹, Peter Westenberger², and Eric Ho³*

¹Thermo Fisher Scientific, Merignac Cedex, France
²Thermo Fisher Scientific, Düsseldorf, Germany
³Thermo Fisher Scientific, Shanghai, China
*Email: eric.ho@fei.com

Abstract
Computed Tomography (CT) is on its way to become the de facto standard in the field of material sciences especially for the analysis of fibrous materials. It provides full 3D details inside the materials, and enables non-destructive analysis to assess the physical properties of the materials. The current question is mostly about the compromise between image resolution and volume of data being analyzed, to extract accurate information allowing for the characterization of the fibrous material. Among those statistics, we focus here particularly on the distribution of fiber orientations within the material. We will highlight three different approaches that may operate at different resolutions to provide insights about the fiber orientations. After presenting these different methods, we will describe the data used for this study. We will apply the described procedures to real data that has been acquired by a state of the art μCT system. We will also work with an artificial dataset generated with user-defined properties as a gold standard reference. For both real and synthetic data, we will also investigate the behavior of the proposed approaches with respect to the scanning resolution, simulated here by using down-sampled versions of the same original images (shown in Fig 1).

Keywords: Three-dimensional hollow fabric, Composite, Mechanics property, Electrical properties

Fig. 1 (a) Slice through the synthetic volume, (b) 3D volume rendering of the synthetic volume, colorized according to the estimated major orientation (the red, green, blue axes indicate the color code), (c) slice through the synthetic volume, downsampled by a factor 4, (d) slice through the synthetic volume, downsampled by a factor 8.
Enhanced Interphase Between Modified Thermoplastic Matrix and UHMWPE Fiber with Carbon Nanotube Modified Dopamine Coating

Logesh Shanmugam, Xiaming Feng, and Jinglei Yang*

Hong Kong Univ Sci & Technol, Dept Mech & Aerosp Engn, Hong Kong SAR, China

*Email: maeyang@ust.hk

Abstract

The fiber phase, matrix phase and fiber/matrix interphase are different phases of fiber reinforced polymers (FRPs). FRP property such as mechanical strength is highly dependent on the adhesion level between the fiber and matrix for efficient load transfer. In this study, functionalized multiwalled carbon nanotubes modified dopamine coating solution is coated on fiber surface to enhance the interfacial bonding strength between ultra-high-molecular-weight polyethylene (UHMWPE) fiber and thermoplastic matrix (Elium), which has resin infusion capability. The polydopamine (PDA) coating, PDA + 0.05wt% MWCNT and PDA + 0.1wt% MWCNT were performed by soaking fibers in dopamine aqueous solution. The scanning electron microscopic (SEM) images of surface treated fibers were shown in Fig 1. The interfacial bonding strength of UHMWPE fiber and Elium resin were investigated by transverse fiber bundle tension test (TFBT), as shown in Fig 2, which is the more efficient than single fiber pullout test. In contrast, the addition of 0.05wt% and 0.1wt% carbon nanotubes into Elium matrix is also investigated on enhancing the interphase between neat PDA coated UHMWPE fiber and matrix. The report explains the interfacial property and discloses the discrepancy of PDA, PDA-CNT coated fiber with neat matrix and neat PDA coated fiber with modified matrix.

Keywords: UHMWPE fiber, Polydopamine, Elium matrix, Interfacial bonding

Fig. 1 SEM of surface treated UHMWPE fiber (A) Pristine fiber (B) UHMWPE-PDA fiber (C) UHMWPE-PDA-0.05wt% CNT fiber (D) UHMWPE-PDA-0.1wt% CNT fiber.
Abstract
Continuous Ship Unloader (CSU) Bucket Elevator (BE) is used for excavating and vertically transporting the cargos such as iron ore, coal etc. by driving system which consists of a high load roller chain. High load roller chain require impact, wear resistance and durability for transportation of cargos. Large noise and vibration is occurring due to impact between roller chain and sprocket while conveying. Hence, It is essential to focus on the weight of roller chain for the reduction of noise and vibration. Present study investigates the vibration damping effect and weight saving by replacement of the metal pin to Carbon Fiber Reinforced Plastic (CFRP) and Glass Fiber Reinforced Plastic (GFRP) composite pin. The damping effect was confirmed by analyzing the acceleration-time data with shock and impact hammer as shown in Fig. 1. Composite material pins were manufactured for applications related to high load roller chain. The results confirmed that it is possible to achieve damping effect (Fig. 2) and weight saving design for impact force. Application of this design in a bucket elevator system is considered to be a great help in reducing the overall structure.

Keywords: Heavy load roller chain, Composite Pin, Dynamic impact, Damping
Preparation and Characterization of Novel Vacuum Insulation Panels With Super-Stratified Ceramic Fiber Blanket

Xinli Ye, Zhaofeng Chen*, Junxiong Zhang, and Ping Zhang

College of Material Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing, China

*Email: zhaofeng_chen@163.com

Abstract
Thermal insulation materials have attracted interests in recent years, which was mainly focused on how to extend their applied temperature range from cryogenic to extremely heat applications. A novel vacuum insulation panel (VIP) with low cost and perfect thermal insulation had been prepared and fabricated especially for building and fire prevention. And, its core material was the super-stratified ceramic fiber blanket made by melt-spinning method to reduce the gaseous convection and conduction because of its low thermal conductivity and long-term stability. The blanket consisted of several layers of ceramic fiber layers as well as of aluminium foils with a thickness of 1 mm. The fine diameter of ceramic fiber was 2.85 μm for keeping the low thermal conductivity and long-term stability of core material. The aluminium foils were utilized to divide the blanket into several parts to increase the reflection coefficient. The initial thermal conductivity of this novel VIPs was only 2.0 mW/m·K, nearly the same as VIPs with glass fiber core material materials, however its cost was a half. The reliability of ceramic fiber blanket with thermal-resistant was expected to provide VIPs a relatively prolong service life.

Keywords: Vacuum insulation panel, Building insulation, Ceramic fiber blanket, Thermal conductivity, Service life

Fig. 1 SEM and statistical quantities of the ceramic fibers.
New Insights into Stiffness Matching between Standard and Double Angle-Ply Laminates

Christopher York*

Aerospace Sciences, University of Glasgow, Glasgow, Scotland
*Email: christopher.york@glasgow.ac.uk

Abstract

This article presents a methodology for matching bending stiffness between standard ply laminates (with 0˚, ±45˚ and 90˚ ply orientations) and double angle-ply laminates (with ±ψ and ±ϕ ply orientations). The methodology is only possible through the development of a series of databases containing laminate configurations with specific mechanical coupling characteristics, which also account for ply percentages and/or ply contiguity constraints. Figure 1(a) demonstrates that the extensional stiffness requirements for a typical spar and stiffener can be closely matched by adopting the (40/60) ply percentages of a typical wing skin, with ϕ = 60˚, and adjusting only the ply orientation, ψ, in the secondary angle-ply sublamine to give (±ψ/±ϕ =) ±60°/±5° for the stiffener and ±60°/±35° for the spar. Figure 1(b) demonstrates the variation in the in-plane properties (ξ₁, ξ₂) for stiffness matched laminates in bending; here, all possessing bending isotropy.

Keywords: Stiffness matching, Double angle-ply, Standard ply laminates, Failure, Buckling

![Fig. 1 Lamination parameter design space (ξ₁, ξ₂) illustrating double angle-ply laminates with stiffness properties matched to standard ply designs in: (a) extension and; (b) bending.](image-url)
Mechanical Properties of Diamond Nanothread-Based Nanofibers

Haifei Zhan\(^1\)*, Gang Zhang\(^2\), Vincent B.C. Tan\(^3\), and Yuantong Gu\(^1\)

\(^1\)School of Chemistry, Physics and Mechanical Engineering, Queensland University of Technology, Brisbane Queensland, Australia

\(^2\)Institute of High Performance Computing, Agency for Science, Technology and Research, Singapore

\(^3\)Department of Mechanical Engineering, National University of Singapore, Singapore

*Email: zhan.haifei@qut.edu.au

Abstract

Carbon nanotube (CNT) fibers have been witnessed as emerging multifunctional nano-textiles in recent years. They have outstanding mechanical, chemical and physical properties and well over-perform traditional carbon and polymetric fibres. Various appealing applications have been proposed for CNT fibers, such as twist-spun yarn based artificial muscles which can respond to the electrical, chemical, or photonic excitations, aerospace electronics and field emission, intelligent textiles and structural composites. Very recently, a new type of ultrathin 1D carbon nanostructure — diamond nanothread (DNT), was synthesized through solid-state reaction of benzene under high-pressure. Similar to the hydrogenated (3,0) CNT, DNT has a hollow tubular structure, which is interrupted by Stone-Wales (SW) transformation defects. Encouraged by this experimental success, researchers found that there are different kinds of stable DNT structures through first principle calculations. Preliminary studies have shown that the DNTs with SW transformation defects have excellent mechanical properties, a high stiffness of about 850 GPa, and a large bending rigidity of about 5.35 \times 10^{-28} \text{ N}\cdot\text{m}^2. Our following works reveal that the brittleness of DNTs can be changed via controlling the density of the SW transformation defects. With these excellent mechanical properties, ultrathin dimensions and a non-smooth surface (compared to CNT), it is of great interest to determine how DNTs can be used in fiber applications. Our study shows that DNT is ideal candidate for fiber applications. Not only do they possess excellent torsional deformation capability, they possess excellent interfacial load transfer efficiency.

Keywords: Diamond nanothread, Carbon nanofiber, Mechanical property, Molecular dynamics simulation
Abstract

Some studies on the bearing strength and mode of failure have been carried out in the bolted joints of the T700 carbon-epoxy composite. As a typical parameter to induce the bearing failure mode, e/D ratio which is the distance (e) from the free end to the bolt hole divided by the hole diameter (D) is used. In this study, a preliminary test was conducted to find the e/D ratio resulting in bearing failure mode of T700/Epoxy carbon fiber reinforced composite material. The preliminary test was conducted according to the paper of Hundley1. Using the obtained e/D ratios, specimens were fabricated with the same thicknesses of actual targeted structures and bearing tests were conducted. Following the previous study, single-lap bolted joint tests were designed. Various bearing tests were carried out with the number of bolt holes, pre-torque, and countersunk bolt as experimental variables. The bearing strength was not significantly different in the case of 1 bolt hole and 2 bolt hole. Bearing strength increased as the pre-torque increased. Through the bearing tests, bearing failure mode could be observed with designed e/D ratio.

Keywords: Carbon-epoxy composite, Bolted joints, Single-lap, Bearing failure

Fig. 1 OM images obtained from a cross-section of the tested bolted joints.
Die Drawn PP/POE Blends: Toughening and Reinforcing

Pingping Wu, Qi Yang*, Zhongguo Zhao, and Tongying Zhang

College of Polymer Science and Engineering, the State Key Laboratory for Polymer Materials Engineering, Sichuan University, Chengdu, China.

*Email: yangqi@scu.edu.cn

Abstract

Polypropylene (PP) is notch sensitive and poor impact resistance under severe conditions, which has limited its applications in engineering fields. Toughening by poly(ethylene-co-octene) (POE) has been considered the most effective way1-3. The tensile strength and the modulus decrease correspondingly with progressive addition of POE for polymer blends. Orientation structure can bring about obvious property enhancement in polymers. Polymer via solid die drawing, which implements above Tg and below Tm, can easily introduce and reserve orientation structure in blends. In this study, highly orientated uncross-linking and cross-linking PP/POE blends were prepared by a self-design apparatus. The results showed that the addition of POE improved the impact properties significantly, whereas tensile strength and modulus decreased. After adding cross-linking agent, simultaneous toughening and reinforcing could be realized. Moreover, the two-step cross-linking modification could improve toughness and strength further than one-step cross-linking process. High density polyethylene (HDPE) together with POE could have synergistic toughening effect.

Keywords: Isotactic polypropylene, Poly(ethylene-co-octene), Reinforcing; Toughening, Die drawing
Curved Stiffener Design for Grid-Stiffened Composite Structures

Dan Wang¹*, Mostafa Abdalla², Zhenpei Wang³, and Zhoucheng Su¹

¹Institute of High Performance Computing, Agency for Science, Technology and Research, Singapore
²Zewail City of Science and Technology, Sheikh Zayed District, Giza, Egypt
³Department of Civil and Environmental Engineering, National University of Singapore, Singapore

*Email: wangdan.npu@gmail.com

Abstract

Grid-stiffened composite structures have gotten renewed interests due to their exceptional performances. The configuration made of both the composite skin and multiple intersected stiffeners provides plenty of opportunities for optimization. In this work, curved and non-uniformly distributed stiffeners are used as substitutions of the conventional straight stiffeners. The curved stiffeners are classified into different groups and then defined according to the streamline analogy to realize an arbitrary stiffener layout. The calculation is implemented on a homogenization-based global/local model with equivalent material properties from local representative cell configurations (RCCs). Parallelogram RCCs are assumed to obtain analytical sensitivities with respect the stiffener spacings and orientations. The optimization is done to maximum the critical buckling load of the structures with the structural weight constrained. At the same time, the stiffener spacings are also constrained in the design process on one hand to meet the manufacturing requirements and on the other hand to avoid local buckling in cells. Numerical examples show the effectiveness of the proposed method for curved stiffener design.

Keywords: Curved stiffener, Optimization, Bucking, Grid-stiffened composite structures
Study on CFRP-to-CFRP Joining with Fiber Metal Laminates for Improvement of Fatigue Strength

Dong-Woo Lee, Chang-Uk Kim, and Jung-Il Song*

Department of mechanical engineering, Changwon National University, South Korea
*Email: jisong@changwon.ac.kr

Abstract

Carbon Fiber Reinforced Plastic (CFRP) have been widely used due to their high specific strength and stiffness. However, it is very expensive that fabrication of huge structure which made of CFRP. Adhesive joining method have been used to fabricate the CFRP structure for cost reduction. But it has been reported that CFRP adhesive joining structure have relatively less fatigue strength due to their joining area. In this study CFRP-to-CFRP joint method was investigated to improvement of fatigue strength. Fiber Metal Laminates (FMLs) structure was adopted in CFRP-to-CFTP joining area. Mild steel sheet was inserted between upper CFRP and lower CFRP plate for connection of below two plates. After single strap joint specimens were fabricated using Vacuum assisted Resin Infusion (VaRI) process. The mechanical properties and fatigue strength were compared with conventional single strap joint method. The results show that FMLs structure is effective for improvement of fatigue strength due to their ductility and stiffness. This joining method can be applied to CFRP assembly structure which demand the fatigue strength.

Keywords: CFRP-to-CFRP, Joining, Fiber metal laminates, Fatigue strength

Fig. 1 Dimension and laminate sequence of single strap joint specimen.
Fabrication of Fiber-Metal Laminates and Study Impact Behavior through Fem Analysis

Byungjin Park\(^1\)*, Dongwoo Lee\(^1\), Sangyun Park\(^2\), and Jungil Song\(^1\)*

\(^1\)Department of mechanical engineering, Changwon National University, South Korea
\(^2\)Hyundai Automotive Research & Development Division, Hyundai-Motor Company, South Korea

*Email: jin91120@naver.com, and jisong@changwon.ac.kr

Abstract

Fiber-Metal Laminates (FMLs) are composite materials in which metal and fiber are alternately laminated. FMLs have excellent mechanical properties along with lightweight and impact resistance. In the automobile industry, the impact resistance and light weight composite materials were mainly applied to interior parts of automobiles and recently, started structural parts instead of metal components too. Hence, present study focused on manufacturing of FML by using CFRP and steel and optimization of the manufacturing process of Autoclave and to prevent the delamination between the fiber and the steel layer, adhesive film was used. In order to confirm the relation between fiber direction and impact damage, the listed patterns as tabulated in Table 1 were chosen and conducted drop weight impact test. The impact behavior was explained by comparing cracks and load-displacement curves generated in the lower part of the test specimens. In addition, the absorbed energy of each case obtained from the experiment was compared with the FEM analysis value and the excellent impact resistance of FMLs was confirmed by comparing with steel.

**Keywords:** Fiber-steel laminates, Low velocity impact, FEM analysis, Drop-weight impact

<table>
<thead>
<tr>
<th>Case</th>
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<td>S/90/0/90/S</td>
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Table 1 Laminated patterns of Fiber-Steel Laminates (FMLs).
Effect of 2.5D Braided (Shallow Bend-Joint) Fabric Parameters on the Fiber Volume Fraction

Tianru Guan* and Zhaofeng Chen

College of Material Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing, China

*Email: guantianru@nuaa.edu.cn

Abstract

This research paper establishes the relationship between fabric parameters and fiber volume fraction through analyzing representative unit cell of the Two-and-a-half-dimensional (2.5D) shallow bend-joint preform. A piece of 2.5D shallow bend-joint fabric was manufactured by quartz fiber to verify the fiber volume fraction. The reason of difference between prediction result and experimental result was analyzed. The paper also reports on a theoretical study to evaluate the effect of fabric parameters on the fiber volume fraction. It is found that as warp yarn density and Tex no. increase and fabric thickness decreases, the overall fiber volume fraction and warp yarn fiber volume fraction increase, but weft yarn fiber volume fraction decreases. Warp yarn has greater influence on fiber volume fraction of fabric than weft yarn. The more compact the fabric is, the higher the overall fiber volume fraction is.

Keywords: 2.5D shallow bend-joint, Fabric parameters, Fiber volume fraction, Representative unit cell

Fig. 1 Photograph and structure of 2.5D (shallow bend-joint) fabric (a: Three-dimensional view of the fabric; b: Schematic diagram of 2.5D shallow bend-joint fabric; c: Surface photography of the fabric).
Session: Sandwich and Foam Structures
Struc-3-1-I1

Sandwich Plates with Miura-Ori Foldcore under Quasi-Static Loadings
Xinmei Xiang¹, Guoxing Lu²*, and Zhong You³

¹Faculty of Science, Engineering and Technology, Swinburne University of Technology, Hawthorn, VIC, Australia.
²Faculty of Science, Engineering and Technology, Swinburne University of Technology, Hawthorn, VIC, Australia.
³Department of Engineering Science, University of Oxford, Oxford, UK.
*Email: glu@swin.edu.au

Abstract
Sandwich structures are widely used in industries, such as aerospace, satellite, automotive, etc. due to their high energy absorption capacity and excellent bending strength with light weight. Miura-ori foldcore, which is fabricated by folding the sheet along a pattern with straight and zigzag creases, may provide acoustic and heat insulation and act as energy absorbers. Compared with honeycomb core, air ventilation to avoid deterioration caused by long term moisture exposure is an additional advantage of foldcores. This research presents finite element analysis (FEA) using ABAQUS/Explicit and theoretical analysis on rectangular sandwich plates with Miura-ori folded core. Parametric study was conducted in terms of the sector angle, lateral dihedral angle and side lengths. Two loading conditions were studied: three-point bending and uniformly distributed pressure loading. Load-displacement curves were obtained and energy absorption performance was assessed. In addition, theoretical analyses were conducted based on the plastic hinge theory and they matched well with the results from FEA. Furthermore, fully plastic bending moment of the sandwich plate and critical stress of the incipience of core buckling were calculated.

Keywords: Miura-ori core, Three-point bending, Uniformly distributed pressure, Energy absorption

Fig. 1 Deformed shape of a sandwich panel ($\phi = 75^\circ$ and $\phi_A = 83^\circ$) under three-point bending: (a) $d = 0$ mm; (b) $d = 2.4$ mm; (c) $d = 15.6$ mm; (d) $d = 36$ mm.
An Experimental and Numerical Study on the Performance of Composite Corrugated Core Structure under Compression Load with Various Support Conditions

Sartip Zangana¹*, Jayantha Epaarachchi¹, Peter Schuble¹, X. Zeng¹, J. Leng²

¹Centre of Future Materials, University of Southern Queensland, Australia
²Centre of composite materials and structures, Harbin institute of technology, Harbin, China

*Email: Sartip.zangana@usq.edu.au

Abstract

Lightweight composite corrugated core sandwiches are gradually making inroads to construction of high-performance sandwich panels, which has comparatively high stiffness to weight ratio. This paper aims to investigate experimentally and numerically the influence of the elastic foundation (support span) on mechanical performance of trapezoidal woven GFRP corrugated core sandwich (TCS) under quasi-static load. The results revealed that the support span (SS) has a significant influence on the TCS’s structural stiffness, and structural ductility. It has been shown that the energy absorption by the TCS due to quasi-static loading was highly dependent on the supporting span. Interestingly, the FEA results were in excellent agreement with the experimental outcomes. This is also confirms the robustness of the finite element model as an effective design tool for development and optimization of TCS.

Keywords: Corrugated core structure, Structural stiffness, Structural ductility; Energy absorption; support span

Fig. 1 The experimental set-up on one unit cell with using a servo-hydraulic uniaxial material testing machine MTS 100kN.
Investigation of Nickel Plated Luffa Sponge

Sha Yin1,2, Huitian Wang1,2, and Jun Xu1,2*

1Department of Automotive Engineering, School of Transportation Science and Engineering, Beihang University, Beijing, China
2Advanced Vehicle Research Center, Beihang University, Beijing, China
*Email: junxu@buaa.edu.cn

Abstract
Natural materials often possess excellent properties because of their intrinsic micro-structures and bio-inspired engineering materials that can mimic their thorough structure is generally difficult to synthetic. In this study, novel cellular materials were fabricated using luffa sponges as templates through electroless- and electro-plating. Morphology and chemical composition of nickel plated luffa sponges were characterized by SEM and XRD. Then, mechanical properties of these biomaterials by electroless- and electro-plating were tested under quasi-static compression and compared with natural luffa sponges. The results showed that nickel-plated luffa sponges were stronger than natural ones, and also exhibited a long stress plateau during compression. Alkali treatment before plating was proved to be important for the interfacial properties and thus mechanical properties of those luffa sponge based biomaterials.

Keywords: Biomaterials, Cellular materials, Plating. Energy absorption

Fig. 1 Nickel plated luffa sponge.
Shear Properties of Kenaf/Polypropylene Honeycomb Core
Nabihah Sallih1,2*, Peter Lescher1, and Debes Bhattacharyya1
1Centre for Advanced Composite Materials, The University of Auckland, Private Bag, Auckland, New Zealand
2Department of Mechanical Engineering, Universiti Teknologi PETRONAS, Perak, Malaysia
*Email: nabihah.sallih@utp.edu.my

Abstract
Light weight and sustainable sandwich panels are increasingly sought for an extensive range of applications, from structures in airliners to wall linings in buildings. A study on shear properties of honeycomb cores manufactured from kenaf/polypropylene sheets has been conducted. The influences of directionallities, cell wall thicknesses, and core depths on the stiffness and strength of the cores have been examined. The use of honeycomb cores with thicker (1.2 mm) cell walls resulted in higher absolute shear strengths while those with thinner (0.6 mm) cell walls resulted in higher specific shear strengths. Cores with thicker cell walls demonstrated noticeably higher (≈ 29-34%) absolute and specific shear strengths when the depth of the cores was set to 20 mm (in comparison to those of 30 mm deep cores). The shear moduli of cores with thicker cell walls tended to be sensitive to the core directionality while such sensitivity diminished for cores with thinner cell walls. This is due to the less-than-perfect manufacturing which was worse with thicker walls. The thinning at the bends of F-TMD corrugated sheets appeared to be a major flaw and resulted in a significant reduction in shear properties of the resultant cores.

Keywords: Shear properties, Natural fibre, Honeycomb, Composites

Fig. 1 Typical shear stress-strain plots for sandwich panels made of aluminium face sheets and kenaf/PP cores of various combinations of directionality, cell wall thickness and core depth. The asterisk (*) marks that the reported values may not reflect their actual shear strengths.
Abstract

In this work the damage tolerance of PMI-foam filled sandwich panels against delamination propagation was investigated. The use of structural sandwich elements is a highly competitive design option due to their structural performance and multifunctional capabilities. However, one disadvantage of foam core materials in sandwich application is its weak performance in skin-core bond which causes delamination. Hence, knowledge of a laminate composite material’s resistance to interlaminar fracture is crucial for product development and material selection. This study focuses on the effect of foam core properties, such as core density, its geometrical cell properties, use of adhesive material and type of manufacturing process on the Mode I interlaminar fracture toughness between carbon fibre composite face and foam core. To investigate the effect of the manufacturing process on the skin-core bond, panels manufactured in an out-of-autoclave process, were compared to autoclave manufactured sandwich structures. It was found that the interfacial fracture toughness in the sandwich is not only depended on the foam density, but also on the cell architecture of the foam within one density. The sandwich fracture toughness values were significantly higher with increasing cell wall thickness and size due to the adhesive penetration depth. The application of adhesive film between face and core proved to be only beneficial (up to 150% improvement) in sandwich structures with higher density. The majority of sandwiches manufactured using the out-of-autoclave QuickstepTM process provided higher peel torque values than panels produced in the autoclave, indicating damage of the cell structure due to higher production pressure.

Keywords: Fracture toughness, Sandwich, Foam, Core density
Compressive Performance of Bio-Inspired Novel Honeycombs
Jun Xu\textsuperscript{1,2}, Yaobo Wu\textsuperscript{1,2}, Luming Wang\textsuperscript{1,2}, and Sha Yin\textsuperscript{1,2}\textsuperscript{*}

\textsuperscript{1}Department of Automotive Engineering, School of Transportation Science and Engineering, Beihang University, Beijing, China
\textsuperscript{2}Advanced Vehicle Research Center, Beihang University, Beijing, China
*Email: shayin@buaa.edu.cn

Abstract
Honeycomb structures are widely used as sandwich panel cores in many industries. However, honeycombs tend to buckle at low density and somehow restricts their crashworthiness capability. In this study, bio-inspired novel honeycombs were designed by integrating tubes into honeycombs with various geometrical configurations, forming novel hollow tube reinforced honeycombs (TRHs). The structures were fabricated by 3D printing and subjected to flatwise compression. Compressive stress-strain responses were obtained with the corresponding failure modes. Finite element models were further established and parametric studies were performed on different TRHs. Results showed that TRHs exhibited advantages in terms of specific strength/stiffness and energy absorption compared with traditional honeycombs. Effects of geometrical parameters, topologies, boundary conditions, tube position and alignment were comprehensively discussed. This work demonstrates that bio-inspired design that capitalize on micro-topologies can populate vacant regions in mechanical properties charts, and provide increased energy absorption as crushing protection structures.

Keywords: Honeycomb, Honeytube, Lattice materials, Mechanical properties, Finite element analysis (FEA)

![Fig. 1 Illustrations for four types of honeytubes: (a) Sq_symtube, (b) Sq_udtube, (c) Kag_udtube, (d) Tri_udtube, with (i) 3D view, (ii) top view and (iii) representative unit cell of these honeytube structures.](image-url)
An Experimental Study on the Physical and Mechanical Properties of B₄C/Cf/Pi/Aa6061 Hybrid Composites with Various Configurations

Xuelong Fu¹,²*, Huaguan Li¹, and Jie Tao¹

¹College of Material Science & Technology, Nanjing University of Aeronautics & Astronautics, Nanjing, China
²Department of Mechanical & Electronic Engineering, Jiangsu Polytechnic of Finance & Economics, Huai’an, Jiangsu, China

*Email: 308851010@qq.com

Abstract

The effects of boron carbide (B₄C) particles in the adhesive layer on the physical and interfacial bonding properties of hybrid composites were systematically investigated. Co-mixing composites were composed of polyimide (PI) resin and B₄C particles at weight ratios of 90:10, 80:20, 70:30, 60:40 and 50:50. The effects of alkoxysilane coupling agent KH550 on the chemical structures were also examined using Fourier Transform Infrared (FTIR) Spectroscopy. The testing results showed that, addition of alkoxysilane coupling agent was helpful to improve the interfacial adhesion between PI resin and B₄C particles, and the peak at 2932.12 cm⁻¹ was emerged which corresponded to the C-H antisymmetric stretching vibration peak of -CH₂ group. The single-lap-shear (SLS) strength of specimens was firstly increased and then decreased with the increasing fraction of B₄C particles, and the maximum value appeared at 30wt% B₄C. It is analyzed that physical crosslinking structure between B₄C particles and PI resin is formed, which can effectively prevent the formation of crack and fracture in the adhesive layer under the action of tensile stress.

Keywords: Hybrid composite, FTIR spectra, Single-lap-shear (SLS) strength
Preparation of SiC Nanowires/Carbon Flexible Composites Foam via CVI Method with Ni Catalysis

Junxiong Zhang*, Zhaofeng Chen*, Xinli Ye, and Songbai Xue

MIIT Key Laboratory of Material preparation and protection technology facing harsh environment, International Laboratory for Insulation and Energy Efficiency Materials and Jiangsu Collaborative Innovation Center for Advanced Inorganic Function Composites, College of Materials Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing, China

*Email: zhangjunxiong126@163.com, and czf_msc@nuaa.edu.cn

Abstract

A novel flexible foam of SiC nanowires/carbon composites was prepared by the chemical vapor infiltration (CVI) with Ni catalysis. Melamine based carbon foam (MCF) was utilized as the flexible matrix. The typical structure of this composites foam was the MCF matrix with porous skeletons covered with numerous SiC nanowires, and the porosity of the foam was filled with SiC nanowires. The composites foam possessed a density range from 5.49 mg/ml to 10.9mg/ml. The MCF matrix was amorphous carbon and the SiC nanowires was $\beta$-SiC characterized by the XRD.

Keywords: SiC nanowires, MCF, SiCnw/MCF composites foam, CVI

Fig. 1 Photos of samples and relative morphology of SiC nanowires covered on the MCF skeleton, (a) Photos of samples, (b) morphology of MCF, (c)morphology of sample A, (d) morphology of sample B.
Abstract

Hierarchical designed structures in nature often display remarkable mechanical properties including high structural efficiency. In this study, hierarchical octet-truss lattice structures were fabricated by additive manufacturing, and mechanical properties were studied using analytical, numerical and experimental methods. The experimental results and theoretical analysis of quasi-static compression indicated that the failure mode of hierarchical lattice changes with strut slenderness ratio in different hierarchical levels. Mechanical properties of hierarchical lattice can outperform those of non-hierarchical lattice through serious geometrical design. A beam-element finite element model was developed with LS-DYNA to further examine effects of geometrical parameters (such as inclination angle of lattice members). Besides, how hierarchical lever and truss configuration in each hierarchical order affect the compressive performance was also studied with the numerical method. This work will provide insights on the role of hierarchical design to regulate mechanical properties of such mechanical metamaterials which are desirable for a range of lightweight material applications.

Keywords: Lattice materials, Architected materials, Hierarchy, Mechanical behavior, 3D Printing

Fig. 1 Experimental and Numerical study of hierarchical octet-truss materials under quasi-static compression.
A Novel Hierarchical Thermoplastic Composite Honeycomb Cylindrical Structure: Fabrication and Axial Compressive Properties

Liming Chen*, Wenjun Wu, Bing Du, and Houchang Liu
Chongqing Key Laboratory of Heterogeneous Material Mechanics, College of Aerospace Engineering, Chongqing University, Chongqing 400030, China
*Email: clm07@cqu.edu.cn

Abstract
A novel hierarchical thermoplastic composite honeycomb cylindrical structures (HTCHCS) with recyclability were designed and fabricated using interlocking assembly technique as shown in Fig 1. The quasi-static axial compression tests were conducted to investigate the mechanical response and energy absorption of HTCHCS. The structural crushing force efficiency can be risen from 0.35 to 0.67 after optimizing the placement mode of axial ribs. The deformation of HTCHCS were experimentally and numerically studied and typical deformation modes of two kinds of HTCHCS were obtained. Different from the layer-by-layer collapse for HTCHCS with regular ribs, HTCHCS with staggered ribs showed negative Poisson’s ratio deformation. Excellent deformation recovery over 90% initial height was found and then reloading property of HTCHCS was also investigated. Reloading carrying and energy absorption abilities can reach to 40% and 35% of initial ones respectively.

Keywords: Hierarchical, Thermoplastic, Cylindrical structures, Negative Poisson’s ratio, Deformation recovery

Fig. 1 The schematic of (a) regular HTCHCS, (b) staggered HTCHCS and (c) improved staggered HTCHCS.
Local Impact Resistance of Singly Curved Sandwich Panel with Composited Honeycomb Core

Jiefu Liu\textsuperscript{1,2*} and Zhonggang Wang\textsuperscript{2}

\textsuperscript{1}School of Civil and Mechanical Engineering, Curtin University, Australia
\textsuperscript{2}School of Traffic & Transportation Engineering, Central South University, Changsha, China

*Email: 274275C@curtin.edu.au

Abstract
Curved sandwich panel is naturally granted with better load carry ability compared to other structural panel subjected to impact load due to spatial curvature as illustrated in Fig 1. To overcome the disadvantage of mechanical instability of curved sandwich panel with hexagon honeycomb core, a composited honeycomb core consist of outer honeycomb container and inner circular tube has been proposed. As shown in Fig 2, to keep the effective hexagon configuration of honeycomb, a curve-like cutting profile will penetrate the honeycomb cube, next each cell will be filled into circular tube. Inner circular tube plays like an extra skeleton which could be benefit for the deformation resistance of honeycomb core, while interaction between circular tube wall and honeycomb foil obviously improving the impact kinetic absorption. Local impact resistance performance of singly curved sandwich panel considering global bending of panel, local indentation and energy absorption will be discussed. The comparison study will be carried out between flat panel and curved panel with monolithic honeycomb core, furthermore, to study the influence of filling mode on the curved panel, comparison between curved panel with monolithic honeycomb core and composited core will also be presented.

Keywords: Curved sandwich panel, Honeycomb, Local impact, Composited structure

Fig. 1 Comparison of response behaviour of honeycomb and HFCT under local impact load.
Numerical Simulation on Residual Stresses of TiGr During the Curing Process
Yingmei Xu, Huaguan Li, and Jie Tao*

College of Material Science and and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing, China
*Email: taojie@nuaa.edu.cn

Abstract
Residual stresses are inevitably produced in the Ti/CFRP laminates (TiGr) during the manufacturing process, owing to the different thermal expansion coefficients of the constituents. The residual stresses state requires further investigation since it significantly affect the properties of the laminates. A finite element model was established to simulate the residual stress of 2/1TiGr in the cooling process from glass-transition temperature ($T_g$) to ambient temperature. Distributions of residual stresses in each ply have been obtained, and the cohesive element was applied to simulate the interlaminar stresses. Also, the free boundary problem, usually led to the generation of cracks, was observed especially in the edge vertical to the fiber direction. These are in good agreement with the analytical and experimental results, which demonstrated that the established model and corresponding simulation is effective to describe residual stresses in TiGr.

Keywords: Numerical simulation; Finite element; TiGr; Residual stress; Cohesive element

Fig. 1 Distribution of residual stresses along fiber direction (1/4 part of the laminate).

(a) Titanium

(b) CFRP composite
Improved Ferroelectric and Leakage Current Behavior of 
(Ba$_{0.65}$Sr$_{0.35}$)TiO$_3$/ (Bi$_{0.875}$Nd$_{0.125}$)FeO$_3$/ (Ba$_{0.65}$Sr$_{0.35}$)TiO$_3$

Sandwich Structured Thin Films

Cai-Bing Ma$^1$, Xin-Gui Tang$^*$, Q.X. Liu$^1$, Y.P. Jiang$^1$, L. Luo$^1$ and L.L. Jiang$^2$

$^1$School of Physics & Optoelectric Engineering, Guangdong University of Technology, Guangzhou, Higher Education Mega Centre, Guangzhou, China

$^2$Laboratory Teaching Center, Guangdong University of Technology, Guangzhou Higher Education Mega Center, Guangzhou, China

*Email: xgtang@gdut.edu.cn

Abstract

A multiferroic trilayered structure composed of a (Bi$_{0.875}$Nd$_{0.125}$)FeO$_3$ (BNF) layer and two (Ba$_{0.65}$Sr$_{0.35}$)TiO$_3$ (BST) layers are grown on a Pt/Ti/SiO$_2$/Si substrate by rf-magnetron sputtering. For the comparison, single-layered BNF was also prepared on the same substrates. The result shown that the trilayered BST/BNF/BST exhibits a quite lower leakage current (10$^{-8}$A/cm$^2$ at electric field 100 kV/cm) and dielectric loss (0.0012 at 100 kHz) at room temperature, enhanced ferromagnetic and ferroelectric properties. The remnant polarization and coercive field were 2.668 $\mu$C/cm$^2$ and 9.137 kV/cm, and the remnant magnetization and the coercive magnetic field of the BST/BNF/BST film are 10.06 emu/cm$^3$ and 351.33 Oe, respectively. We considered that the bismuth's volatilization was limited by BST layers making the Bi/Fe in good station and the action of BST in the charge transfer between BNF and electrode leaded to the quite low leakage current and enhanced ferroelectric property.

Keywords: Multiferroic, Low dielectric loss, Leakage current, Ferromagnetic, Ferroelectric

Fig. 1 (Left) The dielectric constant ($a$) and loss tan$\delta$ ($b$) versus frequency for BST, BNF and BST/BNF/BST films on Pt/Ti/SiO$_2$/Si substrates. (Right) J-E characteristics of BNF and BST/BNF/BST films on Pt/Ti/SiO$_2$/Si substrates.
The Shot Peen Forming of Fiber Metal Laminates Based on the Aluminum-Lithium Alloy-Deformation Behavior

Huaguan Li$^{1,2}$, Yi Lu, Xiaoge Hua$^2$, Zhengdong Han$^2$, Xiaocun Xu$^2$, and Jie Tao$^{2*}$

$^1$Jiangsu Key Laboratory of Advanced Structural Materials and Application Technology, Nanjing Institute of Technology, Nanjing, China

$^2$College of Material Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing, China

*Email: taojie@nuaa.edu.cn

Abstract

The deformation behavior of the novel fiber metal laminates based on aluminum-lithium alloy (NFMLs) during the shot peen forming was investigated to seek a desired forming method. The results indicated that shot peen forming was suitable to manufacture the NFMLs component. Good forming effects could be achieved using the small-sized (diameter $\leq$ 0.425mm) ceramic ball. The forming curvature of 3/2 cross-plied NFMLs had been reduced to 165.24mm successfully using AZB425 ball under the intensity of 0.193A. For the deformation characteristics, NFMLs was inclined to deform perpendicular to fiber direction. Meanwhile, plastic deformation was only produced in the shot peened metal layer, while elastic deformation in other layers. Furthermore, comparing with metal materials, NFMLs possessed similar deformation rules following the variation of shot peen intensity and coverage. Besides, shot peening significantly changed the residual stress state of NFMLs, and the stress relaxation was negligible without the external force or thermal field.

Keywords: Fiber metal laminates, Aluminum-lithium alloy, Shot peen forming, Deformation behavior

Fig. 1 The production line of shot peen forming and NFMLs strips: (a) the production line of shot peen forming, (b) NFMLs strips.
Experimental And Numerical Investigation on Effect of Impact Damage on Bending Elastic Modulus of CFRP

Mamoru Mizuno*, Masahiro Hosoi, and Jian Shi

Department of Machine Intelligence and Systems Engineering, Akita Prefectural University, Japan

*Email: mizuno@akita-pu.ac.jp

Abstract

In order to clarify the effect of impact damage on bending elastic modulus of CFRP laminated plates, drop-weight impact tests and three-point bending tests were performed. Then the bending elastic modulus was estimated by finite element analysis by taking into account the internal damage. CFRP laminated plates were subjected to impact loading with different energy by a drop-weight impact testing machine, and internal damage was evaluated by cross-sectional observation. Bending elastic modulus of the damaged plate was measured by three-point bending test, and the change in the modulus due to the damage was clarified experimentally. Then three-point bending test for CFRP laminated plates was simulated by finite element method, and overall bending elastic modulus was estimated numerically. In the simulation, delamination and transverse cracks were taken into account as artificial internal damage, and the number and location of the damage within the laminates were changed systematically. Fig 1 shows bending elastic modulus for CFRP laminated plates with various internal damage and an undamaged plate. Fig 2 shows experimental and numerical results for bending elastic modulus of damaged plates. The numerical results for CFRP laminated plates with internal damage corresponding to damaged specimens agree with experimental results.

Keywords: CFRP, Impact damage, Bending elastic modulus, FE analysis

![Fig. 1](image-url)  
(a) Numerical results for change in bending elastic modulus due to delamination (DL), transverse cracks (TC) and their combination (UD: undamaged).  
(b) Comparison of bending elastic modulus between experimental results and numerical ones considering internal damage depending on impact energy.
Modelling Damage Initiation and Evolution in Composite Laminates under Cyclic Loading

Marino Quaresimin*, Paolo Andrea Cararro, and Lucio Maragoni

Department of Management and Engineering, University of Padova, Vicenza, Italy

*Email: marino.quaresimin@unipd.it

Abstract

The development of fatigue damage in composite laminates is characterised by multiscale and hierarchical processes, from damage initiation at the microscopic scale to the onset and propagation of macro (visible) cracks and delaminations, that degrade the global elastic properties of a laminate and promote the final failure. For a safe and reliable design against fatigue degradation and failure, the entire damage process must be modelled, to predict the cycles spent for the first crack initiation ($N_{ci}$), for crack multiplication and propagation ($N_{cp}$), for the initiation and propagation of delaminations ($N_{di}$ and $N_{dp}$), and eventually the final failure (Fig. 1). An overview is given here on the authors’ recent work concerning the development of a damage-based design procedure to predict damage evolution and the stiffness degradation in composite laminates. The main pillars of this procedure are the definition of a criterion for off-axis crack initiation based on the use of local stress parameters, the development of a procedure for predicting the crack density evolution and then the stiffness degradation using the crack initiation criterion, statistical considerations, stress-redistribution and stiffness models. The inclusion of delaminations in the global framework will also be discussed, and some preliminary work to predict the cycles spent for the final failure of a laminate will be presented.

Keywords: Fatigue, Modelling, Damage evolution

Fig. 1 Schematic of the modelling strategy for the life assessment of composite laminates.
Modelling and Simulation on Fatigue Failure of Composite Bolted Joint Structures with Hygrothermal Effects
Meijuan Shan¹, Libin Zhao¹, Fengrui Liu¹, and Jianyu Zhang²

¹School of Astronautics, Beihang University, Beijing, China
²College of Aerospace Engineering, Chongqing University, Chongqing, China
*Email: mjshan@buaa.edu.cn, and lbzhao@buaa.edu.cn

Abstract
Bolted joints, which are widely used in high-loaded composite structures to satisfy the demands of manufacture, assembly and maintenance, are generally weak parts of the entire structures because of the potential damage caused by the drilling process and the remarkable stress concentration around the fastener hole. Therefore, failure analyses of composite bolted joints under special conditions (e.g. fatigue loading, hygrothermal environment) by numerical modelling and simulation play an important role in designs of composite structures. To simulate the fatigue failure of the bolted joints, a progressive fatigue damage model (PFDM) was proposed. In the PFDM, a residual strain model was presented based on the fatigue-accumulated damage mechanisms of composites and accompanied with a residual stiffness model to evaluate the gradually degraded material properties during fatigue cycles. The residual-strain-based gradual material degradation model was combined with a micromechanics-based sudden material degradation model to describe the damage of composite materials. To consider hygrothermal effects, a unified model was built to evaluate the variation of composite material properties caused by hygrothermal environments. The hygrothermal-induced material properties were utilized in the stress analysis model, material degradation models and fatigue failure criterion. Besides, fatigue tests and progressive fatigue damage analyses of typical joints were performed in both standard and hygrothermal environments, which validated the proposed PFDM. The PFDM-based numerical modelling and simulation revealed the fatigue failure characteristics of composite bolted joints effectively.

Keywords: Composite bolted joints, Residual strain model, Progressive fatigue damage model, Hygrothermal environment, Fatigue life
Prediction of Mechanical Properties of CFRP-Metal Hybrid Composites

Minchang Sung and Woong-Ryeol Yu*

Department of Materials Science and Engineering, Seoul National University, Seoul, South Korea
*Email: woongryu@snu.ac.kr

Abstract
Carbon fiber-reinforced plastics (CFRPs) have attracted much attention from various discipline and many industries due to their excellent mechanical, chemical and thermal properties, in particular, high specific strength. However, CFRPs show a lower fracture strain than other materials such as metals and polymers, resulting in a brittle fracture behavior, which is one of demerits for their practical applications. These limitations can be overcome by hybridizing CFRP with very ductile materials such as metals. Hybridization of CFRP and metal can be a way of developing new materials with all the advantages of both materials. In this study, multi-directional fiber metal laminates (FMLs) were manufactured using unidirectional CFRP. Metal sheets and unidirectional CFRP with various orientations were laminated and bonded by hot-pressing process to fabricate the FMLs. The mechanical properties of multi-directional FMLs were characterized using tensile and bending tests. The fracture strains of multi-directional FML were higher than the fracture strain of 0˚ CFRP composing it, and the increase was dependent on the orientation and volume fraction of the CFRP. Finally, the mechanical properties of multi-directional FMLs were predicted based on the global load sharing model used to predict the properties of CFRP. The experimental and predicted values of the variations in the mechanical properties of the FML according to the structure were reasonably consistent.

Keywords: Carbon fiber reinforced plastic, Fiber metal laminate (FML), Multi-dimensional CFRP, Lightweight materials, Synergist
Maximizing the Translaminar Fracture Toughness with a Variable-Axial Reinforcement Design

Jose Humberto Almeida Jr., Lars Bittrich, and Axel Spickenheuer

Composite Materials Department, Leibniz-Institut für Polymerforschung Dresden e. V. – IPF, Dresden, Germany

*Email: jhsajunior@globomail.com

Abstract

Translaminar fracture in continuous fiber-reinforced polymers (CFRPs) refers to a fracture mode in which a crack grows through the laminae, along the fiber direction, thereby fiber breakage is the main role. Taking inspiration from biological-materials (e.g., wood and nacre), accurately tailoring the reinforcement may improve the toughness. This work proposes a methodology to design and analyze the fracture toughness associated with the fiber tensile failure in compact tension (CT) specimens employing a variable-axial (variable-stiffness) fiber reinforcement design concept, taking into account local adjustment of both fiber angle and thickness distribution within the lamina level, aiming at achieving more damage tolerant structures. The fracture response and crack growth are predicted numerically via three approaches: (i) eXtended Finite Element Method (XFEM), (ii) Virtual Crack Closure Technique (VCCT), and (iii) Cohesive Zone Method (CZM). The finite element (FE) mesh, as well as the boundary conditions applied in the CT specimen is shown in Fig 1. Fiber preforms are manufactured via Tailored Fiber Placement (TFP) following the optimum fiber path previously determined. Later on, the preform is vacuum-assisted infused with an epoxy matrix for 12 h followed by post-curing. After that, experimental tests are carried out. The crack growth and the pin opening displacement are collected via a digital image correlation (DIC) system. The variable-axial specimen optimized following the Direct Fiber Path Optimization (DFPO), proposed by the authors, has higher toughness when compared to a unidirectional fiber configuration. In addition, numerical predictions performed with XFEM generate more accurate predictions regarding crack growth and toughness.

Keywords: Translaminar fracture toughness, Damage tolerance, Variable-axial fiber design, optimization, Tailored fiber placement

Fig. 1 Finite element mesh highlighting boundary conditions and crack growth area with a fine mesh.
Equivalent Modeling for Composite Material Thin-Wall Bolted-Joint Structures Based on the Multi-Point Coupling Element

Maoqing Fu¹*, Guodong Fang¹*, Jun Liang²*, Zengwen Wu¹*, and Shuo Liu¹*

¹Science and Technology on Advanced Composites in Special Environments Key Laboratory, Harbin Institute of Technology, Harbin, China
²Institute of Advanced Structure Technology, Beijing Institute of Technology, Beijing, China

*Email: fmqsimon@126.com, fangguodong123@163.com, Liangjun@bit.edu.cn, springwzw@126.com, and langfangliushuo@163.com

Abstract

In order to improve the computational efficiency for composite material thin-wall bolted-joint structures, it is necessary to establish the equivalent model for the complex bolted-joint structures. Generally, the connection equivalent stiffness in the equivalent treatment methods is depended on the test results. Based on the multi-point coupling element and the standard of VDI2230 for the steel plate, the equivalent axial, bending and shear connection stiffness model for composite material thin-wall bolted-joint structures were obtained. The ratio of the equivalent axial connection stiffness and normal contact stiffness of the joint structures is used to distribute the preloading, which is a dualistic fraction distribution function in the present study. As for composite material thin-wall bolted-joint structures, the axial stiffness, bending stiffness and shear stiffness are obtained by all axial moduli, all axial tensile moduli and the corresponding direction shear modulus, respectively. The suitability and rationality for the connection stiffness used in the equivalent modelling is verified in the composite material thin-wall bolted-joint structures with bending load.

Keywords: Multi-point coupling element, Multi-point coupling element, Bolted joints, Equivalent connection stiffness
Abstract

Analysing and controlling the microscopic structures considering variability or uncertainty by computational tools are the important key to improve the properties of composite materials. In this study, the first-order perturbation based stochastic homogenization method was used with the help of finite element method considering many random physical parameters for the constituent materials of short fibre reinforced plastics. Especially, a new computational method to analyse the microscopic strain under given macroscopic strain condition is proposed in this paper. Following this, the prediction of damage propagation in the fibre/matrix interphase was carried out in a stochastic way for a single short fibre model as shown in Fig. 1.

Keywords: Stochastic homogenization method, Short fibre reinforced plastics, Fibre/matrix interphase model, Finite element method

Fig. 1 RVE model of short fiber reinforced plastics.
Multi-Scale Finite Element Simulation of Triaxially Braided Composites

Chao Zhang*, Zhenqiang Zhao, and Haoyuan Dang

School of Aeronautics, Northwestern Polytechnical University, Xi’an, Shaanxi, China

*Email: chaozhang@nwpu.edu.cn

Abstract
Carbon-fibre reinforced textile/braided composites are being gradually used in aerospace and automotive structures to resist external impact load due to their outstanding impact resistance. For instance, the two-dimensional triaxially braided composite (2DTBC) is introduced to fabricate engine fan case structure, which exhibits excellent damage tolerance and reduces significantly the weight of the aero-engine. In this work, a multi-scale method is proposed to investigate the impact response of 2DTBC. Micromechanical model is used to obtain the properties of fibre tows based on the properties of fibre and matrix extracted from literature. Then, a validated meso-scale finite element (FE) model is adopted to simulate the failure behavior of the braided composites under different load conditions, taking into consideration the realistic test boundary conditions. Finally, an enhanced macro-scale subcell model for a six-layer braided composite plate is developed to study the impact behavior of the 2DTBC. The homogenized material properties of the subcell model is acquired by using a volume averaging method from the effective stress-strain responses of the subcell elements. The presented modeling framework presents a new tool for impact simulation of textile composites and shows advantages in capturing the failure initiation and progression during an impact load. The impact simulation results compare well with the experimental results and provide insights on the impact failure characters of this material.

Keywords: Multi-scale model, Impact behaviour, Progressive damage, Braided composites, Engine fan case

Fig. 1 Scheme of multi-scale modelling framework for triaxially braided composite.
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Three-Dimensional Constitutive Model for Woven Fabric-Reinforced Shape Memory Polymer Composites Considering Interfacial Residual Stress

Seok Bin Hong¹, Joon-Hyeok Jhang¹, Jin-Gyun Kim², Nam Seo Goo³, and Woong-Ryeol Yu¹*¹

¹Department of Materials Science and Engineering and Research Institute of Advanced Materials, Seoul National University, Seoul, South Korea
²Department of Mechanical Engineering, Kyung Hee University, Gyeonggi-do, South Korea
³Department of Aerospace Engineering, Konkuk University, Seoul, South Korea
*Email: woongryu@snu.ac.kr

Abstract

Structural shape memory polymer composites (SMPC), e.g., carbon fiber-reinforced SMPCs, have been developed to improve the mechanical properties of shape memory polymers (SMPs) and to design and develop new smart devices. For these purposes, the prediction of the mechanical behavior of fiber-reinforced SMPCs is most important, in particular their constitutive modeling. In this study, a 3D constitutive model of woven carbon fiber-reinforced SMPC was developed by extending a phenomenological two-element model (rubber and glassy phases in parallel) already developed for SMP. An element for the woven fiber reinforcement was added in parallel to the previous model. Then, the anisotropic behavior of woven fabric reinforcement such as high stiffness with slight nonlinearity in the warp and weft directions and nonlinear shear behavior was modeled using anisotropic hyperplastic constitutive equation, which were obtained by decomposing total strain energy into warp and weft stretching and fabric shearing energies. Finally, 3D constitutive equation for woven fabric-reinforced SMPCs was obtained by summing the stresses coming from rubbery and glassy phase and from fabric reinforcements considering interface effect by thermal residual stress.

The constitutive equation was implemented into commercial finite element software COMSOL. The shape memory anisotropic bending behavior of woven fabric-reinforced SMPC was simulated and their results were compared with experiments to investigate the validity of the current constitutive model. The consideration of interfacial residual stress was critical to simulate thermodynamic mechanical behavior of woven fabric-reinforced SMPC and details will be presented at the Conference.

Keywords: Shape memory polymer, Woven fabric composite, Constitutive equation, Finite element method
A Novel Constitutive Model for Carbon Fiber Reinforced Shape Memory Polymer Composites

Jianping Gu\(^1\)*, and Huiyu Sun\(^2\)

\(^1\)Jiangsu Key Laboratory of Advanced Structural Materials and Application Technology, School of Materials Science and Engineering, Nanjing Institute of Technology, Nanjing, China

\(^2\)State Key Laboratory of Mechanics and Control of Mechanical Structures, Nanjing University of Aeronautics and Astronautics, Nanjing, China

*Email: gujianping@njit.edu.cn

Abstract

Shape memory polymers (SMPs) are a class of smart materials which can recover a large pre-deformed shape in response to external stimulus. The evident shortcoming of SMPs is that the mechanical properties of these materials are relatively low, which seriously limits the development of this area. Therefore, the carbon fiber reinforced shape memory polymer composites (SMPCs) have been developed to increase the mechanical properties of SMP matrix. In our work, a thermoviscoelastic constitutive model is developed for thermally activated unidirectional continuous carbon fiber reinforced SMPCs based on thermodynamics with internal state variables. It should be noted that the recent works mainly focus on the thermomechanical behavior of carbon fiber reinforced SMPCs in the small strain range, for the allowable tensile strain of carbon fiber is small (about 2\%). In this study, it is theoretically proved that the unidirectional continuous carbon fiber reinforced SMPCs can also be used in finite deformation for the first time with the constitutive model developed in our work.

Keywords: Shape memory polymer, Carbon fiber, Composites, Thermomechanical property

![Fig. 1 1D analogy of the constitutive model for the carbon fiber reinforced SMPCs.](image-url)
Nonlinear Viscoelastic Modelling of Polymers for Simulating Their Rate and Temperature-Dependent Three-Dimensional Deformation Behavior

Wonbo Shim*, Jinhyeok Jang, Jae Hyuk Choi, and Woong-Ryeol Yu

Department of Materials Science and Engineering, Seoul National University, Seoul, South Korea

*Email: woongryu@snu.ac.kr

Abstract

Polymers are being used widely in many areas including fiber-reinforced plastic composites. The mechanical behavior of polymers is known to be time and temperature dependent and can be analyzed using shift factor obtained from dynamic mechanical analysis. For small deformation case, linear viscoelastic constitutive model can predict time- and temperature-dependent mechanical behavior with acceptable accuracy, however it is not suitable for large deformation analysis, e.g., large deformation and failure behavior of structural adhesive. In this study, we developed nonlinear viscoelastic model by modifying Schapery equation for predicting the nonlinear and large deformation of polymers and their failure. Stress relaxation tests were carried out at various strains and parameters in the nonlinear viscoelastic model were obtained as a function of strain. Finally, the nonlinear viscoelastic model was implemented into ABAQUS using user material subroutine. The tensile and shear tests at different strain rates were performed experimentally and were compared with simulated ones. The stress-strain curve obtained from the simulation showed a good agreement with the experiments. Lastly, the mechanical properties of polymers at very high strain rate which is unobtainable by experiment was predicted, demonstrating that the nonlinear viscoelastic model is suitable for simulating time and rate dependent behavior of polymers including failure analysis.

Keywords: Nonlinear viscoelastic model, Schapery equation, Rate and temperature dependent behaviour, Failure analysis
Effects of Strain Rates and Temperatures on fff Axis Failure Mode for Heat Resistant Polymer Matrix Composites
Mio Sato¹*, Sakie Shirai¹, Jun Koyanagi², and Yuichi Ishida³

¹Graduate School of Tokyo University of Science, Tokyo, Japan
²Department of Materials Science and Technology, Tokyo University of Science
³Japan Aerospace Exploration Agency, Japan
*Email: 8216628@ed.tus.ac.jp

Abstract
In the present study, failure mode transition in transverse tensile of unidirectional heat resistant CFRP under various temperatures and strain rates are numerically simulated by finite element analyses. The computational simulation are performed by using a 2D-unit cell model containing 30 fibers and applied periodic boundary condition. In the numerical simulation, interface failure and matrix failure are expressed by cohesive zone modeling and continuum damage mechanics, respectively. In the continuum damage mechanics, Christensen’s failure criterion of multi-axial stress state for each strain rate are applied into the resin properties. It is assumed that cohesive zone modeling has temperature- and time-independent. The time and temperature superposition principle is applied to the relationship between time and temperature. The tensile simulations are performed by various temperatures and strain rates. When temperature is low and/or strain rate is high, interface crack significant, i.e. failure mode becomes interface-crack-dominant mode. On the other hand, when temperature is high and/or strain rate is low, matrix crack occurs very often and the failure mode is matrix-failure-dominant mode. In the experiments, transverse tensile failure test under various temperatures and strain rates are conducted according to analysis conditions in order to verify the validity of numerical simulation.

Keywords: Heat resistant polymer matrix composites, Unidirectional CFRP, Finite element method, Cohesive zone model, Continuum damage mechanics

Fig. 1 Simulation images
Modeling and Simulation of Composite Reticulated Shell Structure Based on Moire’s Circle

Fusheng Zhang¹,², Jiazhong Xu*, Meijun Liu¹, and Hai Yang¹

¹School of Mechanical Engineering, Harbin University of Science and Technology, Harbin, China
²Software college, Harbin University, Harbin, China
*Email: mwzfs@163.com

Abstract

In order to improve the lightweight and bearing efficiency of the composite material component, the geodesic theory, Mohr’s circle analysis theory and computer simulation text are used. Starting from the relationship between minimum strain energy, curvature and modeling direction angle of the composite material net shell structures, research the influence based on the reverse and curvature of the geodesic fiber composite material strips node to the net shell modeling strain energy. Every node of net shells is regarded as a connected Mohr’s circle, the mathematical model of the net shell node strain energy is established. Examples and tests show that because of nodes restrict each other, the minimum strain energy of each node tends to be equalization and relative minimum but not absolute minimum. This research has provided a new idea to realize the ultra-light, high load-carry duty and low calculation cost of the composite material net shells, and a model and method of the structures design and application.

Keywords: Composite material, Mohr’s circle, Net shells, Strain energy, Simulation test

Fig. 1 (a) 3D graphs of the strain energy $G_T(\theta,R_m)$, (b) Contour map of the strain energy $G_T(\theta,R_m)$, (c) Contour line map of local minimum and absolute minimum strain energy $G_T$, and (d) 3D map of local minimum and absolute minimum strain energy $G_T$. 
Fatigue Life Prediction of Composite Materials Based on Ultrasonic Wave Velocity
Jinhao Qiu*, Hongli Ji, and Chongcong Tao
College of Aerospace Engineering Nanjing University of Aeronautics and Astronautics, Nanjing, China
*Email: qiu@nuaa.edu.cn

Abstract
In this paper, the S0-mode lamb wave phase velocity at low frequency range is chosen to characterize fatigue damages accumulated in composite laminates under cyclic loadings. A stiffness/velocity degradation model is proposed based on three distinctive damage mechanisms: fiber breaks, matrix cracks and delamination, all of which are always involved in fatigue damage process. In order to reduce the complexity of the damage model, fiber damage is treated as an independent damage and delamination is coupled with matrix cracks. An approximation of shear-lag model is then proposed to avoid any direct measurements of crack density for it is highly impractical in real applications. Following this, energy release rate for formation of matrix cracks is extracted based on measured phase velocity and damage evolution is realized by incorporating a modified Paris law. Controlled fatigue experiments were conducted where in-situ phase velocity was measured by a laser ultrasonic system. The fatigue damages were then characterized using the proposed damage model with the measured velocity. Finally, a statistical model for fatigue life prediction was established and its ability to predict residual lives of composite materials was validated with good accuracy in the fatigue test.

Keywords: Fatigue life prediction, Composite materials, Ultrasonic wave velocity, Laser ultrasonic technique
Modelling of Organic Flame Retarded Polymers in Building Fires

Timothy Bo Yuan Chen¹, Anthony Chun Yin Yuen¹*, and Guan Heng Yeoh¹,²

¹School of Mechanical and Manufacturing Engineering, University of New South Wales, Sydney, NSW, Australia
²Australian Nuclear Science and Technology Organisation, Locked Bag, Kirrawee DC, NSW, Australia

*Email: c.y.yuen@unsw.edu.au

Abstract

The burning of polymers can be detrimental to the environment and human health. Amongst all the polymer composites, flexible polyurethane (FPU) is the most applied material in soft furnishing. The uses of organic flame retardant (FR) not only avoid the threat of creating halogenated products, the disposal of such materials is also proven to be eco-friendly to the natural inhabitation. However, their wide applications result always with high toxicity emissions in building fires. Therefore, it is essential to create a standardised method to identify the potential risks by characterising their flaming properties and toxicity when exposed to fire. This article presents a generalised approach for assessing fire behaviours and performance of FR polymers. A novel multi-phase porous media pyrolysis model is developed which considers all essential physical phenomena including surface regression, char formation, melting of solids and evaporation, emission of gas volatile, and interaction with the heat feedback from the fire. This model coupled with detailed degradation kinetics extracted from a range of laboratory-scale experiments provides (i) in-depth understanding of interactive chemical and physical fire phenomena between the solid decomposition and flaming processes and (ii) toxic gas emissions, with significant upscaling potential for analysing FR polymers in realistic building fires.

Keywords: Flame retarded polymer, Pyrolysis kinetics; Cone calorimetry; Thermogravimetric; Fire modelling

Fig. 1 Conceptual framework of proposed fire field model.
On the Transition of the Folding Mode for the Foam-Filled Thin-Walled Circular Columns

Fan Yang*, Kun Tian, Qi Zhao, and Yuan Zhang

School of Aerospace Engineering and Applied Mechanics, Tongji University, Shanghai China

*Email: fanyang@tongji.edu.cn

Abstract

Thin-wall columns are widely used to absorb impact energy through progressive folding deformations. Experiments and numerical simulations have shown two basic folding modes for the circular columns, the non-axisymmetric (diamond) mode and the axisymmetric (concertina) mode, depending on the geometry, the boundary condition and the foam filling condition. Based on the kinematically admissible folding mechanisms and the upper-bound theorem, a theoretical model is proposed for the foam-filled circular columns from the energy viewpoint. The interaction between the foam and the outer shell is represented as a pressure applied on the inward bending proportion of the shell. The mean and the instantaneous crushing force as well as the folding mode can be well predicted. Our theoretical model indicates that the progressive folding mode transforms from diamond to concertina when the empty column is filled with aluminium foam of adequate density, which is consistent with the experiment and simulation results.

Keywords: Thin-walled column, Progressive collapse, Collapse mode transition, Foam filling

Fig. 1 Mean crushing force versus (a) column radius and (b) foam yield stress.
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Experimental and Numerical Ablation Study of Low Density Carbon-Phenolic Composites
Wei Li¹, Guodong Fang¹*, and Jun Liang¹,²

¹Science and Technology on Advanced Composites in Special Environments Key Laboratory, Harbin Institute of Technology, Harbin, China
²Institute of Advanced Structure Technology, Beijing Institute of Technology, Beijing, China
*Email: fangguodong123@163.com

Abstract
The lightweight ablators which can decrease the weight of the reentry vehicle’s thermal protect system have been paid more attention by researchers in recent years. The low density carbon-phenolic composites as the typical lightweight ablators have good performance owing to the ablation and heat insulation and have been successfully used in several planet probes. It is necessary to evaluate and predict the performance of the low density carbon-phenolic ablator (LDCA) under severe aerothermal environment in order to be helpful for the design of the thermal protection system in reentry vehicles. In this manuscript, both the experimental and the numerical study for the ablation of the low density carbon-phenolic composites have been carried on. In the experiment, one side of LDCA was heated by the oxyacetylene radiation heating system, and the surface recession distance and the temperature distribution for the composites were measured. Then, the ablator was sliced up in order to observe the micromorphology of the composites with different depth. Furthermore, the mathematical model by the coupled partial differential equations was built for describing the temperature, the inner pressure and the pyrolysis gas velocity for the composites. The mathematical model was solved by the finite element methods. The numerical results of thermal responses coincide with experiment results, showing validity of the model and solver. This research will help on the application of low density ablative composites in aerospace industry.

Keywords: Low-density carbon-phenolic composites, Ablation, Oxyacetylene radiation heating experiment, Numerical simulation
Design and Evaluation of Nature-Inspired Composites

Myungsoo Kim*

School of Automotive & Mechanical Design Engineering, Youngsan University, Gyeongnam, South Korea

*Email: mskimy2@gmail.com

Abstract

The exoskeletons of several arthropods, such as crabs and lobsters, are so hard, and they are receiving great attentions recently by the intention to reveal the relationship between the structure of exoskeletons and mechanical properties. The rigid shells have a unique structure called Bouligand structure, which is a helicodial structure. The object of this work is to evaluate mechanical properties of fibre-reinforced composites in which fibres aligned in helicodial orientation. Several types of helicodial orientation were set up using various degree changes of fibre through thickness direction. A pressure load was applied to the composite plane, and the failure analysis executed using FEA. The results showed that the helicodial alignment of fibre exhibited efficient dissipation of energy and generated improved mechanical properties.

Keywords: Mechanical property, Fibre-reinforced composites, Nature-inspired
Finite Element Simulation Of Afrp Strengthening Short Steel Tube Under Axial Compression

Abderrahim Djerrad\textsuperscript{1,2*}, Feng Fan\textsuperscript{1,2}, Xu-Dong Zhi\textsuperscript{1,2}, and Qi-Jian Wu\textsuperscript{1,2}

\textsuperscript{1}Key Lab of Structures Dynamic Behavior and Control of the Ministry of Education, Harbin Institute of Technology, Harbin, China

\textsuperscript{2}Key Lab of Smart Prevention and Mitigation of Civil Engineering Disasters of the Ministry of Industry and Information Technology, Harbin Institute of Technology, Harbin, China

*Email: djerradabderrahim@gmail.com

Abstract

This paper presents the results of an experimental and numerical study of the behavior of circular hollow section (CHS) steel tubes strengthened by Aramid fiber-reinforced polymer (AFRP). The aramid fiber used for this experiment is available under the trade name of Kevlar 49. The test consists of thin-walled circular short steel tubes externally bonded with aramid fiber in the transverse direction tested under axial compression, to examine the effects of the AFRP layer number, on their axial load carrying capacity and axial shortening. The three-dimensional finite element (FE) models of AFRP strengthened circular hollow section (CHS) were developed using ANSYS Workbench 17.0 and ACP (ANSYS Composite Prep/Post) tool considering both geometric and material nonlinearities. The results which involve the failure modes, load vs axial shortening curve and ultimate load capacity obtained from experimental and non-linear numerical simulation were compared for validation. Both the experimental and numerical results are in good agreement and show that the AFRP external strengthening can considerably enhance the strength of steel tubes.

Keywords: FRP, AFRP, Circular hollow section (CHS), FEM, Axial load, Load capacity

Fig. 1 Experimental test setup (Short tubes).
Adaptive Discrete-Smeared Crack Model for Multi-Scale Progressive Damage in Composites

Tong-Earn Tay¹*, Xin Lu¹, B.Y. Chen², Muhamad Ridha¹, and Vincent Tan¹

¹National University of Singapore, 117576, Singapore
²Delft University of Technology, Delft, Netherlands
*Email: mpetayte@nus.edu.sg

Abstract

The failure of fibre-reinforced composite laminates is often an interaction of different failure mechanisms, including matrix cracking, interfacial delamination and fibre breakage. Apart from the major cracks which cause macroscopic discontinuities, extensive short matrix cracks (diffuse damage) is generally observed, resulting in degradation of structural stiffness. While discrete crack model (DCM) offers great potential to capture the interaction of different failure modes, it cannot efficiently model the material softening process. In contrast, smeared crack model (SCM) is well suited for describing the diffuse damage but is not able to account for the local coupling effects and final fracture. To predict the sophisticated progressive failure behavior of composites, an adaptive discrete-smeared crack model is proposed (Figure 1). Initially, DCM is used to model each individual matrix crack and its interaction with cohesive interface. Transition from DCM to SCM is performed once certain criterion is satisfied: the critical cracks are reserved while the non-critical ones are converted to diffuse damage using SCM. The transition is performed based on the principle of energy conservation, which ensures the physical correctness and consistency³. The proposed method is adopted to model the tensile failure of composite laminates. Compared to the experiments, close agreement is obtained.

Keywords: Discrete-smeared crack model, Computational modelling, Laminates, Fracture

Fig. 1 Schematic illustration of the adaptive discrete-smeared crack method: (a) matrix damage captured by discrete crack model; (b) an integrated model describing both critical cracks and diffuse damage.
A Large Cubic Cohesive Element for Modelling Delamination with Coarse Meshes

Raffaele Russo and Boyang Chen*

1Faculty of Aerospace Engineering, TU Delft, Kluyverweg 1, 2629 HS Delft, The Netherlands
*Email: b.chen-2@tudelft.nl

Abstract

Cohesive Elements (CE) are known to suffer from the limitation that its size must be several times smaller than the cohesive zone length. The willingness of the authors is to present, with this paper, a large cohesive element which employs a higher-order interpolation of the separations. The validation of the CE has been made by simulating delamination problems chosen from already verified cases in literature1. The authors present here a 2D, two-node cohesive element. In addition to the usual two displacement degrees of freedom, each node contains an rotational degree of freedom, thereby achieving a higher-order interpolation of the separation field. While the interpolation remains unchanged during analysis (i.e., no additional partitioning or enrichment involved), the integration scheme changes with respect to the damage/failure status of the element. Comparisons with the results of the linear CE demonstrate that the proposed element is able to substantially improve the prediction accuracy of large cohesive elements (Fig 1) while saving significantly on computational time.

Keywords: Discrete-smeared crack model, Computational modelling, Laminates, Fracture

Fig. 1 Load-displacement curves of DCB simulations with different element sizes for both the standard linear formulation and the proposed cubic formulation.
A Nonaffine Molecular Chain Network Model for Polyelectrolyte Gels

Isamu Riku*, Masashi Ueda, Tomoki Sawada, and Koji Mimura

Department of Mechanical Engineering, Osaka Prefecture University, Japan

*Email: riku@me.osakafu-u.ac.jp

Abstract

A polyelectrolyte gel is formed when a cross-linked polymer network carrying ionisable groups, generally acidic, absorbs a solvent containing ionic species. Polyelectrolyte gels have the capacity to absorb large amounts of solvent, leading to their use in a broad range of applications in healthcare and personal hygiene. The degree of swelling depends sensitively on environmental conditions such as pH and salinity, and in some cases even electric fields, temperature, or light. Thus polyelectrolyte gels can also be used as smart materials in sensors and actuators. These applications have motivated the development of theoretical models characterizing the cheo-mechanical behaviour of polyelectrolyte gels. In this study, we apply the nonaffine molecular chain network model to polyelectrolyte gels based on the concept of the ideal elastomeric gel, which was proposed by Cai and Suo1. The Helmholtz free energy of polyelectrolyte gel is separated into the contribution due to stretching the nonaffine molecular chain network, that due to mixing of the polymer and solvent, and that due to the redistribution of the ionic species. The effect of the nonaffine movement of the molecular chain on the deformation behaviour of polyelectrolyte gels is discussed.

Keywords: Gel, Polyelectrolyte, Nonaffine molecular chain network

Fig. 1 Comparison between the calculation results based on the affine model and that based on the nonaffine model.
Effects of Cohesive Element Parameters on Delamination Modelling
Xin Lu*, Vincent B.C. Tan, and Tong-Earn Tay
National University of Singapore, Singapore
*Email: xinlu@u.nus.edu

Abstract
The cohesive element (CE) has been widely adopted to model delamination in composite laminates. The penalty stiffness, interfacial strength and fracture toughness are three important parameters of the CE. Except for the fracture toughness which can be determined experimentally, the other two parameters are very difficult to obtain but play crucial roles in predictive numerical modelling of progressive damage. These parameters are often characterized using data from fracture tests such as double cantilever beam (DCB) and end-notched flexure (ENF). However, the derived parameters are then applied to predict delamination and damage in structures such as open-hole tension (OHT), open-hole compression (OHC) and impact-induced composite laminates, often with varying degrees of success or accuracy. The question whether the parameters derived from crack-dominant DCB and ENF tests can be meaningfully used without modification to model delamination in composites structures in general remain a valid and important one. It is this question that inspires the current study. There are significant differences between the behaviour of composite structures modelled with and without pre-existing cracks. For the cases without pre-crack, unstable delamination progression occurs after delamination onset and the subsequent failure process is governed by the cohesive strength parameter. In contrast, due to the high stress concentration in the cases where pre-cracks are modelled, the delamination propagation is more stable and less sensitive to the interfacial strength parameter. Other sensitivity studies of the predicted damage progression patterns and structural response on the cohesive element parameters will also be presented.

Keywords: Cohesive element, Delamination, Computational modelling, Damage progression, Cohesive strength parameter

Fig. 1 Numerical results for stiffener debonding analyses.
Ultimate Failure of CFRP Blade Stiffened Panel due to Three-Point-Bending

Bambang Kismono Hadi*, Jacky, and Hariyanto

Faculty of Mechanical and Aerospace Engineering, Institut Teknologi Bandung, Indonesia

*Email: bkhadi@ae.itb.ac.id

Abstract

Explicit finite element analysis using LS-DYNA was used to analyze the ultimate failure of blade stiffened panel due to three point bending. The blade stiffened panel was made using a combination of CFRP T700/2510 UD and T300 woven fabric. In the numerical analysis, a MATERIAL 54 Enhanced Composite Damage Model was used together with Chang-Chang failure criteria. The numerical analysis showed that the panel experienced stiffener damage without buckling, followed by a separation between the stiffener and the skin. The panel was able to sustain 68 kN without stiffener damage and a total of 70 kN ultimate failure load. Comparison with experimental data will be done.

Keywords: Blade stiffened panel, Ultimate failure, Three-point-bending, LS-DYNA

Fig. 1 (a) initial failure, (b) ultimate failure, (c) load-displacement curve.
Abstract
Additive manufacturing technology plays an important role in the development of the modern industry, additive manufactured aluminum (Al) becomes the hotspot of current research in order to achieve the high-precision manufacturing. Additive manufactured Al parts generate pore defects easily due to poor fluidity and low density, which in turn affects the mechanical properties. In this paper, the damage behavior of additive manufactured Al parts with pore defects under tensile load is simulated in a meso-scale by a two dimensional rate-dependent crystal plasticity model. The stress-strain curves and the stress nephogram are obtained for different combinations of models. The effects of different orientations and pores for single crystal and polycrystal are discussed. The results demonstrate that the mechanical properties of additive manufactured Al parts severely depend on the crystal orientation of materials, the shape and size of pore.

Keywords: Additive manufacturing, Aluminum, Pore defects, Crystal plasticity
Prediction of Tensile Strength of Unidirectional Carbon Fiber Reinforced Plastics

Go Yamamoto1*, Miho Onodera1, Jun Watanabe2, Haruki Okuda2, Fumihiko Tanaka2, and Tomonaga Okabe1

1Department of Aerospace Engineering, Tohoku University, Sendai, Japan
2Composite Material Research Laboratories, Toray Industries, Inc., Ehime, Japan
*Email: yamamoto@plum.mech.tohoku.ac.jp

Abstract

The tensile strengths of two types of unidirectional CFRP composites were predicted by considering the fiber failure due to the stress concentration resulting from a fiber break in a neighboring fiber. Two types of epoxy matrix with different mechanical characteristics were used for composite preparation and tested in order to verify the validity of proposed prediction method. Numerical simulation together with multi-fiber fragmentation experiments having an interfiber spacing ranging from half to four fiber diameters were used to characterize the stress concentration factors. The results show that no apparent difference in the extent of stress concentration was observed even when the interfiber spacing (half to four fiber diameters) and the number of fibers (two to four fibers) are varied. On the other hand, by utilizing an epoxy resin having a higher Young’s modulus and tensile strength for the composite preparation, compared to the other, the stress concentration factor was found to decrease from approximately 2.0 to 1.75. It was also shown that by applying the measured stress concentration factors and a bimodal Weibull distribution for the statistical distribution of fiber strength, the predicted strengths of the two types of unidirectional CFRP composites were reasonably consistent with the experimental data.

Keywords: Carbon fiber reinforced plastic, Stress concentration, Tensile strength prediction, Multi-fiber fragmentation test, Spring element model

Fig. 1 Relationships between stress concentration factor and percentage of coordinated fracture obtained from double fibre composite.
Functionalized Nanomaterials in Energy Applications: Theoretical Design

Ting Liao*

School of Chemistry, Physics and Mechanical Engineering, Science and Engineering Faculty, Queensland University of Technology, Australia
*Email: t3.liao@qut.edu.au

Abstract

Inexpensive, metal-free materials of high performance in energy application as diverse as catalyst, supercapacitors, and electronic devices, is highly desirable to replace currently widely used metal or metal oxides. Modification of carbon-based nanomaterials by the introduction of appropriate elements or functional groups or nanosized particles may enable the manipulation of electronic, structural, and chemical properties that allows targeting of superior performance. In this presentation, a strong facilitating effect of heteroatom doping or welding graphene nanoribbons has been illustrated by DFT calculations, which includes stimulating sensing and dissociation of molecules, charge carrier adsorption and transfer in an aqueous environment, and change to the hydrogen evolution reaction with the presence of semiconducting nanoparticles. The calculated results not only confirm the possibility of manipulating the performance of carbon-based electronic, optical and electrochemical devices in energy application through chemical functionalization but, more importantly, provides the physical rationale for further design strategies.

Keywords: DFT, Carbon, Photovoltaic, Catalysis
The Effect of Rubber Layer on Mechanical Behavior of Core-Shell Nanoparticle Reinforced Composite
Hailing He*, Zhenqing Wang*, Zhiwei Duan*, and Wenyan Liang*

Smart Structures and Advanced Composite Materials Lab, Harbin Engineering University, Harbin, China

*Email: hehailing@hrbeu.edu.cn, wangzhenqing@hrbeu.edu.cn, duanzhiwei@hrbeu.edu.cn, and liangwenyan@hrbeu.edu.cn

Abstract
A designed silica-rubber core-shell nanoparticle was used to improve the strength of polylactide (PLA) without loss of elongation at break. For comparison, the mechanical properties of the nanocomposites incorporating by the raw silica and silanized silica were also characterized. The experiment results showed that the core-shell with the rubber layer has a more excellent reinforcement on PLA. The rubber layer properties of core-shell filler have a significant effect on the strengthening and toughening of composite. The effect of thickness, strength of rubber layer on mechanical properties of core-shell reinforced nanocomposite was numerically investigated. The micromechanical model was constructed based on the cohesive zone model and extended Drucker–Prager model, in which the spherical particle was arranged on the body-centred cubic distribution. The progressive failure procedure for both the matrix and interface is incorporated in the simulation. The experimental and numerical results were compared as well.

Keywords: Rubber layer, Core-shell nanoparticle, Micromechanical model, Polylactide

Fig. 1 The tensile strength and roughness of nanoparticles reinforced polylactide.
Realizing Nanoscale Quantitative Thermal Mapping of Scanning Thermal Microscopy By Resilient Tip-Surface Contact Resistance Models

Yifan Li, Nitin Mehra, and Jiahua Jack Zhu*

Department of Chemical and Biomolecular Engineering, The University of Akron, Akron, USA

*Email: jzhu1@uakron.edu

Abstract

Existing scanning thermal microscopy (SThM) has unique capability to probe qualitative thermal properties of surfaces but quantitative techniques are not available yet due to the presence of unpredictable thermal contact resistance (TCR) at tip/substrate interface. In this work, we developed two mathematical models, linear and non-linear, those can be used to quantitatively describe the TCR for both smooth and rough contacting interfaces. The developed models bridge heat transfer across tip/surface interface and enable continuous thermal analysis at system level. This work extends the capability of SThM in quantitative measurement and enables a unique platform for thermal measurement at nanometer spatial resolution. This unique feature endows SThM new capability in quantitative thermal analysis with spatial resolution down to nanometer, which is critically important to quantify the thermal conduction across interfaces within composites, multi-layer structures, photovoltaic devices, microelectronics, etc. Thermal conductivity from model prediction matches very well (<10% error) to the measured values from bulk polymer samples. Such models use general surface feature as inputs, so it has wide applicability to other similar materials especially polymers. Moreover, the model has been tested valid when extrapolated to predict thermal conductivity beyond the range of model development.

Keywords: Scanning thermal microscopy, Thermal conductivity, Polymer composites, Model, Heat transfer
Session: Modelling and Simulation
Struc-2-5-O3

Prediction of Mechanical, Electrical and Dielectric Properties of Graphene Reinforced Polymer Nanocomposites Based on Effective Medium Theory

Chuang Feng*, Yu Wang, Zhan Zhao, and Jie Yang*

School of Engineering, RMIT University, Melbourne, Australia

*Email: chuang.feng@rmit.edu.au, and j.yang@rmit.edu.au

Abstract

Due to the possession of excellent mechanical and electrical properties, graphene and its derivatives not only remarkably enhance the mechanical properties of polymer composites, but also considerably improve the electrical and dielectric properties. This makes graphene reinforced polymer composite promising in developing multifunctional materials and structures. The prediction of the mechanical, electrical and dielectric properties of the nanocomposites is of great importance for their potential applications. This paper uses effective medium theory to predict the Young’s modulus and frequency dependent electrical conductivity and dielectric constant of graphene/polymer nanocomposites with considering interface effects. The developed model was validated by comparing with experimental results. It is demonstrated that the interphase plays important role in determining the properties of the nanocomposites. The increase of electric frequency increases the electrical conductivity of the nanocomposites while it decreases the dielectric constant. At lower AC frequency, significant differences exist among the curves with various graphene concentrations while the curves tend to merge together as the AC frequency increases. This indicates that at lower AC frequency, frequency facilitated electron hopping is negligible and graphene concentration dominates the electrical properties of the composites. However, as the AC frequency increases, frequency facilitated electron hopping starts to take over the electrical properties of the composites, which is indicated reduced difference among the curves with various graphene concentrations.

Keywords: Graphene platelet, Nanocomposites, Dielectric permittivity, Effective medium theory

Fig. 1 (a) Electrical conductivity and (b) dielectric constant of graphene/polymer composites.
Transverse Tensile Failure Simulation Using Fracture Mechanics: Growth and Interaction of Debonds

Janis Varna*, Luca Di Stasio, and Linqi Zhuang

Division of Materials Science, Lulea University of Technology, Lulea, Sweden

*Email: Janis.Varna@ltu.se

Abstract

It is commonly assumed that unidirectional composite failure in transverse tension is initiated by fiber/matrix debonding which is followed by coalescence of debonds forming large defects which growth unstable in the lamina thickness direction and also in the direction of fibers creating so called transverse cracks in laminates. The crack propagation along the fiber direction is usually studied on homogenized layer scale using LEFM. Phenomena depend on average parameters of the composite like fiber content and constituent properties but also on local distribution of fibers (clustering): variation of stress concentrations in closely located fibers leads to statistical transverse strength distribution along the transverse direction of the composite often described by Weibull distribution. In spite of qualitative understanding of the phenomena we are still far from quantitative linking micro-parameters with the Weibull distribution parameters for crack initiation. In this paper we use LEFM to calculate energy release rate due to debond growth a) in different geometrical configurations of fibers; b) at different fiber contents; c) at different boundary conditions (free surfaces, adjacent layers); d) accounting for thermal stresses; e) describing the interaction between several fibers with debonds ; f) analyzing fracture modes and contact zones.

Keywords: Energy release rate, Micro-architecture, Debonding, LEFM, FEM
**Detection of Impact Damage in a Composite Structure Using Highly Nonlinear Solitary Waves**

Eunho Kim* and Mead-Eum Yu

*Division of Mechanical System Engineering, Chonbuk National University, Jeonbuk, South Korea

*Email: eunhokim@jbnu.ac.kr

**Abstract**

We design and fabricate a new sensor system based on a nonlinear stress ‘solitary’ wave to detect damage of composite structures. A solitary wave generated in a sphere chain by an impact excitation propagates through the chain without dispersion thus, high density stress wave can be injected to a specific inspection area. This highly nonlinear stress wave is sensitive to the local stiffness of the inspection medium when it is reflected from the chain boundary, which enable us to distinguish the damages or defects in the composite structures. Here we demonstrate that the detection of impact damage in a CFRP cylinder by scanning the surface of the cylinders with the sensor system. The reflected waves near the barely visible impact damage (BVID) and the ones away from the impact damage show large discrepancy as shown in Fig. 1b. The proposed sensor system based on the nonlinear mechanical waves can be used not only to detect the damage of composite structure but also to detect various defects leading to local stiffness change.

**Keywords:** CFRP, Impact damage, Solitary wave, Nondestructive testing

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**Fig. 1** (a) A sensor system based on stress solitary wave. (b) Identification of Impact damage in a composite cylinder.
Modelling Damage and Ballistic Performance of Bio-Inspired Helicoidal Composites

M.R. Abir*, T.E. Tay, and H.P. Lee

Department of Mechanical Engineering, National University of Singapore, Singapore

*Email: abir@u.nus.edu

Abstract

This work explores the mechanisms underlying the toughness, strength and impact resistance of composites with helicoidal lay-ups, inspired by naturally occurring biological composites in the shells of some predator stomatopods. The helicoidal arrangement has been shown to improve impact resistance and energy absorption. In this study, the ballistic performance of conventional composites with helicoidal architecture and common lay-ups is investigated computationally where explicit matrix cracking is modelled using embedded cohesive elements throughout the damaged region. The fibre damage is initiated based on the maximum stress criterion, while matrix and fibre damage progression are modelled by energy-based linear degradation. Delamination is also modelled using cohesive interaction. It is shown that the helicoidal architecture gives rise to a spiralling damage pattern in the through-thickness direction in contrast to a cross-shaped damage typically seen in cross-ply composites (Fig1). As a result, for a 37-ply composite laminate, the ballistic limit of the helicoidal arrangement (152.5 m/s) is about 7% higher compared to an equivalent cross-ply laminate (140 m/s). The higher ballistic limit is attributed to the higher energy absorption capabilities of a helicoidal arrangement. These findings have implications in the design of armours, aerospace and automotive structures.

Keywords: Ballistic impact, Helicoidal, Biological composite, Damage, Energy absorption

Fig. 1 Through-thickness damage distribution (a) spiralling damage in 37 ply single helicoidal (SH37) (b) clean looking damage in 37 ply cross ply (CP37).
Experimental Assessment of SMC Process Simulation
Mohammad Rouhi\textsuperscript{1}* and Chih-Chung Hsu\textsuperscript{2}

\textsuperscript{1}Swerea SICOMP, P.O. Box 104, Mölndal, Sweden
\textsuperscript{2}CoreTech System (Moldex3D) Co., Ltd., ChuPei City, Hsinchu, Taiwan

*Email: mohammad.rouhi@swerea.se

Abstract

Process modelling of composite manufacturing is a challenge due to the high level of uncertainty in the material and its behaviour during the process. There have been many attempts to predict different process phenomena such as flow of resin, interaction between the fibres and resin, fibre orientation and distribution, etc. In this work, different type of SMC materials were used for compression moulding technique. A Process simulation study of the compression moulding process was carried out using the commercial software Moldex3D and the results were compared against the experimental testing responses. Fig 1 below shows the sample geometry, a manufactured instance, the warpage measurement and the simulation results. The study shows the capability of the simulation tool in providing reliable prediction of the manufacturing process which can be used to optimise the process in order to reduce the time and cost for high volume manufacturing.

Keywords: SMC composites, Process simulation, Manufacturing, Testing, Moldex3D

![Fig. 1](image)

(a) The demonstrator, (b) a manufactured sample, (c) the process simulation screen shot from flow movement in the cavity and (d) a comparison between the measured sample and the simulation result.
Session: Modelling and Simulation  
Struc-2-6-O4  

Contact Damping Characteristics of Delaminated Composite Plates  

Yi He and Yi Xiao*  

School of Aerospace Engineering and Applied Mechanics, Tongji University, Shanghai, China  

*Email: y_xiao@tongji.edu.cn  

Abstract  

Damping performance of delaminated composites is a high-sensitivity dynamic parameter that can be utilized to identify delamination. The damping of the delaminated plates contains material damping, which was calculated by the strain energy method, and contact damping. Based on the viscoelastic static friction model, a static-sliding-integrated friction model was established to calculate the contact damping of delamination interfaces of the 1st-order mode delaminated plates. The finite element models (FEMs) of delaminated plates were built up by using ABAQUS finite element software, in which interface contacts were introduced by means of penalty stiffness method. The contact stiffness and contact damping parameters were imported by specific transformations, and the dynamic response of the FEMs was calculated. The 1st-order free decay experiment was applied on measuring the dynamic parameters of plates with different delamination sizes and locations along thickness direction, which were compared with the finite element results to verify the accuracy of the FEMs. The results show that damping has obvious sensitivity advantage in delamination detection contrasted with other dynamic parameters, and the contact damping accounts for the main part of the overall structural damping of delaminated plates. The greater influence exists with the larger area proportion of delamination and the closer to the middle.  

Keywords: Delaminated composite plates, Finite elements method, Contact damping, Penalty stiffness  

Fig. 1 Experiment and fitting 1st-order damping ratio results of delaminated composite plates: (a) offset delamination and (b) central delamination.
Composite Technologies in Civil and Infrastructure – a Global View

Thiru Aravinthan*

Centre for Future Materials, University of Southern Queensland, Toowoomba, Queensland, Australia

*Email: Thiru.Aravinthan@usq.edu.au

Abstract

The application of fibre reinforced polymer (FRP) composites has substantially increased around the world in the last two decades. The diverse areas include civil, marine, mining, oil and gas infrastructures. This has been a result of breakthrough research and development on composite materials and structures well over three decades internationally by key research groups. This paper highlights the on-going research, developments and applications of new and emerging composite technologies in diverse areas. These include sustainable bridge girders, composite pile systems, boardwalks and walkways, railway sleepers, strengthening of existing structures, and other innovative technologies utilising the unique advantages of FRP materials. These case studies have been selected from Australia, Europe, Japan, Malaysia, North America and New Zealand. Several new and innovative structural systems have shown that fibre composites are reaching a point of commercial reality globally for infrastructure applications. Moreover, the current development of guidelines and design standards, could be very effective in gaining acceptance of FRP composites in addition to the traditional construction materials. Such developments would pave way for FRP composites to be the future material in civil and infrastructure applications.

Keywords: FRP composites, Infrastructure, Research and development, Structural rehabilitation
Axial Compressive Behaviour of CFRP Confined Ultra-High Performance Fibre-Reinforced Concrete

Weiqiang Wang and Chengqing Wu*

Centre for Built Infrastructure Research, School of Civil and Environmental Engineering, University of Technology Sydney, Sydney, Australia

*Email: chengqing.wu@uts.edu.au

Abstract

Ultra-high performance fibre-reinforced concrete (UHPFRC) is a promising cementitious composite material which possess ultra-high strength, ultra-high toughness, low permeability, increased abrasion resistance, as well as increased durability over traditional normal strength concrete and high strength concrete. This study presents the results of an experimental program on the axial compressive behaviour of carbon fibre reinforced polymer (CFRP) confined UHPFRC. A total of eight specimens were cast and tested under axial compression. Different CFRP layers were selected to cover different confinement levels. The test results indicate that the CFRP confined UHPFRC can exhibit highly ductile behaviour if sufficient FRP layers is provided. However, due to the ultra-high strength as well as the unique microstructure of UHPFRC, CFRP confined UHPFRC is more likely to exhibit brittle behaviour. Sudden stress reduction or stress fluctuations are observed shortly after the initial peak stress (axial stress at the first peak point) for CFRP confined UHPFRC, as shown in Fig 1. Afterwards, the stress-strain behaviour of CFRP confined UHPFRC may experience a second ascending branch or a continuous descending branch after the sudden stress reduction or stress fluctuations.

Keywords: FRP, UHPFRC, Concrete, Compression

Fig. 1 Stress-strain behaviour of FRP confined UHPFRC with different CFRP layers.
Investigation on Filled Pultruded Frp Tubes for Civil Infrastructure

Ali Al-Saadi*, Thiru Aravinthan*, and Weena Lokuge*

Centre for Future Materials, University of Southern Queensland, Toowoomba, Queensland, Australia

*Email: AliUmranKadhum.Alsaadi@usq.edu.au, Thiru.Aravinthan@usq.edu.au, and Weena.Lokuge@usq.edu.au

Abstract

The main reason for the limited use of pultruded fibre reinforced polymer (PFRP) profiles in column applications in the construction industry is the buckling failure and the rapid drop in the load carrying capacity after reaching the peak value. One way to overcome this shortage is using concrete as a filler material to increase the stiffness and the strength of a given FRP column and to enhance the buckling resistance. The aim of this study is to investigate how the concrete infill can improve the load carrying capacity and modify the failure mode of the pultruded FRP tube columns to ensure their safe and effective use. Different sections of PFRP tube sections were filled using normal and lightweight concrete. The results of square and circular PFRP tube show that the load carrying capacity is increased due to filling with concrete when the hoop stiffness of the PFRP tube is adequate. All the filled columns failed in a more ductile manner compared with the hollow PFRP sections. The findings would make a contribution to the field of PFRP-concrete column applications in the civil engineering as it provides an approach to enhance the axial behaviour of the PFRP columns.

Keywords: FRP tube, Concrete infill, Civil infrastructure, Axial behaviour

Fig. 1 (a) PFRP pedestrian bridge. (b) Hollow and filled tube columns.
Square FRP-Concrete-Steel Hybrid Multitube Concrete Columns: Stub Column Tests

Chun-Wa Chan, Tao Yu*, and Shi-Shun Zhang

School of Civil, Mining and Environmental Engineering, University of Wollongong, Wollongong,
NSW, Australia
*Email: taoy@uow.edu.au

Abstract
This talk presents results from an experimental study on a novel form of hybrid columns, namely, square fibre-reinforced polymer (FRP)-concrete-steel hybrid multitube concrete columns (MTCCs). The MTCCs, recently developed at the University of Wollongong, consist of an external FRP tube and a number of circular internal steel tubes, with the space inside all the tubes filled with concrete. In the experimental study, axial compression tests were conducted on stub column specimens of MTCCs as well as a similar column form: plain concrete-filled FRP tubes (CFFTs). The test results showed that the concrete in the MTCCs was very effectively confined despite the square shape of the columns, and that the buckling of the internal steel tubes was completely prevented before the rupture of FRP, leading to a very ductile response. The test results also showed that compared to the concrete in CFFTs, the concrete in MTCCs with the same FRP tube exhibited much superior behaviour in terms of both strength and ductility.

Keywords: FRP, Hybrid columns, Square columns, Confinement, Compression tests
Session: Civil and Infrastructure Applications
Appl-3-1-O3

Mechanical and Durability Performance of Modified Bamboo Fibers Reinforced Cement-Based Composites
Demei Yu, Tengfei Fu, Wei Zhi, Yang Ban, and Renhui Qiu*

College of Transportation and Civil Engineering, Fujian Agriculture and Forestry University, Fuzhou, China
*Email: renhuiqiu@fafu.edu.cn

Abstract
This study aims to prepare bamboo fibers reinforced cement composites and provide a solution to the issue of poor interfacial adhesion between bamboo fibers and cement matrix. The original bamboo fibers were modified by three moderately low cost and easy-to-handle treatments including glycerol, aluminato ester, and silane. The performance of the modified bamboo fibers reinforced cement composites were evaluated by a series of mechanical and durability experiments to measure flexural and compressive strength, water absorption, chloride ion penetration, drying shrinkage, freeze-thaw resistance, and carbonization. In addition, the microstructures and porosity of composites were characterized by SEM and NMR. The results showed that the composites reinforced with glycerol-modified bamboo fibers had the lowest porosity (Fig 1), which translated to 14% increased flexural strength and comparable compressive strength. From durability perspectives, all treatment showed similar performance in drying shrinkage, whereas aluminate ester treatment was the most effective in terms of impermeability, chloride resistance, frost resistance to freeze-thaw cycles, and carbonization.

Keywords: Bamboo fibers, Cement composites, Mechanical properties, Durability

Fig. 1 Porosity distribution of mortar sample with bamboo fibers with different treatment.
Effectiveness of a Novel Frp Jacket in Repairing Concrete Columns with Steel Corrosion Damage

Ali Mohammed\textsuperscript{1,5*}, Allan Manalo\textsuperscript{1}, Ginghis Maranan\textsuperscript{2}, Yan Zhuge\textsuperscript{3}, and John Pettigrew\textsuperscript{4}

\textsuperscript{1}Centre for Future Materials, University of Southern Queensland, Toowoomba, Australia
\textsuperscript{2}Civil Engineering, School of Engineering, Faculty of Science and Engineering, University of Waikato, Hamilton, New Zealand
\textsuperscript{3}School of Natural & Built Environments, University of South Australia, Adelaide, Australia
\textsuperscript{4}Joinlox Pty Ltd, Unit 2, 30 Walker Street, Brisbane, Queensland, Australia.
\textsuperscript{5}Environmental Engineering Department, College of Engineering, The University of Mustansiriya, Baghdad, Iraq.

*Email: alikuraishy88@gmail.com

Abstract

Fibre reinforced polymer (FRP) composites have become extremely versatile and popular construction materials for strengthening and rehabilitating damaged infrastructures, especially those that are located in harsh environments such as marine or mining areas. Recently, a new type of prefabricated FRP composite jacket with an innovative joining system for repair of structures has been developed. The novelty of this strengthening system is that it is quick and safe to install due to the easy-fit and self-locking mechanical joint. It works by wrapping the FRP jacket around the damaged structure and filling the annulus with a water displacing grout. This paper presents an experimental investigation to evaluate the effectiveness of this pre-fabricated composite repair system for rehabilitation of deteriorating and structurally deficient concrete columns. Large-scale concrete columns with different levels of simulated steel corrosion defect and repaired with the FRP jacket was investigated (Fig 1). The results showed that the provision of the FRP jacket fully restored the axial stiffness and up to 99\% and 95\% of the capacity of concrete columns with 25\% and 50\% corrosion damage, respectively.

Keywords: Novel repair system, Composite jacket, Pre-fabricated FRP jacket, Damaged concrete columns and corrosion damage

Fig. 1 (a) Test set-up for repaired column. (b) Load-deformation behaviour.
Session: Civil and Infrastructure Applications
Appl-3-2-I1

A State-Of-The-Art Review of Cellulose Nanomaterials: Manufacture, and Their Applications in Civil and Infrastructure Engineering
Tengfei Fu, Demei Yu, Wentao Fu and Renhui Qiu*

College of Transportation and Civil Engineering, Fujian Agriculture and Forestry University, Fuzhou, China.

*Email: renhuiqiu@fafu.edu.cn

Abstract
Cellulose nanomaterials, used as enhancing materials in composite materials, has many advantages over traditional inorganic nanomaterials, for it is intrinsically sustainable, easy to disperse, low cost, and low health and environmental risks. Meanwhile, nanosized characteristics (as shown in Fig 1) of CNs can significantly enhance cement-based materials in terms of workability, microstructures, and mechanical properties. This review summarizes recent advances in development of applications in the area of civil and infrastructure engineering. A critical review of potential enhancing mechanisms is also presented, followed by a discussion of limitations and current challenges. At last, a brief introduction of ongoing research on CNs manufacture and applications in Fujian Agriculture and Forestry University is presented.

Keywords: Cellulose, Cellulose nanofibril, Cellulose nanocrystal, Infrastructure, Review

Fig. 1 Materials used to produce concrete, particle size versus specific surface.
Performance of Geopolymer Concrete Beams with Hybrid GFRP-Steel Reinforcement

Ginghis Maranan¹*, Allan Manalo², Brahim Benmokrane³, Warna Karunasena⁴, and Priyan Mendis⁴

¹School of Engineering, Faculty of Science and Engineering, University of Waikato, New Zealand
²Centre for Future Materials, University of Southern, Toowoomba, Australia
³Department of Civil Engineering, University de Sherbrooke, Sherbrooke, Quebec, Canada
⁴Department of Infrastructure Engineering, The University of Melbourne, Victoria, Australia

*Email: gmaranan@waikato.ac.nz

Abstract

The use of hybrid glass-fibre-reinforced polymer (GFRP)-steel reinforcement system is becoming a popular technique for enhancing the ductility and serviceability of concrete beam while maintaining its structural integrity. There are limited studies, however, investigating the use of the system in geopolymer concrete beam. This study therefore investigated the performance of geopolymer beam reinforced with hybrid GFRP-steel bars. Four 200-mm wide by 300-mm high by 3100-mm long beam specimens were cast and tested up to failure. The first beam – the control specimen – was reinforced with 3-15.9-mm GFRP bars in the tension zone. The second, third, and fourth beams were longitudinally reinforced at the bottom with hybrid GFRP-steel bars in increasing order (i.e. 2-15.9-mm GFRP + 1-16.0-mm steel bars, 2-15.9-mm GFRP + 2-16.0-mm steel bars, and 3-15.9-mm GFRP + 2-16.0-mm steel bars). Based on the test results, the ductility and deflection at service of the second hybrid beam was 54% and 88% higher than that of the control beam, respectively. In general, the ductility and serviceability tend to increase with the hybrid reinforcement ratio. On the other hand, the hybrid beams produced strength ranging from 95% to 110% of the strength of the control beam.

Keywords: Geopolymer concrete beam, GFRP bars, Hybrid GFRP-steel reinforcement

Fig. 1 Load-deflection (P-Δ) behaviour of the tested beams.
Hollow Concrete Columns Reinforced with GFRP Bars
Omar Alajarmeh¹*, Allan Manalo¹, Warna Karunasena¹, and Brahim Benmokrane²

¹Centre for Future Materials, University of Southern, Toowoomba, Australia
²Civil Engineering, University of Sherbrooke, Department of Civil Engineering, Sherbrooke, Canada.

*Email: omar.alajarmeh@usq.edu.au

Abstract
Steel-reinforced hollow concrete columns have many applications in civil engineering such as bridge piers, poles, and ground piles due to its reduced material usage and high strength-to-weight ratio. However, such columns suffer from brittle failure mechanism when the reinforcing steel yields. In addition, the corrosion of steel bars is a major issue which affects the performance of hollow concrete columns. Therefore, using non-corrosive reinforcements such as glass fibre reinforced polymer (GFRP) bars can eliminate the corrosion problem and have the potential to develop a more structurally efficient structure. Accordingly, this study explore the use of GFRP bars and spirals as internal reinforcement to hollow concrete columns. A comparative study of the structural behaviour of solid and hollow circular concrete columns reinforced with GFRP bars was therefore conducted. The behaviour of GFRP reinforced hollow columns was also compared to that of steel reinforced hollow concrete columns. The results showed that hollow concrete columns reinforced with GFRP bars yielded 36% higher deformation capacity and 21% higher strength confinement efficiency than solid column. The hollow concrete columns reinforced with GFRP bars also exhibited 11% higher axial capacity, 22% higher ductility and 54% better confinement efficiency than the steel-reinforced hollow column.

Keywords: Hollow columns, GFRP bars, Steel bars, Spirals, Confined Strength, Ductility

Fig. 1 Concrete column cross sections
Motion and Time Study for Precast Concrete Ramp Planks Reinforced with GFRP Bars

Dean Cooper* and Allan Manalo*

Centre for Future Materials, University of Southern, Toowoomba, Australia

*Email: u1069746@umail.usq.edu.au, and allanmanalo@usq.edu.au

Abstract

Reinforced concrete (RC) is the most widely adopted building material for the construction of precast reinforced concrete boat ramp planks (RC planks). The issue of corrosion in concrete structures could be eliminated by replacing steel reinforcement with corrosion resistant glass fibre reinforced polymer (GFRP) bars. Motion and time studies were conducted to compare and evaluate the fabrication methodologies employed in manufacturing the precast GFRP and conventional galvansied steel (GS) RC planks. Three RC plank designs were investigated, single layer GS reinforced and single and double layer GFRP reinforced. The amount of materials and equipment used, and the man-hours needed in every stage of the fabrication were documented and carefully examined. Alternative lean manufacturing methods were determined in efforts to potentially boost manufacturing efficiencies. The results of the analyses revealed that: (1) The GS single layer mesh fabrication process had the fastest fabrication time. (2) A forklift was required to transport the assembled GS cage due to its heavy weight. (3) The lightweight of a GFRP cage enabled it to be carried manually by two workers. (4) The GS single layer mesh installation process had the fastest installation time. (5) GFRP single and double layer mesh installation required four workers and no forklift. (6) Alternative manufacturing methods can potentially increase GFRP fabrication and installation efficiency to a point where GFRP single layer mesh fabrication is faster than that of the GS mesh, and GFRP mesh installation time almost equals that of the GS mesh (while requiring less workers and no forklift).

Keywords: Boat ramp planks, GFRP bars, Reinforced concrete, Motion and time

Fig. 1 (a) GFRP single layer mesh fabrication. (b) Installation of GS mesh into formwork.
Effect of Threaded Bolts with Variable Edge Distance-to-Bolt Diameter on the Bolted-Joint Strength of Pultruded FRP

Mohammad Hizam Rusmi*, Allan Manalo*, and Warna Karunasena*

Centre for Future Materials, University of Southern, Toowoomba, Australia

*Email: mohammadhizamshah.rusmi@usq.edu.au, manalo@usq.edu.au, and karu.karunasena@usq.edu.au

Abstract

The ability to provide adequate and effective connection assembly will enhance the performance of pultruded FRP (PFRP) structures and fully exploit the material’s attributes such as high strength to weight ratios and high resistance to corrosive environment. Conventional metallic fastener is still a preferable way to join the PFRP structural members due to ease of assembly and design familiarity. There are a number of fastening parameters associated with designing FRP bolted connections, such as bolt-hole clearance, joint geometries and clamping pressure. However, the effect of bolt threads on the PFRP joint performance has received very little attention so far. This paper investigated the effect of steel threaded bolts with different end distance-to-bolt diameter ratio (e/db) (maximum e/db = 4) against two different PFRP thickness, 6.5 mm and 5 mm (Fig. 1). Due to the threaded bolts, specimen 6.5 mm and 5 mm experienced decrease in joint resistance at an average of 40% and 32%, respectively. The thicker PFRP material may have experienced higher thread embedment across the pultruded lamina, therefore decreasing the joint capacity further by 8%. Additionally, specimens with threaded bolts, attained consistent joint strength and has insignificant outcome across the e/db range.

Keywords: Boat ramp planks, GFRP bars, Reinforced concrete, Motion and time

Fig. 1 Bolt threads against different plate thicknesses.
Characterization of Composite Sandwich Star Cross Sections for Integral Torsionally Compliant Wind Turbine Blade Tips

Soham Umbrajkar and D. Stefan Dancila*

Department of Mechanical and Aerospace Engineering, Arlington, Texas, USA

*Email: dancila@uta.edu

Abstract

Composite star beams with cross sections of the type shown in Fig 1, have been proposed and analytically, numerically, and experimentally investigated by one of the authors and his collaborators as a structural tailoring solution combining high bending and axial stiffness with torsional compliance and the effective implementation of extension-twist coupling. The applications targeted related to helicopter and propeller blades, where the varying centrifugal loads due to varying rpm could be used to passively and favourably change blade twist distribution. An alternate application targeted was for the star-beam support of blade tips and/or blade flaps, in which case the star beam provides a simple compliance mechanism for pitch, allowing actuation and control of the blade tip or flap. In this work the concept of composite star beam is extended to sandwich construction with a target application of integral, torsionally compliant wind turbine blade tips. A structural characterization of response is sought to provide the basis for subsequent aerodynamic blade actuation and control.

Keywords: Torsionally-compliant, Sandwich, Star-beam, Wind-turbine, Blade tip

Fig. 1 Composite star beam configurations.
Effect of Ceramifyable Particles to Improve Fire Performance of Structural Insulation Panels

Kate Nguyen1*, Nam Kim2, Tuan Ngo1, Priyan Mendis1, and Debes Bhattacharyya2

1Department of Infrastructure Engineering, The University of Melbourne, Victoria, Australia
2Centre for Advanced Composite Materials, Department of Mechanical Engineering, The University of Auckland, Auckland, New Zealand

*Email: kate.nguyen@unimelb.edu.au

Abstract

With the current trend for sustainable construction, much focus is given on the energy efficiency of buildings. Structural insulation panels (SIPs) which are constructed of sandwich panels from glass fibre reinforced composites and foam core to provide superior thermal, structural and acoustic performance, have been increasingly used in the prefabrication industry1. In addition, the light weight and flexibility in design allows SIPs to be tailored to meet a wide range of construction requirement of both external façades and partition walls. However, the important aspect of fire performance of such SIPs in fire is of less attention. Since the construction design, and its behaviour in fire changed significantly, it can be the most critical element of building fire spread, if it is not designed with adequate fire resistance. The Grenfell Tower fire has demonstrated how vulnerable modern buildings may be to fires and how this vulnerability directly affects the safety of building occupants. In this work, ceramifiable particles with replacement level of 30%, 40% and 50% are used to improve the flammability and heat release of SIPs subjected to high temperature. Cone calorimetry is combined with thermo-gravimetric analysis and modified to mimic the fire condition for buildings and structures.

Keywords: Glass fibre reinforced composite, Ceramifyable particles, Fire performance, Structural insulation panel, Prefabricated housing

Fig. 1 Schematic of the horizontal test using Cone calorimeter according to ISO 5660.1.
Barriers to the Potential Growth of Prefabricated Modular Buildings in Australia

Wahid Ferdous1* and Allan Manalo2

Department of Civil and Environmental Engineering, Imperial College London, Kensington, London, UK
Centre for Future Materials, University of Southern, Toowoomba, Australia
*Email: wahid.ferdous03@gmail.com

Abstract

Off-site construction technique offers faster and safer manufacturing, better predictability to completion time, superior quality, less number of workers on site, less resource wastage, lower weight and more environmentally friendly solution than the conventional construction process. Despite having well-documented benefits, the off-site construction uptake rate for building industry is slower than anticipation, and the construction sector still relies heavily on conventional on-site construction method. This paper identifies the key barriers to the potential growth of prefabricated modular buildings in Australia. An extensive survey of literature has suggested that the barriers are not related to the product itself, but mainly to the lack of logistical support. The lack of design guidelines due to the conflict with traditional design process, lack of skilled workers and potential investors, transportation difficulty, high overall cost and lack of suitable interlocking connection between modules are identified as the major barriers towards the potential growth of prefabricated modular buildings. The outcome of this study will help understand the necessary action required to overcome the challenges.

Keywords: Off-site construction, Modular buildings, Composite materials, Benefits, Challenges
Experimental investigation of Reinforced Concrete Arches Strengthened with Externally Bonded Composite Materials

Ehab Hamed*, and Zhen-Tian Chang

Centre for Infrastructure Engineering and Safety, University of New South Wales, Australia
*Email: e.hamed@unsw.edu.au

Abstract

An experimental study that includes testing to failure of three medium-scale (4m long by 0.6m height) reinforced concrete shallow arches that are strengthened with externally bonded composite materials will be presented. One of the three arches is used as a control arch without strengthening, while the other two are strengthened with different patterns. The loading system includes six non-symmetric vertical point loads equally spaced along the arch. The loads are not equal in order to introduce some imperfection and bending of the arch, which simulates realistic loading scenarios in arch bridges. The results show that applying the FRP strips leads to an increase of about 40% in the failure load of the arch, which is also associated by changes in its cracking pattern. Edge debonding of the FRP strip is observed during the test, but without causing total failure of the arch.

Keywords: Arches, Concrete, FRP, Strengthening
Effect of Elevated Temperature on the Properties of Epoxy-Based Polymer Coating

Mojdeh Mehrinejad Khotbehsara¹*, Allan Manalo¹, Thiru Aravinthan¹, and Kate Nguyen²

¹Centre for Future Materials, University of Southern, Toowoomba, Australia
²Department of Infrastructure Engineering, The University of Melbourne, Victoria, Australia

*Email: Mojdeh.Mehrinejad@usq.edu.au

Abstract

Epoxy-based polymer resins are being used as coating for civil composites like railway sleepers. In this application, the composite sleeper is exposed to harsh environmental conditions, including elevated temperature, particularly in the summer season. As the epoxy based polymer resin coats the sleepers, this material is the one directly exposed to elevated temperature. However, its properties when subjected to this type of in-service environment is not yet been properly understood. This study investigated the effect of a range of in-service temperature (ranging from 23°C to 80°C) on the compression and tensile properties of epoxy resin with various percentages of lightweight filler materials (0%, 20%, 40% and 60%). The results showed that both the compressive and tensile strength properties of epoxy-based fillers decreased with increasing in-service temperature. However, the addition of lightweight fillers helped in retaining the mechanical properties of epoxy-based resin at high level of temperatures. The epoxy-based resin with 40% fillers was the least affected by the increase in temperature.

Keywords: Arches, Concrete, FRP, Strengthening

Fig. 1 (a) Compressive Strength and (b) Split Tensile of solid polymer matrices.
Two Stage Reactive Shape Memory Polymer Network Forming System and Application in Smart Space-Deployable Structure

Yuyan Liu¹*, Wu Wang¹, and Hongjun Kang²

¹MIIT Key Laboratory of Critical Materials Technology for New Energy Conversion and Storage, School of Chemistry and Chemical Engineering, Harbin Institute of Technology, Harbin, China.

²National Key Laboratory of Science and Technology on Advanced Composites in Special Environments, Harbin Institute of Technology, Harbin, China.

*Email: liuyy@hit.edu.cn

Abstract

Two-stage-reactive shape memory polymer-network forming system (TSMPS) is a very promising technique in some advanced fields. In the TSMPS, intermediate polymer with shape memory effect can not only remember original shape and recover it in response to external stimulus, but can fix deformed shapes at a low temperature. By utilizing the “fixed features” and improving the crosslinking density of intermediate shape memory polymer, final polymer with well-designed structure can be further fabricated after the second curing stage. Thus, potentially applications in aerospace may come true. Herein, a novel two stage reactive shape memory polymer networks forming system based on non-stoichiometric thiol, epoxy, and acrylate was designed and researched. As shown in Fig 1, in the first thermal curing stage, intermediate shape memory polymer with custom-tailoring properties can be prepared. Then, final polymer with stable and complex shape can be further fabricated after the second photo curing stage. Therefore, applications will be potentially achieved in areas of 3D structure manufacturing, mold-free fabrication, as well as space-deployable structure.

Keywords: Two stage reaction; Shape memory polymer; Preparation; Characterization; Space-deployable structure

Fig. 1 Schematic representation of the procedures of this novel TSMPS.
Enhanced Atomic Oxygen Resistance of CFRP Using Poss/Epoxy Nanocomposites
Chunghyeon Choi, Yunho Kim, Sarath Kumar Sathish Kumar, Venkat Akhil Ankem, and Chun-Gon Kim*
*Korea Advanced Institute of Science and Technology, South Korea.
*Email: cgkim@kaist.edu

Abstract
In this study, in order to protect CFRP in low Earth orbit (LEO) space from atomic oxygen (AO), CFRP consisting of POSS/epoxy nanocomposite as a matrix was suggested. CFRP consisting of POSS/epoxy nanocomposite matrix, and CFRP consisting of neat epoxy matrix were prepared, and their resistances to AO were measured using simulated LEO space environmental chamber in Fig.1. As a result, CFRP consisting of POSS/epoxy matrix had lower mass loss than normal CFRP after 9.62×10^20 of AO fluence. The AO erosion yields of CFRPs were calculated from the AO erosion yield of Kapton HN which is 3.0×10^-24. The results indicate that CFRP consisting of POSS/epoxy matrix has higher resistance to AO than CFRP consisting of neat epoxy matrix. The results of the tensile test showed that CFRP consisting of POSS/epoxy matrix have similar mechanical properties. POSS/epoxy nanocomposite can enhance the resistance of CFRP to atomic oxygen effectively without loss of mechanical properties. Therefore, CFRP consisting of POSS/epoxy nanocomposite matrix could replace normal CFRP for use in LEO space.

Keywords: Carbon fiber reinforced plastic, Low Earth orbit, Atomic oxygen, Polyhedral oligomeric silsesquioxane

Fig. 1 Simulated LEO space environmental chamber.
Impact Behaviour of Fibre Reinforced Composites
Syed Idros Syed Abdullah*, Lorenzo Iannucci, and Emile Smith Greenhalgh

Department of Aeronautics, Imperial College London, United Kingdom
*Email: s.syed-abdullah14@imperial.ac.uk

Abstract
The problem of impact on composite structures has been a subject of review for more than three decades. Foreign Object Damage (FOD), characterized by the velocity of impact, is of particular importance due to its relevance in real-life applications. Many research normally centers on two types of velocity regime - low and high velocity impact. The two types of impact - low and high velocity - presents a serious danger to the composite structure with unique types of damage in each velocity regime. Barely Visible Impact Damage (BVID), commonly associated with Low Velocity Impact (LVI) loading, is a hidden menace due to the obscure damage which may be hidden in the structure, unnoticed from the naked eye. For High Velocity Impact (HVI), transverse loading close to its ballistic limit often induces maximum localized damage which could severely damage the global structural integrity. In this paper, three fibre reinforced composites would be subjected to LVI and HVI loading, each with varying intensity (different energy levels) so as to characterize the type/level of damage induced from each level on the laminated composite. Finally, the resistance to impact on each laminated composite will be ranked in both velocity regime.

Keywords: Impact, Delamination threshold load, Damage
In-Situ Crack Growth Detection in Composites Subjected to Mode II for a Fatigue Spectra Simplification Program

Nabil Chowdhury¹*, Wing Kong Chiu¹, John Wang², Nik Rajic² and Chris Wallbrink²

¹Department of Mechanical and Aerospace Engineering, Monash University, Clayton, VIC, Australia
²Aerospace Division, Defence Science and Technology Group, Fishermans Bend, VIC, Australia

*Email: nabil.chowdhury@monash.edu

Abstract

The quest for light-weight high-stiffness structures with excellent durability and corrosion resistance has led to the increasing use of composite materials in aircraft structures. Understanding the damage growth behaviour and the fatigue characteristics of composite laminates is essential for composite safe-life predictions and determining maintenance cycles of aircrafts. In composite fatigue testing, it is advantageous to condense the fatigue load spectrum to reduce the testing time to a manageable level. However, very limited research has been reported in the area of fatigue spectrum simplification for composites to achieve reliable and efficient life prediction and damage growth behaviour. To support this research an initial program of work has been developed that focuses on experimental crack growth rate measurements of unidirectional composites subjected to shear (mode II) loading using a custom reversible three-point-bend test rig. In this loading scenario, complexities arise in detecting the crack tip in-situ while cyclically loading the test specimen. In the present paper the authors report on an investigation of five different techniques for crack tip detection. These techniques are digital image correlation, thermography, distributed fibre sensing, acoustic emission and a semi-automated optical method using a telescopic camera. The performance of each method is assessed and the relative advantages and disadvantages summarised.

Keywords: Fatigue, Spectra simplification, In-situ testing, Mode II

Fig. 1 (a) DIC, (b) TSA, (c) DOFS strain measuring, (d) AE.
Deflection Control of a Composite Beam with Embedded Shape Memory Alloy Actuators

Sang-Hak Lee and Sang-Woo Kim*

Department of Mechanical Engineering, Hankyong National University, Gyeonggi-do, South Korea
*Email: swkim@hknu.ac.kr

Abstract

A shape memory alloy (SMA) actuator has a self-sensing capability to estimate its strain by referring the electrical resistance during the actuation. We implemented the deflection control of a composite beam with the embedded SMA actuators based on their self-sensing capability. The carbon fiber reinforced polymer (CFRP) composite beam with a stacking sequence of [90°/SMA/90°/0°/0°/0°/0°/90°/90°] T was fabricated using carbon/epoxy prepreg and NiTi-type SMA actuators. Four SMA actuators with a diameter of 0.2 mm were embedded with 2 mm intervals. Before embedding, the SMA actuators were positioned in the polyimide tubes, which makes the actuators freely actuate in the tubes. A dummy mass of 2.4 kg was used to provide the pre-strain to the SMA actuators, and they were clamped at the edges of the composite beam. The sine wave voltage signal was applied to the embedded SMA actuators. Then the electrical resistance of SMA actuators and the deflection of the beam were simultaneously measured. The correlation between the measured resistance and deflection was curve-fitted as a polynomial equation so that the deflection can be directly calculated from the resistance. We investigated the control capability of the composite beam with embedded SMA actuators when the desired target input was applied.

Keywords: Shape memory alloy, Polyimide tube, Morphing structure, Deflection control, CFRP

Fig. 1 A composite beam with the embedded SMA actuators and polyimide tubes.
Influence of Extension-Bending Coupling Effect on Asymmetric Composite Structures
Da Cui, Daokui Li* and Huiru Cui

College of Aerospace Science and Engineering, National University of Defense Technology, Changsha, China
*Email: lidaokui@nudt.edu.cn

Abstract
The application of asymmetric composite materials in the adaptive structures such as fan blades, fixed-wing aircrafts and tilting rotors can effectively improve the hygro-thermal stability of structures. However, the influence of extension-bending coupling effect on mechanical properties of such structures is unknown. The wing skin is taken as an example to obtain a variety of hygro-thermally stable laminates with extension-bending coupling effect by optimal design method. It is compared with laminates with no extension-bending coupling effect through theoretical calculation and simulation verification. The merits and drawbacks of extension-bending coupled effect on other coupling effect, yield strength, buckling load, and robustness of the asymmetric composite structures have been obtained.

Keywords: Laminates, Extension-bending coupling effect, Optimal design, Hygro-thermal stability, Mechanical properties

Fig. 1 Shrinkage deformation of laminates due to 180°C temperature changes.
Intelligent Nanoparticles for Delivery of Drug Gene and Nitric Oxide

Won Jong Kim¹ and Il Keun Kwon²

Pohang University of Science and Technology, South Korea
Kyung Hee University, South Korea
*Email: wjkim@postech.ac.kr

Abstract

Intelligent nanomedicine is one of the most promising strategies for the delivery of therapeutics with reduced side effects and enhanced efficacy. To date, we have explored the potential of various stimuli-responsive nanomedicine, including inorganic nanoparticles and biopolymers, for the delivery of a wide range of therapeutic agents such as chemotherapeutics, genes, and the gas molecule. For preparing self-assembled nanostructures, we judiciously conjugated a self-assembly pair into different polymer backbones, achieving highly stable nanostructure formation. Various self-assembled pairs, including a host-guest interaction of paclitaxel (PTX)/cyclodextrin (CD) and base-specific interactions between the sense and antisense strands of siRNA, were chemically conjugated on each polymer backbone. Another strategy is to modulate the size and structure of the assembled structure using the sequence-specific hybridization and dehybridization of pH-sensitive functional DNA known as the i-motif. According to pH changes, the structure of functional DNA was transformed dynamically, leading to a release of the cargo, thus achieving the specific delivery of siRNA or an anticancer drug, doxorubicin (DOX). We also report novel platform of nitric oxide (NO) delivery using polydopamine and light-responsive NO-releasing nanoparticles. For the stimuli-sensitive NO delivery system, we designed a light-responsive gatekeeper for smart NO delivery. The gatekeeper is composed of a pH-jump reagent as an intermediary of stimulus and a calcium phosphate (CaP) coating as a shielding layer for NO release. The light irradiation and subsequent acid generation are used as triggers for uncapping the gatekeeper and releasing NO.

Keywords: Nanomedicine, Self-assembly, Nitric oxide, Drug delivery
Chitosan-Silica Composite Microspheres with Enhanced Hemostatic Efficiency

Haiqing Liu* and Xun Sun

Fujian Provincial Key Laboratory of Polymer Materials, Fujian Normal University, Fujian, China

*Email: haiqing.liu@gmail.com

Abstract

Quick hemostats for controlling massive hemorrhaging are important for reducing mortality and medical costs. Porous chitosan-silica composite microspheres (CSMS-S) were prepared by the reverse phase emulsification in combination with the thermally induced phase separation and CTAB template method. It was found that mesoporous silica microspheres (MSNs) were formed on the outer and interior pore walls of chitosan microsphere (Fig. 1). The specific surface area of CSMS-S increased to 535.3 m²/g from 42.5 m²/g of CSMS. In the rat liver laceration model, the hemostatic time of CSMS-S was respectively 17 s and 52 s shorter than that of CSMS (114 s) and Celox® (149 s). The TEG test showed that CSMS-S had a shorter onset time of fibrin formation and stronger blood clot strength than CSMS. In addition, CSMS-S had no obvious adverse effect on cell activity, and no necrosis and inflammatory changes in the tissue cells around the wound. It is concluded that CSMS-S is a safe and fast hemostatic agent.

Keywords: Chitosan, Silica, Composite, Microsphere, Haemostat

Fig. 1 SEM images of (a) CSMS, (b) CSMS-S3, (c) CSMS-S4, (d) CSMS-S5, (e) CSMS-S6 and (f) cross-section of CSMS-S3. a-1, b-1, c-1, d-1, e-1, f-1 are the partial enlarged images of the corresponding sample.
Nanostructured Microparticles for Topical Drug Delivery to the Eye
Young Bin Choy*

*Department of Biomedical Engineering, Seoul National University College of Medicine Seoul, Republic of Korea
*Email: ybchoy@snu.ac.kr

Abstract
Conventional eye drops have limited effectiveness as a result of low drug bioavailability due to their rapid clearance from the preocular space. To resolve this, we propose several different types of nanostructured microparticles (NM) for topical drug delivery to the eye. The nanostructured microparticles herein are composed of a mucoadhesive material and along with a large specific surface area originated from the nanostructures, they can adhere to the mucous layer better, hence prolonged preocular retention. While staying longer at the eye surface, drugs can be released in a sustained manner. Therefore, the NM can improve bioavailability of ophthalmic drugs when topically administered to the eye. For this purpose, we prepare the polymeric nanostructured microparticles by freeze-milling the nanofibrous mat composed of poly(lactic-co-glycolic acid) and poly(ethylene glycol), which serve as drug-diffusion barrier and mucoadhesive promoter, respectively. We also fabricate the microparticles of anionic mesoporous silica and metal-organic framework. To assess in vivo efficacy of those particles, we examine the change in intraocular pressure (IOP) and drug concentration in the aqueous humor (AH) after administration of the drug-loaded NM, which are about twice as large as those obtained with Alphagan P, the marketed eye drops. This finding indicates enhanced ocular drug bioavailability with the NM proposed in our work.

Keywords: Drug delivery, Microparticles, Nanostructures, Ocular drug
Effect of Utilising Degradable Composites as Bone-Plate Material on the Predicted Stresses at the Fractured Bone

Xi Gao¹*, Menghao Chen², Xionggang Yang¹, Lfty Ahmed², Jiawa Lu¹

¹Faculty of Science and Engineering, University of Nottingham Ningbo, China
²Faculty of Engineering, University of Nottingham Ningbo, UK

*Email: xi.gao@nottingham.edu.cn

Abstract

A numerical study investigating the alleviation of stress shielding by implementing an implant made of degradable phosphate glass fibre reinforced composites on fractured bone is presented in current work. A simplified finite element (FE) model of the fractured bone and plate-screw implant was built to simulate the healing period of the bone. The stress shielding at the fracture interface during the healing period was studied through the Von Mises stress. Three representative healing stages, 1%, 50% and 75%, of the fractured bone were selected to study the Von Mises stresses at the fracture interface. Comparisons were carried out amongst using the titanium (Ti) alloy implant and stainless steel (SS) implant. The results showed that when the healing percentage was 50% there was a 7.5% fall in stress shielding caused by Ti alloy implant comparing with that by SS implant, and a further 18.2% reduction was observed in the comparison of degradable implant over Ti alloy implant. When the healing percentage was 75%, the difference in the stress shielding caused by the degradable implant and Ti alloy implant decreased to about 7.1%. It was concluded that the implementation of degradable implant alleviated the stress shielding significantly.

Keywords: Degradable composites, Bone-plate, Stress shielding, Finite element

Fig. 1 Von Mises compressive stress distribution at the fracture interface at different healing stages for different types of implants.
Novel Nanomaterials for Cancer Diagnostics
Michał M. Godlewski¹,², Paula Kielbik¹,², Jarosław Kaszewski¹,²,³, Emanuel Borgstrom¹, Bartłomiej S. Witkowski³, Zdzisław Gajewski³, and Marek Godlewski³

¹Department of Physiological Sciences, Faculty of Veterinary Medicine, Warsaw University of Life Sciences – SGGW, Warsaw, Poland
²Veterinary Research Centre, Centre for Biomedical Research, Department of Large Animal Diseases with Clinic, Faculty of Veterinary Medicine, Warsaw University of Life Sciences – SGGW, Warsaw, Poland
³Institute of Physics, Polish Academy of Sciences, Warsaw, Poland

*Email: mickgodl@hotmail.com

Abstract
Exponentially growing field for research in the nanomaterials prompts an enormous potential of possible applications of nanoparticles in medicine. We focused on the applications of biocompatible, oxide, non-heavy metal nanoparticles (NPs) in the field of cancer diagnosis and therapy. This work was focused on the development of fluorescent Tb-doped ZrO₂ NPs for application in lung cancer diagnostics. Obtained, hydrothermally created NPs were below 100 nm with very low influence of Tb concentration on size. Mice received suspension of nanoparticles (10 mg/ml, 0.3 ml/mouse) via gastric gavage. All protocols were according to the EU guidelines and approved by LEC agreements No 2/2012 and 13/2015. At 3 h and 24h mice were sacrificed and all tissues collected for analyses under confocal microscope and scanning cytometry. Following oral administration, ZrO₂:Tb nanoparticles were passively targeted to all tumour loci via the enhanced permeation and retention (EPR) effect. Due to the very tight endothelial barrier in the lungs NPs in this organ were targeted specifically to the areas of metastases rendering them a highly specific diagnostic tool for cancer diseases with high potential applications as a carrier of therapeutic factors.

Keywords: Biocompatible oxide nanoparticles, ZrO₂:Tb, Tumour diagnostics, Enhanced permeation and retention (EPR)
Application of Multimodal Wide-Band-Gap Oxide Nanoparticles Doped for Magnetic Properties in the MRI and Fluorescence Imaging of Tumours

Jaroslaw Olszewski1,2, Jaroslaw Kaszewski1,2,3, Bartlomiej Witkowski3, Paula Kielbik1,2, Lukasz Kiraga2, Zdzislaw Gajewski1, Marek Godlewski3, and Michal Marek Godlewski1,2

1Veterinary Research Centre, Centre for Biomedical Research, Department of Large Animal Diseases with Clinic, Faculty of Veterinary Medicine, Warsaw University of Life Sciences – SGGW, Warsaw, Poland
2Department of Physiological Sciences, Faculty of Veterinary Medicine, Warsaw University of Life Sciences – SGGW, Warsaw, Poland
3Institute of Physics, Polish Academy of Sciences, Warsaw, Poland

*Email: jarek.olszewski01@gmail.com, and mickgodl@hotmail.com

Abstract

MRI is a non-invasive gold standard method for cancer detection. Until now, in its medical application, the biggest problem is toxicity of currently used Gd-based contrast agents, necessary for small lesions imaging. Novel contrast agents should selectively delineate small metastases, without Gd drawbacks. Hereby, we propose a novel, multimodal, high-k oxide-based, non-Gd contrast agents of high magnetic moment. Tested NPs were developed in the Institute of Physics, PAS. The NPs core was based on HfO2, ZnO, or ZrO2, doped with Eu and Fe, as well as HfO2 with Gd as a positive control. All NPs were tested for magnetic properties, fluorescence emission and absorption spectra. T1 and T2 relaxation time in different concentrations was measured in phantoms. Selected NPs were then tested in vivo on rats, clinical oncologic patients. Examined rats underwent the initial MRI screening followed by oral application of NP (1mg/ml, 1ml/rat). MRI was conducted 24 and 48h before tumors were surgically removed and histopathologically evaluated. Obtained MRI images were subjected to quantitative analyze of mean relaxation time in selected organs and tumours.

Keywords: Oxide nanoparticles, MRI, Fluorescence, Tumour diagnostics

Fig. 1 MRI imaging in rat patients. Images taken 24h after the administration of NPs. The imaging done with the CUBE T2 1mm core sequence. (A) rat with sarcomas NPs HfO2:Gd. (B) rat with sarcomas NPs HfO2:Eu. (C) rat with hard fibromas NPs HfO2:Gd. (D) rat with hard fibromas NPs HfO2:Eu.
Trypsin Free Cell Stamping System Using Gelatin Nanofibers

Jihyun Chang¹, Soo-Hong Lee², and Hansoo Park¹

¹School of Integrative Engineering, Chung-Ang University, Seoul, Republic of Korea
²Department of Biomedical Science, CHA University, Seongnam-si, Republic of Korea
*Email: heyshoo@gmail.com

Abstract

For tissue engineering applications using scaffolds, cells should be expanded and subcultured to be seeded on the scaffolds before implantation. However, the process requires several steps including trypsin treatment leading to a possible decrease in productivity and quality of cells. In this study, we examined a trypsin-free cell stamping system that transfers cells to scaffolds by using gelatin based nanofibers for osteogenic differentiation of adipose-derived stem cells (ASCs). For experiments, ASCs were cultured with osteogenic differentiation media and stamped onto gelatin nanofibers fabricated by electrospinning. We found out that all the cells were viable after cell stamping and showed similar osteogenic differentiation as compared with cells seeded and cultured in a conventional way. These results indicate that cell stamping system could be used as an easy and effective way of cell transfer onto scaffold in tissue engineering applications.

Keywords: Cell stamping, Gelatin nanofiber, Adipose-derived stem cell, Osteogenic differentiation

Fig. 1 (A) Scheme of cell stamping system. (B) Optical microscope image of before and after cell stamping (X4).
Biodegradable Zinc-Based Nanoparticles for Application in Biology And Medicine

Paula Kielbik\textsuperscript{1,2*}, Bartłomiej Dominiak\textsuperscript{2}, Jaroslaw Kaszewski\textsuperscript{1,2,3}, Julita Rosowska\textsuperscript{3}, Bartłomiej S Witkowski\textsuperscript{3}, Mikolaj A Gralak\textsuperscript{1}, Zdzislaw Gajewski\textsuperscript{2}, Marek Godlewski\textsuperscript{3}, and Michał M Godlewski\textsuperscript{1,2}

\textsuperscript{1}Department of Physiological Sciences, Faculty of Veterinary Medicine, Warsaw University of Life Sciences – SGGW, Warsaw, Poland
\textsuperscript{2}Veterinary Research Centre, Centre for Biomedical Research, Department of Large Animal Diseases with Clinic, Faculty of Veterinary Medicine, Warsaw University of Life Sciences – SGGW, Warsaw, Poland
\textsuperscript{3}Institute of Physics, Polish Academy of Sciences, Warsaw, Poland
*Email: pskielbik@op.pl

Abstract

Nanomaterials are very promising composites for medical applications. However, for these purposes their exact biodistribution within the body needs to be studied. In the study we examined an intra-organism circulation of biodegradable ZnO NPs (zinc oxide nanoparticles) doped with europium (Eu), as a promising, biocompatible material. ZnO:Eu NPs were intra-gastric (IG) administered to adult Balb-c mice (n=35) and following 3h, 24h, 7d, 14d or 1m mice were sacrificed with collection of internal organs for further analyses. Quantitative and qualitative evaluation of distribution processes of biodegradable ZnO:Eu NPs within the body was performed. Additionally, determination the excretion patterns of ZnO NPs was established by measurement of zinc content in the feces of tested mice (n=24) with previously IG administered of ZnO NPs in different dose. All procedures were conducted according to local and EU regulations and approved by the LEC 44/2012. Biodegradable, zinc-based nanoparticles were able to cross key physiological barriers in the organism (including intestinal barrier and brain-blood barrier) with further degradation and efficient elimination from the body, without causing pathological changes within tissues. These features renders zinc-based nanoparticles invaluable tool for biomedical applications.

Keywords: Biodegradable nanoparticles, Zinc oxide, Biodistribution, ZnO:Eu
Session: Biomedical Composites
Appl-2-2-O3

Comparison of Two Strategies for the Utilisation of Nanoparticle Carriers for Drug Delivery to the Brain

Waldemar Lipiński1*, Jaroslaw Kaszewski1,2,3, Aleksandra Ozogowska2, Zdzislaw Gajewski1, Michal Godlewski3*, and Marek Godlewski1,2

1Veterinary Research Centre, Centre for Biomedical Research, Department of Large Animal Diseases with Clinic, Faculty of Veterinary Medicine, Warsaw University of Life Sciences – SGGW, Warsaw, Poland
2Department of Physiological Sciences, Faculty of Veterinary Medicine, Warsaw University of Life Sciences – SGGW, Warsaw, Poland
3Institute of Physics, Polish Academy of Sciences, Warsaw, Poland

*Email: waldemarm.lipinski@gmail.com, and mickgodl@live.com

Abstract

Over the years, considerable amount of research focused on nanomaterials led to enormous amount of potential applications in various fields including biomedicine. We focused on the applications of wide band-gap metal oxide nanoparticle carriers for drug delivery to the brain. This work is focused on comparison of biocompatible Y2O3:Tb nanoparticles and biodegradable ZnO:Eu nanoparticles for drug delivery to the brain. Both nanoparticles were obtained hydrothermally and were conjugated with lectin from Phaseolus vulgaris, which was chosen as drug model due to its extremely low uptake from gastro-intestinal tract in substantia. Mice received suspension of nanoparticle-lectin conjugate (10mg/ml; 0.3ml/mouse) via gastric gavage. All protocols were according to the EU guidelines and approved by LEC agreements No 2/2012. After 3h, 24h and 1 week mice were sacrificed and all tissues collected for analyses under confocal microscope and scanning cytometry. After oral administration both nanoparticle conjugates transported lectin through intestinal barrier and through blood-brain barrier into the brain (including into the neurons). Both nanoparticles exhibited great potential as drug carriers and follow similar distribution pattern, however, biodegradable nanoparticles enabled faster release of bioactive compound into the target tissue.

Keywords: Biocompatible oxide nanoparticles, Y2O3:Tb, Biodegradable oxide nanoparticles, ZnO:Eu, Lectin
**Session: Composites Repair and Self-healing**

**Appl-4-1-I1**

**Sunlight-Stimulated Intrinsic Self-Healing Polyurethane and Its Electrical Conductive Composite**

Min Zhi Rong*, Wei Min Xu, and Ming Qiu Zhang

*Key Laboratory for Polymeric Composite and Functional Materials of Ministry of Education, GD HPPC Lab, School of Chemistry, Sun Yat-sen University, Guangzhou, China*

*Email: cesrmz@mail.sysu.edu.cn*

**Abstract**

Intrinsic self-healing polymers based on light stimulation mainly used to be focused on ultraviolet (UV) and visible light activated versions, which have the disadvantages of weak penetration of UV light, or instability of the materials under visible light. To overcome the shortcomings, this work developed a sunlight stimulated self-healing polyurethane by means of metathesis of disulfide bonds. Firstly, we proved that the small molecules containing disulfide bonds dynamically exchanged under sunlight and xenon lamp (Fig. 1a), but kept stable under visible light. Accordingly, crosslinked polyurethane carrying disulfide in the main chains was synthesized. Not only high UV responsivity, transparency and yellowing resistance but also balanced mechanical properties of the polymer resulted from the specific compositional and architectural design. The damaged polymer was allowed to be repeatedly healed in the sun in terms of strength restoration as a result of sunlight-triggered reversible exchange of disulfide bonds accompanying by reshuffling of polymeric chains (Fig. 1b). On the other hand, transparent conductive composite films were prepared from the polyurethane and silver nanowires. The healing behaviours of mechanical strength and electrical conductivity of the cracked composite films upon sunlight were studied in details. It is hoped that the outcomes will provide insights into the design and preparation of novel smart materials with practical value.

**Keywords:** Sunlight, Self-healing, Polyurethane, Disulfide bond, Conductive composite films

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**Fig. 1** (a) HPLC analysis of equimolar mixture of HEDS and DEDS as a function of different light sources for 2h. (b) Tensile stress-strain curves of virgin and healed PU-HEDS-400 specimens.
Electrochemical Sensitive Gel Based on Carbon Nanotubes and Supramolecular Interaction

Jinying Yuan*

Department of Chemistry, Tsinghua University, Beijing, China
*Email: yuanjy@mail.tsinghua.edu.cn

Abstract

The host-guest interaction between β-cyclodextrins (β-CD) and ferrocene (Fc) as an electrochemical responsive linker has been investigated for the construction of various stimuli responsive systems, including smart hydrogels. Smart supramolecular hydrogels are desirable materials but their poor mechanical and conductive properties are unsatisfactory for some applications. We designed a hybrid supramolecular system by the combination of π-π stacking and host-guest interaction based on a polymer with Fc pendent groups and single walled carbon nanotubes modified with β-CD. The mechanical strength and conductivity of the hybrid hydrogel was greatly enhanced by the addition of SWNT, while self-healing ability and sensitivity to electrochemical stimuli were preserved due to the reversible CD-Fc linkage. Its gel-sol transition can be reversibly achieved by potential stimuli and thus can function as a switch to electric protection.

Keywords: Supramolecular hydrogel, Electrochemical stimuli, Host-guest interaction, Stimuli responsive polymer, Carbon nanotubes
Self Healing Behavior in a Ti$_2$SnC Material

Shibo Li*

Center of Materials Science and Engineering, School of Mechanical and Electronic Control Engineering, Beijing Jiaotong University, Beijing, China.

*Email: shbli1@bjtu.edu.cn

Abstract

Self-healing engineering materials combining adequate mechanical properties and crack healing ability have attracted much attention. Recently, some MAX materials such as Ti$_3$AlC$_2$, Ti$_2$AlC, and Cr$_2$AlC have demonstrated to exhibit efficient crack healing capability at 1100-1200 °C in air even for rather long cracks up to 1-7 mm.1-3 The main mechanism is oxidation induced crack healing. To improve the healing efficiency of MAX materials, it is still required to lower the healing temperature in a short time. In addition, if materials are used in low oxygen partial pressure environments, oxidation induced repair is impossible. Therefore, study on self healing behavior of materials in low oxygen partial pressures is necessary. In this work, we report on the performance recovery of Ti$_2$SnC by healing in air and in a low oxygen partial pressure. It was found that thinner cracks in Ti$_2$SnC are completely filled by the precipitation of metallic Sn from Ti$_2$SnC at 800 °C for only 1 h both in air and low oxygen partial pressure atmospheres (Fig 1), which promotes the recovery of the performance of Ti$_2$SnC.

Keywords: Self-healing, Ti$_2$SnC, Performance, Recovery

Fig. 1 Cross-sectional back-scattered SEM image of a healed thinner crack in Ti$_2$SnC material. The inset is an EBSD micrograph of metallic Sn distributing in the crack area.
Self-Healing Composites with Highly Thermal Conductivities via Thiol-Epoxy Polymerization

Xutong Yang, Tengbo Ma, Junwei Gu*, and Kaichang Kou

*Email: gjw@nwpu.edu.cn

Abstract

In general, thermosetting composites are susceptible to suffer different kinds of outer damages, and cannot be easily recycled due to their permanent cross-linked network structures. In this paper, thiol-epoxide nucleophilic ring opening reaction was performed to fabricate the self-healing polymers, which were completed by transesterification reaction. Furthermore, micrometer boron nitride (mBN) fillers were then introduced into the above polymers, to obtain the corresponding self-healing composites with highly thermal conductivities by hot pressing. Results revealed that the reaction of thiol-epoxy was robust and efficient. The thermally conductive coefficient ($\lambda$) values of the composites were both improved with the increasing addition of mBN fillers. When the content of mBN was 60 wt%, the corresponding $\lambda$ value was enhanced to 1.058 W/mK, about 4 times than that of pure matrix. In addition, the obtained composites also presented good self-healing effect, recycling use and excellent thermal stabilities.

Keywords: Polymer-matrix composites (PMCs), Thermal properties, Mechanical testing, Compression molding

Fig. 1 SEM morphologies of the impact fractures for mBN/thiol-epoxy elastomer composites (500X).
A Study on Mechanical Behavior after Damage Repair Using Patch of Sandwich Composite Material

Sung-Hoon Kim¹, Jong-Rok Ha¹, Jae-Hyung Cho¹, Tae-Yeob Kim¹, and Myung-Hyun Kim⁵*

¹Department of Ocean ICT & Advanced Materials Technology Research Division, Research Institute of Medium & Small Shipbuilding, Busan, South Korea
²Department of Naval Architecture & Ocean Engineering, Pusan National University, Busan, South Korea

*Email: kimm@pusan.ac.kr

Abstract

With high specific strength, composite materials are applied in various industries such as aerospace, shipbuilding, and automobiles. In particular, sandwich composites composed of a core in between two composite face-sheets have high bending stiffness due to their geometry. Despite these advantages, since composite materials are difficult to recycle, many problems arise when the lifetime of the structure is over. In this paper, an experimental study was conducted to identify efficient repairing method of sandwich composite materials. Repairing methods of sandwich composite materials were applied to external patch, scarf patch respectively. Fig. 1 shows the repair method used in this paper.

Keywords: Sandwich composites, Repair, Patch, Mechanical behavior, Fracture

Fig. 1 Schematic of external and scarf patch repair methods for sandwich composites.

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The Healable Shape-Memory Polymer Networks and Composites Based on Metallo-Supramolecular Interaction

Ke-Ke Yang*, Lan Du, Tian-Hao Zhang, and Yu-Zhong Wang*

Center for Degradable and Flame-Retardant Polymeric Materials, National Engineering Laboratory of Eco-Friendly Polymeric Materials (Sichuan), State Key Laboratory of Polymer Materials Engineering, Sichuan University, Chengdu, China

*Email: kkyangscu@126.com, and yzwang@scu.edu.cn

Abstract

With the prompt development in intellectualization nowadays, the smart materials such as shape-memory polymers (SMPs) and self-healing materials (SHMs) have attracted great attention of researchers in the area of polymer science. Herein, we report a series of shape-memory polymer networks and composites with self-healing capacity by-incorporating metallosupramolecular intercation into the polymer networks or composites. We firstly prepared a poly(p-dioxanone) (PPDO) based dynamic network via metal–ligand coordination between Fe(II) with bipyridine group which embedded in PPDO chains. This strong interaction enable the networks excellent mechanical properties and shape-memory performance. Moreover, the dynamic nature make it easy to recycle and reprocess. Furtherly, inspired by the fascinating adhesion effects of mussels, we develop a metallo-supramolecular poly(ε-caprolactone) (PCL)-based hybrid network constructed around catechol-chemistry, leading to excellent thermal/magnetic/light-responsive two-way shape-memory effects (SME) as well as self-healing capacity. These hybrid networks get readily self-assembled upon metal coordination interaction between superparamagnetic iron oxide nanoparticles (Fe3O4 NPs) and catechol-telechelic PCL. The incorporating of Fe3O4 NPs may act as the strong netpoints which allow the networks with excellent multi-responsive SME. The dynamic nature of this metal coordination interaction inspired by mussel, endow the hybrid networks good self-healing capability.

Keywords: Self-healing, Shape-memory, Multi-responsive, Metallo-supramolecular interaction
Life Prediction of High Temperature Composite Overwrap Repairs System
Yee Chech Tan\textsuperscript{1*}, M Shamsul Farid Samsudin\textsuperscript{1}, M.A. Sugindi\textsuperscript{2}, Russell Varley\textsuperscript{3}, Buu Dao\textsuperscript{3}, Alan Leong\textsuperscript{1}, and Kok Hoong Leong\textsuperscript{1}
\textsuperscript{1}PETRONAS Research, Kawasan Institusi Bangi, Kajang, Selangor, Malaysia
\textsuperscript{2}PETRONAS Chemicals Ethylene, Kertih, Terengganu, Malaysia
\textsuperscript{3}CSIRO Manufacturing Flagship, Normanby Road, Clayton, VIC, Australia
\textsuperscript{*}Email: yeechech@petronas.com

Abstract
In recent years, the success of composite overwrap repairs to rehabilitate pipe works in oil and gas industry gained confident for the industry to explore for more demanding operating requirements e.g. operating temperature up to 250°C. This article discusses on long term thermal stability study of a resin formulation at service temperature up to 250°C was evaluated to predict life cycle of the product. A resin was formulated for composite overwrap repairs system that could operate up to 250°C. During formulation, thermal oxidation was identified as the dominant degradation agent in the intended service environment. Thermogravimetry was used as one of short term test to screen the most thermally stable formulation. Specimen weight loss were monitored and normalised with resin weight fraction. From the monitoring results, an Arrhenius model was developed to predict the repair system life cycle with a pre-defined end of life criterion.

Keywords: Composites life prediction, High temperature composites repair, Arrhenius model, thermal oxidation degradation, Cyanate ester

Fig. 1 Normalised resin weight loss in percentage against exposure time for proof test (aging in oven) and survival test (aging in plant).
Session: Composites Repair and Self-healing
Appl-4-2-O1

Design, Synthesis and Applications of Mechanical Robust Self-Healing Polymers
Cheng-Hui Li*

State Key Laboratory of Coordination Chemistry, School of Chemistry and Chemical Engineering, Nanjing University, P. R. China
*Email: chli@nju.edu.cn

Abstract
Development of self-healing polymers with autonomous self-healing capability and good mechanical performance is highly desired. However, for most self-healing materials, there is often a trade-off between mechanical properties and dynamic healing: strong bonds result in mechanically robust but less dynamic systems, precluding autonomous healing, while weak bonds afford dynamic healing, but yield relatively soft materials. Therefore, it is highly challenging to realize self-healing in mechanical robust materials. Herein we present our strategies on the design, synthesis and application of mechanical robust self-healing polymers. We obtained a series of self-healing polymers with excellent mechanical properties (highly stretchable or rigid). We studied the structure-property relationships of self-healing materials by utilizing various methods such as MASS, NMR and single molecule force spectroscopy. We also investigated the applications of self-healing materials in 3D printing, super glue, orthopedic immobilization, shape memory and photo-electronic devices.

Keywords: Self-healing, Dynamic, Coordination bonds, Polymer, Composite

Fig. 1 Mechanical robust self-heating polymer and their applications.
Effects of Metal Chelation Interaction on the Film’s Self-Healing Property

Jiaoyu Ren and Liqin Ge*

State Key Laboratory of Bioelectronics & National Demonstration Center for Experimental Biomedical Engineering Education, School of Biological Science and Medical Engineering, Southeast University, Nanjing, China

*Email: lqge@seu.edu.cn

Abstract

A series of new double-network films based on Schiff base linkage. The first network is the interaction of between the aldehyde groups on poly (ethylene glycol) functionalized by dialdehyde groups (DF-PEG) and amino groups on chitosan (CS), and the metal coordination-chelation interaction is the secondary network (Fig 1). The double-network films are synthesized and characterized with fluorescence spectra, Ultraviolet-visible transmission spectra and Single column material testing machine. The spectroscopic data show the formation of different double-network films and their properties. The film can heal the external mechanical cracks by itself. According to the results, the secondary network, metal coordination-chelation interaction affected on the self-healing property. The data record that the order of the self-healing ability is: (CS/DF-PEG) 15 film > (CS/DF-PEG) 15-Ca2+ film > (CS/DF-PEG) 15-Zn2+ film > (CS/DF-PEG) 15-Cu2+ film (Fig 2). According to references, self-healing ability is closely related to the chain mobility of polymers 1-2. (CS/DF-PEG) 15 films have abundant of functional groups on the surfaces and can interact with the metal ions, serving as a cross-linking site to weaken the mobility of chain 3. Thus, the self-healing ability of (CS/DF-PEG) 15 film is higher than the Schiff base-metal coordination-chelation interaction double-network films. This paper provides a new view on the effects of metal chelation interaction on the film’s self-healing properties.

Keywords: Schiff base, Metal chelation interaction, Double-network, Self-healing property

Fig. 1 Force-displacement curves of the Schiff base-metal coordination-chelation interaction double-network films before and after different damage/healing processes: (a) Schiff Base-boned (CS/DF-PEG)\(_{15}\) film, (b) (CS/DF-PEG)\(_{15}\)-Ca\(^{2+}\) film, (c) (CS/DF-PEG)\(_{15}\)-Cu\(^{2+}\) film and (d) (CS/DF-PEG)\(_{15}\)-Zn\(^{2+}\) film.
Self-Healing Poly(Thiourethane-Urethane) Elastomers Based on Aliphatic Disulfide Metathesis
Qing Liu¹, Nan Zheng¹,², Hao Zhang¹, and Qiuyu Zhang¹*

¹Key Laboratory of Applied Physics and Chemistry in Space of Ministry of Education, School of Science, Northwestern Polytechnical University, Xi'an, China
²Shaanxi Key Laboratory of Catalysis, School of Chemistry and Environment Science, Shaanxi University of Technology, Hanzhong, Shaanxi, China
*Email: qyzhang1803@gmail.com

Abstract
Biological system has the well-known ability to regenerate the supplementary tissues where a part of body is physically injured and/or wounded, taking an example of the skin of human being. Inspired by the nature, perhaps triggered by the need for the enhanced lifetime of already formed components in industrial application, self-healing polymer material is one of the main subjects of active research. So far self-healable polymers could be achieved by two strategies, one of which is based on the reversible bond exchange or supramolecular interactions. Great significance has been gained for polysulfide materials due to their excellent optical property and chemical resistance. However, the polysulfide materials cannot be reshaped or reprocessed once the liquid polysulfide was fully cured. In this present work, we reported a reprocessable and self-healable cross-linked poly(thiourethane-urethane) elastomer based on disulfide metathesis near room temperature. The kinetics of disulfide metathesis were initially studied by small molecular metathesis model reaction in the presence of a novel phosphine catalyst at ambient temperature. The cross-linked elastomer samples doped with a phosphine catalyst could be mechanically recovered, reshaped and recycled, indicating that the catalyzed disulfide metathesis occurred at a mild condition. This strategy gives the traditional polyurethane elastomer the ability to be smart.

Keywords: Self-healing, Cross-linked, Disulfide metathesis, Polyurethane elastomer

Fig. 1 Optical microscopy images of self-healing poly(thiourethane-urethane) films: pristine film before artificial scratches (a,b), scratches on the films by using a doctor blade manually (c,d), photographics of self-healable polymer films at 15 oC (e) and 40 oC (f) for 4 hrs.
Self-Healing Epoxy via Encapsulated Epoxy-Amine Chemistry

He Zhang\(1^*\) and Jinglei Yang\(2\)

\(1\)South China Univ Technol, Natl Engr Res Ctr Novel Equipment Polymer Proc, Key Lab Polymer Proc Engr, Minist Educ, Guangzhou, China

\(2\)Hong Kong Univ Sci&Technol, Dept Mech & Aerosp Engr, Kowloon, Hong Kong, China

*Email: zhanghe@scut.edu.cn

Abstract

In this investigation, homogeneous self-healing of epoxy matrix was realized by dual microcapsules respectively containing epoxy monomers and pure polyamine hardeners. As the key to achieve this, polyamine microcapsule was successfully synthesized through the combination of microfluidic T-junction and interfacial polymerization. The achieved microcapsule has core-shell structure, controllable size, uniform shell thickness with dense inner wall, high core content with adjustable composition, and high thermal stability. The healing performance was assessed by the recovered mode I fracture toughness using tapered double-cantilever beam (TDCB) specimen. Effects of ratio and total concentration of the dual microcapsules on healing efficiency were studied. Highest efficiency of \(~110\%\) was achieved at ratio of 1:1 for the dual microcapsules with total concentration of 10wt\% when specimens were healed at room temperature for 48h autonomously. It is found that recovery of Mode I fracture toughness is not very sensitive to ratio variation and high efficiency over 90\% was obtained within a wide range of ratio. Notably, efficiency over 90\% can be obtained at concentration as low as 5wt\% and almost full recovery (~97\%) can be achieved at 7.5wt\%, which demonstrates the superiority of this self-healing system.

Keywords: Self-healing epoxy, Epoxy microcapsule, Amine microcapsule, Healing efficiency

![Fig. 1](image_url) (a) Schematic configuration of device for fabrication of microcapsule containing pure polyamine; (b) Synthesized microcapsule containing pure polyamine.
Compression after Impact Behavior of Composite Laminate after Repair with Micro-Bolt
Byeong-Su Kwak, Viet-Hoai Truong, Gi-Won Jeong, and Jin-Hwe Kweon*

School of Mechanical and Aerospace Engineering, Gyeongsang National University, South Korea
*Email: jhkweon@gnu.ac.kr

Abstract
The increasing use of composite material in commercial airplane structures such as the wing and fuselage has raised concerns about safety. The common problem of composite structures is that they are vulnerable to delamination. Once delamination occurred in the composite structure, this delamination can be propagated by low level of load and it might lead to failure of the whole structure. Accordingly, delaminated composite structures must be repaired. There are several technologies of repair for delaminated structures such as scarf patch repair and mechanical fastening repair. However, each method has apparent weaknesses. Therefore, in this paper, a new repair technology using micro-bolts was applied to repair composite structures. This technology uses small fasteners with a micro-sized diameter. A preliminary study confirmed that this technology has an effect on inhibition of local buckling at the specimen level. On the basis of this result, we conducted compression after impact (CAI) tests for repaired composite panels. After an impact process to the composite panel, the delaminated region was checked by non-destructive inspection. After that, the panel was repaired and tested, changing parameters such as the number and diameter of micro-bolts. Following the test, the effect of the new repair technology was verified by analysing test results according to the parameters.

Keywords: Compression after impact(CAI), Composite, Repair, Micro-bolt
Scarf Repair Patch with Variable Angle Tow

Rene Roy¹ and Jin-Hwe Kweon²*

¹Research Center for Aircraft Core Technology, School of Mechanical and Aerospace Engineering, Gyeongsang National University, South Korea
²School of Mechanical and Aerospace Engineering, Gyeongsang National University, South Korea

*Email: jhkweon@gnu.ac.kr

Abstract

Designs with large integrated polymer composite components can reduce the number of parts, joints and fabrication operations. For planning the life cycle of such components, reliable repair solutions are required. This project investigates the use of variable angle tow (VAT) as a parameter for prepreg scarf repair patches. VAT used with an automated fibre placement (AFP) machine make possible to vary fibre angle continuously and create curvilinear fibre paths. This material is also termed variable stiffness laminate panel as its stiffness varies according to direction and in-plane location. VAT has been show to offer advantages in buckling resistance and first-ply failure delay, and aero-elastic tailoring. This study aims to verify the use of VAT to reduce peak stresses and increase scarf repair patch robustness for all directions of loading. This investigation is applied especially on the choice of overlay ply, so that the orthotropic features of the original laminate are better matched. Finite element modelling (FEM) is used to simulate a scarf repair patch. Within the VAT parameter options, fibre curvature minimum radius and angle pattern are considered. In-plane and through-thickness laminate ply stresses are compared for cases of tension, compression, shear and bending patch loading.

Keywords: Composite, Repair, Patch, Scarf, Variable angle tow
Session: Composites Repair and Self-healing  
Appl-4-3-O4

Research on Tensile Strength of Composite Structure of Scarf Joints Reinforced by Micro-Blots  
Hyeon-Seok Choe, Gwang-Eun Lee, Seong-Min Park, and Jin-Hwe Kweon*

School of Mechanical and Aerospace Engineering, Gyeongsang National University, South Korea  
*Email: jhkweon@gnu.ac.kr

Abstract
Composite materials are widely used in the aerospace field due to their excellent mechanical properties and light weight. In recent years, as the fabrication technology of composite structure has been developed, cocuring technology without additional assembly process becomes more popular because it can reduce the weight and the damage caused by fastening. However, repairing technologies are essential to maintain the structural integrity of cocured structures because the replacement cost is high when such structure has local damage. The scarf patch repair method using an adhesive is a typical one for composite structure. It produces little weight increase and no stress concentration as there is no hole. However, in order to obtain a high strength recovery rate by the scarf patch repair method, the scarf angle needs to be made very small, so that even the undamaged parts should be largely removed. In this study, to compensate for such disadvantage, we intend to obtain a sufficient strength recovery rate by reinforcing with micro-bolts on joint structures with large scarf angles. Therefore, tensile tests were conducted by reinforcing with micro-bolts on 1/10, 1/20, 1/30 scarf joint specimens.

Keywords: Composite, Micro-bolts, Repair, Scarf joint
Session: Carbon Fibres and Composites
Comp-2-P01

Terahertz NDE Techniques on the Evaluation of Paint Characization on Composite Materials

Kwang-Hee Im¹*, Sun-Kyu Kim², Young-Tae Cho³, Yong-Deuck Woo¹, Jong-An Jung⁴, and David K. Hsu⁵

¹Department of Automotive Eng., Woosuk University 490, Hujung-ri, Samrae-up, Wanju-kun, Chonbuk, 565-701, Korea
²Division of Mech. System Eng., Chonbuk Natl. University, Duckjin-ku, Jeonbuk ,561-756, Korea
³Dept. of Manufacturing Design Eng., Jeonju University, Wansan-ku, Jeonju, Jeonbuk, Korea
⁴Dept. of Mechanical and Automotive Engineering, Songwon University, 73 Sonarm-ro, Namgu, Gwangju 502-210, Korea
⁵Center for Nondestructive Evaluation, Iowa State University, Ames, Iowa 50011, USA

*Email: khim@woosuk.ac.kr

Abstract

In the present work, the influence of Bi on the microstructures, tensile properties, and fracture behaviour of the cast Al-10 Mg²Si composites have been systematically investigated. It was found that Bi addition caused a significant modification and refinement efficiency on the eutectic Mg²Si in the cast Al-10 Mg²Si alloys. The morphology of the eutectic Mg²Si in the cast alloys was turned from plate-like structure to a thin coral-like and fibrous one, and the mean size and aspect ratio sharply decrease with the increase of Bi content. Bi addition changed the mode of fracture from brittle to ductile due to the presence of a large number of deep and well-distributed dimples and fine Mg²Si particles embedded in the Al-matrix, which leading to the significantly improved tensile properties of the cast Al-10Mg²Si composites.

Keywords: Terahertz waves, C-scan images, Painting thickness, Composites
Interlayer toughening of carbon/epoxy laminates using electrospun polyethersulfone fibers

Chao Cheng, Hui Zhang*, and Muhuo Yu*

*Email: zhanghui@dh.edu.cn; yumuhuo@dh.edu.cn

Donghua University

Abstract

Electrospun polyethersulfone (PES) nanofibers enforced carbon fiber/epoxy composites were prepared via vacuum assistant resin infusion (VARI) progress. The morphologies of polysulfone nanofibers, the fracture surfaces of composites and the dissolution behavior of PES nanofibers in epoxy resin were analyzed via SEM and Optical microscopy. The mechanical properties of the composites were measured by mechanical testing. The results indicated that PES nanofibers with the average diameter of 400 nm could well dissolved in epoxy resin and it could be completely dissolved in epoxy resin within 5 minutes when the temperature was over 55 °C. Additionally, the breaking elongation retention, the bending strength and the interlaminar shear strength of composites enforced by PES nanofibers were better than that of composites without PES nanofibers, increased 8.6%, 6.6% and 34.9% respectively. However, the tensile strength were a little decreased. PES microspheres were discovered between layers of carbon fiber epoxy matrix. These microspheres could prevent crack propagation, which was the main reason for the increasing of the toughness of the composite.

Keywords: Composite, Interlayer toughening, VARI, Polyethersulfone nanofibers
Effect of Epoxyidized Polybutadiene on Tensile Properties of Pre-Cured Resin Storable at Room Temperature

Yoh Kataoka¹*, Tsuyoshi Nomura¹, Yoshiaki Kawaoka², Katsushige Kouge², and Koichi Goda³*

¹Graduate School of Science and Technology for Innovation, Yamaguchi University, Yamaguchi,
²SANSHIN CHEMICAL INDUSTRY CO., LTD., Yamaguchi, 742-0023, Japan
³Department of Mechanical Engineering, Yamaguchi University, Yamaguchi, 755-8611, Japan
*Email: Japan g016vd@yamaguchi-u.ac.jp; goda@yamaguchi-u.ac.jp

Abstract

Many fiber-reinforced plastics (FRP) such as carbon fiber composites are known to be difficult for disposal and recycle. It is also known that green composites can be applied as replacement of FRP[1], and therefore environmental-friendly resins should be used as a matrix. Generally, epoxy resin based prepregs including reinforcing fibers are stored at frozen temperatures, because of precure at room temperature, but a curing agent (SAN-AID SI-100, SANSHIN CHEMICAL INDUSTRY CO., LTD.) used in this research can prevent curing at room temperature. Epoxy resin cured by SAN-AID SI-100 is quite hard, while it shows low toughness. To improve such properties, alicyclic agent (Epoxidized polybutadiene, EPOLEAD PB3600, Daicel Corporation) was used to give flexibility and better tensile properties.

In order to realize the properties, jER828 (epoxy resin, Mitsubishi Chemical Corporation), EPOLEAD and SAN-AID SI-100 were mixed, treated in a vacuum oven, and cured at 80°C for 2 hours as a pre-cure process and at 120°C for 1 hour as a post-cure process in a drying chamber. Finally, the cured resins were polished to remove pores on the surface. From the tensile test results, it is concluded that fracture strain of the cured resins produced from the curing agent can be improved with increase in EPOLEAD content (Table 1).

Keywords: Curing agent, High storability prebaked resin, Bisphenol epoxy, Epoxidized-polybutadiene, Tensile properties
Preparation and Characterization of Nonwoven Composites with Pet Fibers for Cushion Materials

Jung Yeon Kim, Yeong Og Choi*

Technical Textile & Material Group, Korea Institute of Technology
*Email: yochoi@kitech.re.kr

Abstract
Polyurethane (PU) foams are widely used and applied for automotive seat cushion due to their good characteristics such as good light weight and excellent elasticity. However, the disadvantages of the PU foams are poor permeability, difficulty of recycling, and toxic gas release during manufacturing process. Recently, nonwovens are being developed as an alternative cushion materials. For recycling, it is desirable that nonwoven is made from uni-material. In this study, nonwovens for seat cushion material were prepared from 100% poly (ethylene terephthalate) (PET) based fibers and their properties were thoroughly investigated with respect to the effect of process conditions. Two types of PET hollow fibers which are different in diameter were mixed with three kinds of PET-based elastic binder fibers, having a bi-component sheath-core structures. The evenly mixed fibers were carded, needle punched, and then they were heat pressed by flat-bed, resulting in nonwovens. Figure 1 shows that the bulky nonwoven has greater permeability and compression resilience than that of PU foam. The nonwoven composites which are prepared through carding process from PET fiber could be used as an environment-friendly car seat cushion with high cushioning performance.

Keywords: Car seat cushion, Nonwovens, Uni-material, Compression resilience

Fig. 1 Properties of PU foams and nonwovens; (a) Air permeability and (b) Compressive shrinkage.
Session: Graphene based nanocomposites
Comp-9-P01

Efficient Interfacial Interaction for Improving Mechanical Properties of Polydimethylsiloxane Nanocomposites Filled with Low Content of Graphene Oxide Nanoribbons

Guodong Zhang*, Jia-Yun Li, and Long-Cheng Tang

Hangzhou Normal University
*Email: 1920535529@qq.com

Abstract

In the present work, hydroxyl-terminated polydimethylsiloxane (H-t-PDMS) nanocomposites reinforced by different contents of graphene oxide nanoribbons (GONRs) were prepared via a facile solvent-free process, and the mechanical properties of the H-t-PDMS/GONR nanocomposites were investigated and compared with the corresponding nanocomposites containing pristine carbon nanotubes (CNTs) or functionalized CNTs (f-CNTs).

It was found that the GONRs with abundant functional groups showed good compatibility with H-t-PDMS matrix at appropriate content: both good dispersion levels of GONR sheets and strong GONR/matrix interfacial interactions were achieved at low filling content (≤0.5 wt%), although the GONR sheets showed obvious clusters in the matrix at relatively high content. The mechanical testing indicated that incorporation of low content of GONRs into H-t-PDMS polymer resulted in significant improvements in both the tensile and tear strength, e.g. about 158 and 284% at 0.5 wt% GONRs, respectively; and such reinforcement efficiency of GONRs in PDMS nanocomposites showed much better than those of the corresponding CNTs or f-CNTs, even superior to those of other carbon nanofillers in previous PDMS-based nanocomposites systems. Based on the morphology and fracture surface analysis, the possible reinforcing mechanisms were discussed and clarified to understand the discrepancies in the mechanical properties of the nanocomposite systems studied.

Keywords: Polydimethylsiloxane, Nanoribbons, Mechanical property, Nanofillers
Session: Graphene based nanocomposites
Comp-9-P02

Rheological Study on Graphene Nanoplatelets (GNP) Filled Polyvinylidene Fluoride (PVDF) Nanocomposites
Bin Yang*, Peng Chen, Jia-Sheng Qian, Ji-Bin Miao, Ru Xia, Bin Wu, Ming Cao, and You Shi

School of Chemistry & Chemical Engineering, Anhui University, 230601, Anhui, P.R. China
*Email: beanyoung@163.com

Abstract
Nowadays, polyvinylidene fluoride (PVDF) has been widely applied in lithium-ion battery (LIB) separator, packaging materials and many other fields. Graphene nanoplatelet (GNP), a commonly used filler of high thermal conductivity, is easy to form network structure in the matrix. Series of PVDF/GNP composites were prepared via solution method (SM) and melt-solution method (MSM), respectively. Comparison of rheological characteristics between SM and MSM showed that SM was superior to MSM in view of filler dispersion in the matrix. Both rheological and thermal properties were examined. The composites showed obvious complexity of thermal rheology with increasing GNP loading even at a low content of 2 wt.%. The thermal conductivity of PVDF composites was significantly improved with increasing filler content, and the maximum thermal conductivity achieved was 1.03 W/m·K. The result of in-situ temperature measurement was in good agreement with the change of thermal conductivity, which could be utilized as a novel indicator of the thermal conductivity. However, the thermal stability of the composites were almost unaffected by the content of the filler according to thermogravimetry (TG) analysis. This work could be practically significant to further study the "processing-structure-property" relationship of PVDF nanocomposites and the extension of their application fields.

Keywords: Rheological property, Polyvinylidene fluoride, Graphene nanoplatelets, Solution blending

Fig. 1 Thermorheological complexity of PVDF/GNP nanocomposites.
A Novel Nanocomposites Based on “White Graphene” for Thermal Management Applications

Dan Liu¹, Jiemin Wang¹, Yuanpeng Wu¹,², Ye Xue³, Xuebin Wang⁴,⁵, Xiao Hu³, Yoshio Bando⁴,⁶, and Weiwei Lei¹,*

¹Institute for Frontier Materials, Deakin University, Waurn Ponds Campus, Locked Bag 20000, Victoria 3220, Australia.
²School of Materials Science and Engineering, Southwest Petroleum University, Chengdu, China.
³Department of Physics and Astronomy and Department of Biomedical Engineering, Rowan University, 201 Mullica Hill Road, Glassboro, New Jersey 08028, United States.
⁴International Center for Materials Nanoarchitectonics (WPI-MANA), National Institute for Materials Science (NIMS), Namiki 1-1, Tsukuba, Ibaraki 305-0044, Japan.
⁵College of Engineering and Applied Sciences, Nanjing University, Nanjing 210093, China.
⁶Australian Institute for Innovative Materials University of Wollongong North Wollongong, NSW 2500, Australia.

Abstract

Traditional electron devices and electric appliances such as cell phones and televisions are becoming more intelligentized and personalized. However, although these devices have integrated the advantages of smaller size and multi-functions, the issue of low heat dissipation still remains in suspense. Especially with the frequent use of electronics, the batteries consume faster than before, thus generating intense heat and causing accessories failure.¹ Therefore, to design materials with efficient thermal management is of high significance. Here, we design a highly water-soluble functionalized “white graphene”, boron nitride (FBN) nanosheets.²-⁴ Unlike most functional BN nanosheets which are only dispersible in water with polymer matrix at low concentrations, our FBN nanosheets could be mutually dispersed with aqueous polymers such as polyvinyl alcohol (PVA) in arbitrary weight ratios.⁵ The robust FBN/polymer freestanding films with layer by layer laminate nanostructures are well fabricated after facile vacuum filtration.⁶,⁷ The nanocomposite films exhibit superior in-plane thermal conductivity (120 W m⁻¹ K⁻¹ for 90 wt% FBN loading in FBN/PVA film), which is nearly 100 times larger than the pristine PVA film. Meanwhile, the FBN/polymer films could provide good fire-resistance ability, thus effectively retarding the flammability. Those properties, combined with high chemical and temperature stability make the FBN/polymer films useful for various applications, particularly in thermal management (heat spreading), flexible and fire-retardant electronic devices.

Keywords: BN nanosheets, PVA, Composite film, Thermal conductivity
Session: Graphene based nanocomposites
Comp-9-P04

The Effects of Conductive Nano Fillers Alignment on Dielectric and Energy Harvesting Properties of Co-Polymer Matrix
Md Habibur Rahaman¹, and Hyeon Cheol Kim²*

¹School of Electrical Engineering, University of Ulsan, 93 Daehak-ro, Nam-gu, Ulsan 44610, Republic of Korea
²School of Electrical Engineering, University of Ulsan, 93 Daehak-ro, Nam-gu, Ulsan 44610, Republic of Korea
*Email: hckim08@mail.ulsan.ac.kr

Abstract
This research focuses on the improvement of the dielectric and energy harvesting properties of piezoelectric P(VDF-TrFE) matrix by the alignment of conductive RGO nano fillers. The dispersion and the morphology of the conductive nano fillers on the co-polymer matrix was carefully checked by scanning electron microscopy which showed a configurational phase transition (fig.1) due to highly conductive nanochannel formation, steric hindrance, excluded volume interaction [1], vander-walls forces between adjacent RGO sheets [2, 3]. Five different piezoelectric nanocomposites (table 1) were prepared by varying the RGO contents in P(VDF-TrFE) matrix to realize its optimum concentration in the matrix. From our analysis, we observed that, an optimised morphological structure plays a vital role in the formation of polar electroactive β phase on the co-polymer matrix through the good dispersion, filler alignment and interfacial interaction of RGO nano fillers. The as prepared nanocomposite film showed an enhanced crystallinity (50~52%), dielectric constant (72 at 1 kHz), piezoelectric charge constant (-23 pC/N) with an output power of 3.2 μW at 1.8 MΩ load for 2N mechanical force (table 2). All the outputs were observed without applying poling process. We expect that our synthesized self-poled nanocomposite can be a useful candidate for energy harvesting applications.

Keywords: Energy harvesting, Co-polymer, Conductive filler, Fillers alignment, Crystallinity

Fig. 1 (a, c) Schematic representation of isotropic to nematic phase transition of RGO nano fillers. (b, d) corresponding SEM image of RGO fillers in co-polymer matrix.
Dumbbell-Like Fe₃O₄-Au Nanoparticles Immobilized on Graphene Oxide Nanosheets for SERS Detection

Chi-Ming Liu¹, Ting-Yu Liu¹,*, and Yuh-Lin Wang²

¹Department of Materials Engineering, Ming Chi University of Technology, New Taipei City 24301, Taiwan
²Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei 10617, Taiwan

*Email: tyliu0322@gmail.com

Abstract

We have successfully fabricated the dumbbell-like Fe₃O₄-Au nanoparticles (NPs) and then immobilized them on the graphene oxide (GO)-poly (dimethyldiallylammonium) chloride (PDDA) nanosheets for magnetic separation and surface enhanced Raman scattering (SERS) detection applications. PDDA will be modified on the GO nanosheets by stacking interaction and display the positive charge on the surface. Furthermore, the negative charge of dumbbell-like Fe₃O₄-Au NPs will incorporate with GO-PDDA nanosheets to form Fe₃O₄-Au NPs-GO-PDDA (FAGP) SERS substrate by electrostatic force. According to the preliminary results of transmission electron microscope (TEM), the Au nanoparticles can grow on the surface of Fe₃O₄ nanoparticles to form dumbbell-like Fe₃O₄-Au nanoparticles and can uniformly dispersed on the GO-PDDA nanosheet. On the other hand, we also expect to use the quaternary ammonium salt for phase transition (oil to water phase). Long carbon chains on the FAGP surface can be replaced by hydrogen-bonded carbon chains, which can easily transfer oil phase into water phase. The FAGP magnetic SERS substrate can be applied to magnetic separation of the oil-phase sample (copper chlorophyll) or water-phase samples (biomolecules (adenine), bacteria (E. coli)), as well as rapid and label-free detection by SERS nanotechnology.

Keywords: Dumbbell-like Fe₃O₄-Au nanoparticles, Graphene oxide, Magnetic nanoparticles, Surface-enhanced Raman scattering (SERS)

Fig. 1 (Left) Schematic illustration of magnetic separation and SERS detection of Fe₃O₄-Au-GO-PDDA SERS substrate; (Right) Schematic diagram of phase transition of dumbbell-like Fe₃O₄-Au nanoparticles.
Investigations of Raman Enhancing and Photothermal Effects by Various Aspect Ratios of Gold Nanorods on Graphene Nanosheets

Ting-Yu Liu\textsuperscript{1,*}, Yi-Cheng Hu\textsuperscript{2}, Li-Ying Huang\textsuperscript{2}, Ming-Chien Yang\textsuperscript{2}, and Yuh-Lin Wang\textsuperscript{3}

\textsuperscript{1}Department of Materials Engineering, Ming Chi University of Technology, New Taipei City 24301, Taiwan
\textsuperscript{2}Department of Materials Science and Engineering, National Taiwan University of Science and Technology, Taipei 10607, Taiwan
\textsuperscript{3}Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei 10617, Taiwan

*Email: tyliu0322@gmail.com

Abstract

In this study, various aspect ratios of Au nanorods (AuNRs) were successfully prepared by seed-mediated growth methods for surface-enhanced Raman scattering (SERS) detection and photothermal therapy. Furthermore, AuNRs were homogeneously immobilized on the polyvinylpyrrolidone (PVP)-modified reduced-graphene oxide (RGO) nanosheets through charge interactions, termed as AuNRs@RGO. The resulting AuNRs@RGO was characterized systematically by transmission electron microscopy (TEM), zeta potential, X-ray diffraction (XRD), Raman spectroscopy, and X-ray photoelectron spectroscopy (XPS). The result shows that AgNRs/RGO ratio=5/8 (aspect ratio of AuNRs=4.1) displays the highest SERS intensity and photothermal therapy effects. The limit of detection (LOD) of rhodamine 6G (R6G) in AgNRs/RGO is lower than 10\textsuperscript{-8} M, and temperature can increase up to 30\degree C (\textasciitilde T) after laser (808 nm) exposure for 7 mins. The novel AuNRs@RGO nanohybrids are potentials for both SERS sensing and photothermal therapeutic applications.

Keywords: SERS detection, Photothermal therapy, Gold nanorods, Graphene nanosheets

Fig. 1 The schematic diagrams of various aspect ratios of gold nanorods grown on reduced-graphene oxide (RGO) nanosheets for SERS detection and photothermal therapy.
Highly Oriented Poly(Vinyl Alcohol)/Graphene Oxide Nano-Composite Hydrogels and Its Reinforcing Mechanism

Yeqiao Meng, and Lin Ye*

State Key Laboratory of Polymer Materials Engineering, Polymer Research Institute of Sichuan University, Chengdu, China

*Email: yelinwh@126.com

Abstract

The oriented poly(vinyl alcohol) (PVA)/graphene oxide (GO) nano-composite hydrogels were prepared by stretching during the freezing/thawing process. With increasing draw ratio, for both PVA and PVA/GO hydrogels, the crystallinity and orientation factor increased dramatically, while the grain size decreased. Meanwhile, the long period (Lac) of amorphous and crystalline regions increased, indicating that chain slipping of PVA molecules resulted in an increasing distance of neighboring crystal lamella. Compared with PVA hydrogels, by introduction of GO, the synergic orientation effect of both PVA molecules and GO sheets, which could be reflected by increasing intensity of GO peak in the X-ray diffraction (XRD) analysis, resulted in higher crystallinity and orientation degree of the composite hydrogels. The storage modulus and effective crosslinking density were improved remarkably and the reinforced network structure formed. The extremely high mechanical properties of PVA hydrogels can be achieved: the tensile strength and compressive modulus increased dramatically from 1.5MPa and 0.6MPa to 12MPa and 5.36MPa, respectively (Fig. 2). This study shows promising potentials in developing new materials for cartilage replacement with high mechanical property.

Keywords: Poly(vinyl alcohol) (PVA) hydrogel, Graphene oxide (GO), Oriented structure, Effective crosslinking density, Reinforcing mechanism

Fig. 1 (a) 2D-SAXS patterns and (b) XRD spectra of PVA and PVA/GO hydrogels with different draw ratio.
One-Pot Solvothermal Preparation of Fe₃O₄-Urushiol-Graphene Hybrid Nanocomposites for Highly Improved Fenton Reactions

Xuelin Zheng¹,*, Hongyang Cheng¹, and Liangxu Lin²

¹College of Chemical and Material Science, Fujian Normal University, PR China
²The State Key Laboratory of Refractories and Metallurgy, Wuhan University of Science and Technology, PR China
*Email: parrowxg@163.com

Abstract

Fenton reactions have various useful applications in many fields, and significant efforts have been made to improve their efficiency. However, most traditional Fenton catalysts suffer the weaknesses of the generation of sludges, the agglomeration of catalyst, the loss of catalysts during the chemical process, which highly suppressed the practical applications. Here, a new type Fenton-like catalyst was designed and fabricated by anchoring Fe₃O₄ nanoparticles (NPs) on the functionalized graphene oxide (GO) sheets via a one-step and environment-friendly reduction route. The green urushiol (U) monomers were used to modify GO, to stabilize the formed Fe₃O₄ NPs (~8 nm), as well as to strongly link reduced GO sheets and Fe₃O₄ NPs, giving homogenous, stable and highly efficient catalyst for Fenton-like reactions. The generation of the catalytically inactive Fe³⁺ sludges and the decomposition of H₂O₂ (to form H₂O and O₂) during traditional Fenton reactions were also highly inhibited by the urushiol, giving powerful catalytic abilities and excellent cycling performance.

Keywords: Urushiol, Graphene oxide, Fe₃O₄ nanoparticles, Fenton reaction, Catalysis improvement

Fig. 1 Synthesis of Fe₃O₄-U- rGO (a). SEM images of Fe₃O₄-U-rGO (b) and Fe₃O₄-rGO (c). Degradation of RhB solution with Fe₃O₄-U-rGO (d). Cycling degradation of RhB solution with Fe₃O₄-rGO and Fe₃O₄-U-rGO (e).
Session: Graphene based Nanocomposites
Comp-9-P09

**Novel Composite Of FeCo$_2$S$_4$ Nanoparticles Encapsulated Nitrogen Doped Graphene for High-Performance Supercapacitors**

Yazan Al Haj$^1$, Jayaraman Balamurugan$^1$, Ahmed Bahaa$^1$, Nam Hoon Kim$^1$,* and Joong Hee Lee$^{1,2}$,*

$^1$Advanced Materials Institute of BIN Convergence (BK plus Global) & Department of BIN Convergence Technology, Chonbuk National University

$^2$Center for Carbon Composite Materials, Department of Polymer & Nano Science and Technology, Chonbuk National University, Jeonju, Jeonbuk, 54896, Republic of Korea

*Email: nhk@chonbuk.ac.kr; jhl@chonbuk.ac.kr

**Abstract**

Extensive research has been focused on developing alternative energy conversion and storage devices from renewable resources with outstanding energy and power densities. Herein, we have developed a new type of nanocomposite based iron cobalt sulfide nanoparticles encapsulated nitrogen-doped graphene sheets (FeCo$_2$S$_4$@NG) for high-performance supercapacitors. Hierarchical FeCo$_2$S$_4$@NG nanocomposite has been successfully synthesized by a simple, scalable, in-situ hydrothermal technique at the reaction temperature of 180°C for 12 h. FE-SEM study clearly reveals that the FeCo$_2$S$_4$ nanoparticles (particle size of $\sim$40 nm) are homogeneously encapsulated by NG sheets. Remarkably, FeCo$_2$S$_4$@NG nanocomposite delivers an ultra-high specific capacitance of $\sim$1794 F g$^{-1}$ at 1 A g$^{-1}$, excellent rate capability ($\sim$1420 F g$^{-1}$ at 10 A g$^{-1}$), and a superior cycling stability. Such outstanding electrochemical properties due to the unique properties such as high specific surface area, exclusive porous network, super core-shell architecture, and high mechanical stability. This current study provides a new pathway to synthesis new ternary metal sulfide and graphene-based nanocomposite for high-performance energy storage and conversion devices in modern electronics.

**Keywords:** FeCo$_2$S$_4$, Nitrogen-doped graphene, Nanoparticles, Supercapacitors
High Thermal Conductivity Enhancement in Polymer Insulating Materials by Constructing Boron Nitride-Graphene Sponge

Yulan Guo¹²³, Hua Wang¹³*, Xingyou Tian¹³*, Jing He¹²³, Zheng Su¹²³, and Qiqi Qu¹²³

¹Institute of Applied Technology, Hefei Institutes of Physical Science, Chinese Academy of Sciences, Hefei 230088, People's Republic of China
²University of Science and Technology of China, Hefei 230036, People's Republic of China
³Key Laboratory of Photovoltaic and Energy Conservation Materials, Chinese Academy of Sciences, Hefei 230088, People's Republic of China

*Email: wanghua@issp.ac.cn; xytian@issp.ac.cn

Abstract

In this study, a novel method for highly thermally conductive but electrically insulating epoxy composites is reported. The three dimensional graphene sponge (GS) supported boron nitride (BN) sheet (BN@GS) was fabricated through a facial method by using ammonium sulfide under mild conditions. Epoxy resin was used as matrix for the composite. Field emission scanning electron microscope (FESEM), X-ray film and power diffraction (XRD), Confocal Raman Microscopy, High resistivity meter, a digital, four-point probe RTS-9 resistivity measurement system, a TCI thermal conductivity meter, thermogravimetric analysis (TGA) were used to characterize the composites. The thermal conductivity obtained was 1.05 W m⁻¹ K⁻¹ at a filler loading of 30wt%, which was 5.38 times as high as that of the BN/epoxy composites without graphene. The three-dimensional continuous network structure of GS endowed the composites with enhanced thermal conductivity at a relatively low filler loading. In the meantime, the electrical conductivity of the composites corresponded to insulator region. The introduction of BN cut off the transmission of electrons which resulted in the electrical insulation of the composites. The prepared composites showed good thermal conductivity and electrical insulation, which therefore is potentially useful as microelectronic packaging materials in small electronic devices.

Keywords: BN, Graphene, Electrical insulation, Thermal conductivity
Research on Highly Flame-Retardant Rigid Polyurethane Foams by Combination of Inorganic Additives and Phosphorous Compound

Linjie Li, Lijun Qian*, and Yajun Chen

School of Materials Science and Mechanical Engineering, Beijing Technology and Business University, Beijing 100048, China

*Email: qianlj@th.btbu.edu.cn

Abstract

A series of flame-retardant rigid polyurethane foams (RPUFs) containing dimethyl methyl phosphonate (DMMP), expandable graphite (EG), aluminum hydroxide (ATH) and TGIC-DOPO (synthesized by a controllable ring-opening addition reaction between 1,3,5-triglycidyl isocyanurate (TGIC) and 9,10-dihydro-9-oxa-10-phosphaphenanthrene-10-oxide (DOPO) in our laboratory) were prepared via box-foaming. The flame-retardant properties of TGIC-DOPO/DMMP/EG/ATH on RPUFs were systematically investigated. The TGIC-DOPO/DMMP/EG/ATH flame-retardant system with certain components ratio increased the LOI value, decreased the peak value of heat release rate, sustained the effective heat of combustion and total heat release in low level comparing with DMMP/EG/ATH and TGIC-DOPO/EG/ATH systems. The results imply that TGIC-DOPO/DMMP/EG/ATH possessed the component synergistic flame-retardant effect on RPUFs.

Keywords: Flame retardant, Polyurethane foam, EG, Phosphorous compound

Fig. 1 Molecular structures of TGIC-DOPO.
A Novel Bridged Flame Retardant System and Its Application in Low Density-Rigid Polyurethane Foam

Linshan Li, Yajun Chen*, and Lijun Qian

School of Materials Science and Mechanical Engineering, Beijing Technology and Business University, Beijing 100048, PR China

*Email: chenyajun@th.btbu.edu.cn

Abstract

A novel surface modification agent with flame retardancy, phosphorus-containing organosilicon compound (POCO) was synthesized. Then POCO was used to modify graphene oxide (GO) and ammonium polyphosphate (APP), named as MGOAPP. The transmission electron microscope (TEM) and scanning electron microscope (SEM) results illustrated that GO and APP was successfully surface modified by POCO. Moreover, GO and APP was bridged by POCO. The flame retardancy of MGOAPP on low density-rigid polyurethane foam (LD-RPUF) was investigated by cone calorimeter test (CCT) and horizontal burning test. The results showed that the incorporation of MGOAPP obviously reduced the peak of heat release rate values of LD-RPUF comparing with LD-RPUF/APP, which decreased from 418 kW/m² to 222 kW/m². It also effectively restrained the generated heat and smoke during combustion. In addition, the char yield of LD-RPUF/MGOAPP (33.9%) was much higher than that of LD-RPUF/APP (23.4%).

Keywords: Phosphorus-containing silica gel, Graphene oxide, Ammonium polyphosphate, Surface modification, Flame retardancy

Fig. 1 TEM of GO (a) and MGOAPP (b) and SEM of MGOAPP (c).
Synthesis of Aluminum (Hydroxy-Phenyl-Methyl) Phosphinate and Its Application in Poly (Lactic Acid) as a Novel Flame Retardant

Xingguo Wang\textsuperscript{1,2}, Sheng Zhang\textsuperscript{1,2,*}, Jun Sun\textsuperscript{1,2}, Hongfei Li\textsuperscript{1,2}, and Xiaoyu Gu\textsuperscript{1,2,*}

\textsuperscript{1}Beijing Key Laboratory of Advanced Functional Polymer Composites, Beijing University of Chemical Technology, Beijing, China
\textsuperscript{2}Center for Fire Safety Materials, Beijing University of Chemical Technology, Beijing, China
\textsuperscript{*}Email: zhangsheng@mail.buct.edu.cn; guxy@mail.buct.edu.cn

Abstract

Aluminum (hydroxy-phenyl-methyl) phosphate (AlHMPi) was synthesized and characterized. AlHMPi was melt blended with Poly (lactic acid) (PLA) to obtain flame-retarded PLA composite. The results showed only 5 wt\% AlHMPi can endow PLA with a sharply increased limiting oxygen index (LOI) value of 26.8 from 20.0 for neat PLA and V-0 rating in vertical burning test (UL-94). The results indicated the flame retardancy of PLA was effectively improved by a low addition of AlHMPi, which brought limited deterioration on mechanical.

Keywords: Poly(lactic acid), Aluminum (hydroxy-phenyl-methyl) phosphate, Flame-retardant, Synthesis and processing techniques

Fig. 1 FTIR spectrum (L) and 1HNMR spectrum (R) of AlHMPi.
Session: Flame Retardant Composites
Comp-6-P04

Flame Retardant Expandable Polystyrene Foams Coated with Ethanediol Modified Melamine-Formaldehyde Resin and Microencapsulated Ammonium Polyphosphate

Wenfei JI1,2, Jun SUN1,2, Sheng ZHANG1,2,*, Hongfei LI1,2, and Xiaoyu GU1,2

1Beijing Key Laboratory of Advanced Functional Polymer Composites, Beijing University of Chemical Technology, Beijing, 100029, China
2Center for Fire Safety Materials, Beijing University of Chemical Technology, Beijing, 100029, China

*Email: sunj@mail.buct.edu.cn; szhang1966@163.com

Abstract

Melamine-formaldehyde resin was modified by ethylene glycol to prepare microencapsulated ammonium polyphosphate (MCAPP). Afterwards, EMF and MCAPP were mixed and coated on the surface of pre-expanded polystyrene particles to prepare flame retardant expandable polystyrene foams (EPS), the flammability of which was improved a lot. For the sample containing 75 phr MCAPP, the LOI value was increased to 31.4% with V-0 rating in UL-94 test. The cone calorimeter tests showed that the peak heat release rate of the sample declined sharply by 81.6% from that of neat EPS. The smoke production of EPS foams during combustion was suppressed by the presence of MCAPP, and the thermal stability was also improved. Digital char observation showed that the char layer of flame retardant sample after combustion became compact with negligible void or cracks, which could further form an isolated barrier to prevent both heat and flame transfer.

Keywords: Polystyrene, Resins, Foams, Coatings

Fig. 1 Synthesis routes of EMF resin.
Self-Assembly of a Bio-Based Flame Retardant for Polylactic Acid

Yan Zhang¹, Zhengquan Xiong¹, Jian Jing², and Zhengping Fang¹,²,*

¹Lab of Polymer Materials and Engineering, Ningbo Institute of Technology, Zhejiang University, Ningbo 315100, China
²MOE Key Laboratory of Macromolecular Synthesis and Functionalization, Department of Polymer Science and Engineering, Zhejiang University, Hangzhou 310027, China

*Email: zhangyan@nit.zju.edu.cn

Abstract

A novel bio-based core-shell flame retardant was prepared through self-assembly of ammonium polyphosphate (APP), chitosan (CS) and sodium phytate (PA-Na). The thermal stability and flame retardancy were characterized by thermal gravimetric analysis (TGA), vertical burning tests (UL-94), limiting oxygen index (LOI) and the cone calorimetric tests. The results showed that APP@CS@PA-Na could impart better flame retardancy for PLA.

Keywords: Fire retardant, Self-assembly, Core-shell structure, PLA, Biomass

Fig. 1 The SEM images of (A) APP, (B) APP@CS and (C) APP@CS@PA-Na.
Session: Flame Retardant Composites
Comp-6-P06

Intrinsic Flame Retardant Urea Formaldehyde/Polyamide Fiber Composite Foam: Structure and Reinforcing Mechanism
Yalong Liu, Xiaowen Zhao*, and Lin Ye
State Key Laboratory of Polymer Materials Engineering, Polymer Research Institute of Sichuan University
*Email: zhaoxiaowenscu@126.com

Abstract
Polymeric foams based on polyurethane, polystyrene and polyethylene resins usually have the defect of high combustibility[1]. In this study, the intrinsic flame-retardant urea-formaldehyde/polyamide fiber (UF/PAF) composite foam was fabricated via in situ polymerization and water-based foaming process. At low PAF content (<3wt%), PAF can disperse homogeneously in the foam and act as heterogeneous nucleating agent, resulting in smaller cell size, narrower cell size distribution, lower porosity and less water absorption for the foam. For UF/2wt%PAF foam, the pulverization ratio decreased by 11%, while the compressive strength and modulus increased by 198% and 257% respectively compared with neat UF foam. As the "pillar" structure, PAF enhanced the stiffness of the cell wall. Moreover, during the stage of crack propagation, due to the strong hydrogen bonding interaction between PAF and UF matrix, PAF can play a role of bridge between the cracks, preventing the further expansion of the crack, increasing the crack propagation path and thus delaying the disastrous collapse of cells. By addition of PAF, the decomposition temperature and char yield increased, while the UL-94 tests were classed as a V-0 rating, and during burning, the expansion of the flame was suppressed remarkably for the composite foams.

Keywords: Urea formaldehyde, Polyamide fiber, Intrinsic flame retardant, Reinforcing
Molecular Dynamics Simulations of Polyelectrolyte Brushes in Confined Environment

Lujuan Li¹, and Qianqian Cao²,*

¹Centre for Future Materials, University of Southern Queensland, Springfield, QLD 4300, Australia
²College of Mechanical and Electrical Engineering, Jiaxing University
*Email: li.lujuan@foxmail.com; cao.qianqian@foxmail.com

Abstract

The confinement dynamics of polymers brushes still remains unclear so far. To understand the effect of counterion valence on confined polyelectrolyte brushes that is not obtained easily from the experiment, molecular dynamics simulations are employed to address these issues. It is profound to analysis the effect of electrostatic correlation on the conformational behavior of polyelectrolyte brushes in the presence of counterions with different valence on molecular levels. Here, we use molecular dynamics simulations to investigate the effect of counterion valence on the brush structure in confined environment and explain how the slit gap contributes to the electrostatic correlation and counterion diffusion. It was found that the effect of the charge fraction on the brush conformation is opposite for different counterion valence. For monovalent case, the brush thickness increases with the charge fraction due to the excluded volume interaction. However, the grafted chains contract towards the core for the trivalent case. The confinement environment has little effect on the distribution of counterions inside the brushes because most trivalent counterions are confined in the brushes owing to strong electrostatic correlation. Nevertheless, more monovalent counterions can diffuse into the brush as the slit gap decreases.

Keywords: Molecular dynamics simulations, Confinement, Electrostatic correlation, Polyelectrolyte brushes

Fig. 1 The simulation snapshots of the Spherical Polyelectrolyte Brushes in trivalent counterions.
Interaction of Metakaolin-Phosphoric Acid and Its Fire Performance of Polypropylene Composite

Wenjia Wang\textsuperscript{1,2}, Sheng Zhang\textsuperscript{1,2}, Hongfei Li\textsuperscript{1,2}, Jun Sun\textsuperscript{1,2}, and Xiaoyu Gu\textsuperscript{1,2,*}

\textsuperscript{1}Beijing Key Laboratory of Advanced Functional Polymer Composites, Beijing University of Chemical Technology, Beijing, China

\textsuperscript{2}Center for Fire Safety Materials, Beijing University of Chemical Technology, Beijing

*Email: guxy@mail.buct.edu.cn

Abstract

PP is highly combustible with severe dripping and no char residue left, its LOI is only 18\%, which restricts its application in flame-retarded 1. Kaolin has proven to be an effective synergist in intumescent flame retardant systems\textsuperscript{2}. It is reported that acid-kaol significantly promotes the formation of carbonaceous char residues that was helpful to improve the thermal stability and flame retardancy\textsuperscript{3}. Metakaolin soaked in phosphoric acid for 2h to get a mid-product (S4) and then Calcined at different temperatures (200,400,600,800\degree C) to give the acid-kaol (C2, C4, C6, C8). The modified kaolinite has also applied in polypropylene (PP) with intumescent flame-retardant (IFR). The flammability of PP/IFR/acid-kaol were studied by limiting oxygen index (LOI), vertical burning test (UL-94). LOI value of PP/25 wt.\% IFR composite was 27.5\%, it increased to 34.8\% by 3.0wt.\% S6 substitution with IFR. Meanwhile, the addition of acid-kaol in PP/IFR demonstrate better thermal stability at high temperature and char residues than kaolin.

Keywords: Flame retardant, Polypropylene, Phosphoric acid, Kaolinite, Thermal stability

Fig. 1 FTIR spectra of Kaol and its modified products.
Enhanced mechanical properties of mg2si-reinforced Aluminum composites by Bi addition

Zhou Gui*

State Key Laboratory of Fire Science, University of Science and Technology of China (USTC), Hefei, Anhui, 230027, China
*Email: zgui@ustc.edu.cn

Abstract

Thermoplastic polyurethane (TPU) is extensively used due to its excellent physical properties, flexibility at low temperature, abrasion resistance, variable hardness, etc., as other polymeric materials, TPU presents some drawbacks including low thermal stability and flammability. Graphene foams (GF) can be prepared with an extremely low thermal conductivity, but the mechanical properties were unsatisfactory. It will be interesting to produce new composites with good mechanical and other properties by a method that combines TPU and GF each other’s advantages.

In this work, an infiltration method was developed to prepare TPU/GF composites. Different from the past method that polymer composites synthesised by adding inorganic filler to polymer matrix, this time we immerse polymer into the frameworks of GF. Since frameworks of GFs are stably formed, the dispersibility of filler in polymer matrix will not be involved, which is important to the uniformity of composites.

Thermostability, flame retardancy, thermal conductivity and mechanical properties of TPU/GF composites were carried out to verify the enhancement effect. Stable framework of GFs contributed to uniformity of composites and endowed them preferable thermal and mechanics performance. Results of Thermogravimetric analysis (TGA) and microscale combustion calorimeter (MCC) manifested that thermostability and flame retardancy of the composites were superior to pure polymer, which was contributed to barrier effect of GF. Char residue of TPU/GF composites not only remained original shape, but withstood certain pressure, which decreased the potential fire risk.

Polymeric materials design based on GF is a feasible scheme to obtain composite with good integrated performance.

Keywords: Flame retardancy, Thermoplastic polyurethane composites, Graphene foam, Thermal and mechanical properties, Infiltration method
Session: Flame Retardant Composites
Comp-6-1-I1

Influence of Matrix Feature on the Flame Retardant Action Mode of Mutil-Phosphaphenanthrene Compound
Yong Qiu\textsuperscript{1,2}, Zhen Liu\textsuperscript{1}, Lijun Qian\textsuperscript{1,*}, and Jianwei Hao\textsuperscript{2}

\textit{1 School of Materials Science and Mechanical Engineering, Beijing Technology and Business University, Beijing 100048, China}
\textit{2 School of Materials Science and Engineering, Beijing Institute of Technology, Beijing China}

*Email: qianlj@th.btbu.edu.cn

Abstract
As a mutil-phosphaphenanthrene compound (shown as Fig 1), TDBA exhibits excellent performance in improving the limited oxygen index (LOI) and UL94 level of both epoxy thermoset (EP) and polycarbonate (PC), shown as Table 1. The forced combustion behavior in cone calorimeter test also verified the effectiveness of TDBA in restraining the combustion intensity of burning EP and PC. The peak of heat release rate (pk-HRR) and total heat release (THR) were both suppressed obviously. Even so, the detailed traces in quantitatively evaluation results revealed the different action modes of TDBA in above two materials. In the case of TDBA/EP, the enhancement of gaseous-phase flame inhibition effect (1-EHCFR/EHCNeat) kept pace with that of condensed-phase charring effect (1-TMLFR/TMLNeat).\textsuperscript{1} Whereas, although TDBA-containing PC exhibited outstanding flame inhibition effect, the negative effect of TDBA on PC matrix charring behavior exposed its defect in condensed-phase action. Above these results indicated that the flame retardant action mode of phosphaphenanthrene-containing compound not only decided by its specific chemical structure, but also influenced by the structure of matrix greatly. This study reveals that, besides specific flame retardant structure, the potential interaction between additives and matrix also play key roles in a successful flame retardant system.

Keywords: Flame retardant, Phosphaphenanthrene, Epoxy, Polycarbonate

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{TDBA.png}
\caption{Chemical structure of TDBA.}
\end{figure}
Novel Approach to Fabricated Natural Rubber Composites

Dongning He¹,², Jinlong Tao², Pingan Song¹, Venkata S. Chevali¹, Zheng Peng², and Hao Wang¹,*

¹Centre for Future Materials, University of Southern Queensland, Springfield, QLD 4300, Australia
²Agricultural Product Processing Research Institute, Chinese Academy of Tropical Agricultural Sciences, Zhanjiang 524001, China

*Email: hao.wang@usq.edu.au

Abstract

The artificial natural rubber latex with nano-fillers doped inside of natural rubber (NR) particles was prepared using NR gum for polymer matrix as shown in Fig 1. Since the traditional NR nanocomposites processing methods have many disadvantages, including, high energy cost, dust pollution, heterogeneous filler dispersion, and one method unsuitable for both hydrophobic fillers and hydrophilic fillers. Therefore, a new NR nanocomposites processing method needed to be developed. The artificial NR particles were prepared based on the polymer microspheres technology. Due to the nano-fillers need to be put inside of the artificial NR particles (ANRP) and nano-fillers have different sizes, the particle size of ANRP should be tunable. The diameter of the ANRP can be controlled from hundreds of nm to dozens of µm. The vulcanization agents act as crosslinking agents, which could be used to immobilize the morphology of the microspheres. The different categories of fillers should have different pre-treatment to suspend them in the suitable solution also. The hydrophilic filler uses water/oil/water method. Moreover, the hydrophobic filler is suitable for water/oil approach. Moreover, multi-walled carbon nanotubes (MWCNT) protruded from the inside of the particle or not can be controlled as well.

Keywords: Natural rubber, Nanocomposites, Graphene, Multi-walled carbon nanotube, Silica

Fig. 1 TEM image of ANRP filled with different kinds of fillers. (a). Silica filled into ANRP; (b). Graphene filled into ANRP; (c). MWCNT filled with ANRP and the cnt have not protruded from the inside of the particle; (d). MWCNT protrudes from the inside of the particle.
Fabrication of Anisotropic Janus Composite Particles Based on Natural Renewable Urushiol

Qinhui Chen*, Shuning Chen, and Haiqing Liu

*Email: chenqh@fjnu.edu.cn

College of Chemical and Material Science, Fujian Normal University, PR China

Abstract

Janus particles with heterogeneous surface chemistries have been prepared with many methods, among which, the emulsion swelling assisted protrusion of the core from the shell gets a lot of attention because it is easy to control the proportion of two lobes of Janus particles and to be produced in mass1. So far, most of the organic lobe of Janus particles are polystyrene, polyacrylate and other synthetic polymers. Herein, urushiol (U) extracted from natural products of raw lacquer is introduced into the Janus particles. The anisotropic Janus composite particles based on urushiol metal chelate polymer (UM), as UTi/PS, UTi/PANi, UEr/PMMA and UFe/PMPS, were synthesized. The two lobes of Janus particles could be compartialized distinctly and be adjusted by controlling the polymerized time(Fig. 1), the usage of swellin monomer and the sulfonated time. This asymmetric structure was benificial for UM to act as oriental catalysis, oriential optical amplification and oriental obsorbtion.

Keywords: Janus, Urushiol, Natural products, Anisotropic

Fig. 1 Synthesis and adjusting of the Janus particles based on urushiol metal chelate polymer.
Research on Modification of Wood Surface Properties by SiO$_2$ Water-Borne Coating

Zhigao LIU, Penglian WEI, and Yunlin FU*

Forestry College, Guangxi University, Nanning, 530004, China

*Email: fylin@126.com

Abstract

Nano-SiO$_2$ was added into water-borne coating to obtain SiO$_2$ water-borne coating through co-mixing method. The SiO$_2$ water-borne coating was coated on Pinus massoniana wood surface in order to study their coating properties. The paper focused on coating property of wood surface with different SiO$_2$ concentration. Modification of SiO$_2$ in aqueous medium was conducted by using sodium carboxymethyl cellulose as a dispersant and KH-560 as a silane coupling agent. The nano-SiO$_2$ dispersion in coating was characterized by SEM/EDXA. The results were as follows:

(1) SEM/EDAX analysis showed that unmodified SiO$_2$ in water-borne coating had reunion phenomenon. Adhesion and impact resistance property got improvement in some extent. Hardness was enhanced to 3H. The durability of coating with 2% unmodified SiO$_2$ content was improved approximately 1.61 times relative to ordinary water-borne wood coatings after 12 aging cycles.

(2) SEM/EDAX analysis confirmed that modified SiO$_2$ was uniform distribution in water-borne wood coatings. Coatings adhesion was enhanced to 1. Hardness was enhanced up to 5H. The durability of coating with 6% modified suspended SiO$_2$ content was improved approximately 1.57 times relative to ordinary water-borne wood coatings after 12 aging cycles.

(3) The obtained results clearly indicated that the properties of modified SiO$_2$ water-borne coating on the wood surface were superior to unmodified SiO$_2$ water-borne coating in adhesion, hardness, impact resistance property, durability.

Keywords: silicon dioxides; water-borne coating; wood surface properties.

Fig. 1 SEM/EDAX image of water-borne wood coatings surface with unmodified SiO$_2$ and modified.
Effects of Sodium Alginate on the Morphology and Properties of High Energy Insensitive Explosive Tkx-50

Shaohua Jin¹, Wenbo Dong¹, Yu Chen¹*, Qinghai Shu¹, Yunfei Liu², and Shusen Chen¹

¹School of Material Science and Engineering, Beijing Institute of Technology, Beijing, P. R. China
²Academy of Propellants and Explosives, Beijing Institute of Technology, Beijing, P. R. China
*Email: bityuchen@bit.edu.cn

Abstract

High energy insensitive explosive TKX-50 is a new type of green energetic ion salt with high energy level, low mechanical sensitivity and environment friendliness. However, its morphology after crystallization in most solvents is not satisfactory. By the way, the coating effect of conventional binders of ammonium nitrate explosives on TKX-50 is poor. In the current study, we found that the morphology of TKX-50 could be improved by using the environmentally friendly natural anionic polyelectrolyte sodium alginate (SA) as the modifier via the solvent-anti-solvent crystallization method. The results of SEM shows that SA had a great influence on the crystal morphology of TKX-50, and the TKX-50 modified granular samples with low aspect ratio could be obtained at certain condition (Fig. 1). The molecular dynamics simulation on formation mechanism of above mentioned process showed that the addition of anionic polymer SA with more active site could reduce the inhibition of solvent on growth rate of \{0,2,0\} crystal surface of TKX-50, while further reducing the growth rate of \{1, 1, 0\} crystal planes, thereby promote the formation of a granular particle with low aspect ratio. The particle size changes during the modifying process were characterized by Focused Beam Reflectance Measurement (FBRM) and Particle Video Microscope (PVM), and the precipitation process was observed. Based on the results of the XPS characterization, the adhesive percentage of SA on TKX-50 was calculated. Through the characterization of DSC, the non-isothermal kinetic parameters for the thermal decomposition of the inclusion composites were calculated. It was found that the modifying of SA enhanced the decomposition activation energy of TKX-50. The above study explores a new way for improving the morphology and coating properties of TKX-50.

Keywords: TKX-50, Sodium alginate, Crystal morphology
Preparation and Properties of Polylactide Reinforced with Eggshell Modified with Different Fatty Acids

Poonsub Threepopnatkul¹,*, Kanpurassakorn Anuraka¹, Onanong Mekmok¹, Alongkorn Khunkaew¹, Amnard Sittatrakul¹, and Chanin Kulsetthanchalee²

¹Department of Materials Science and Engineering, Faculty of Engineering and Industrial Technology, Silpakorn University, Nakhonpathom 73000, Thailand

²Event and Exhibition Design Department, Suan Dusit University, Bangkok 10300, Thailand

*Email: poonsubt@yahoo.com

Abstract

The composite materials of biodegradable polymer, poly(lactic acid) (PLA) and modified eggshell 15 phr were prepared by twin screw extruder. Eggshell were modified with different types of fatty acids i.e. propionic acid and oleic acid. In addition, peroxide was used as a compatibilizer in amount of 0.02 phr. Samples were molded by injection molding machine to prepare the specimens for mechanical testing. Scanning electron microscope (SEM) was used to characterize the fracture surface of the composites for studying morphological properties of composites. Universal testing machine and impact tester were used to investigate the mechanical properties. From the results, dispersion of modified eggshells with fatty acid on PLA was more uniform than unmodified eggshells. Young’s modulus and tensile strength of the composites between PLA and modified eggshell with propionic acid were higher than the PLA and modified eggshell with oleic acid. On the other hands, percentage of elongation at break and impact strength of PLA and modified eggshell with propionic acid were lower than the PLA and modified eggshell with oleic acid.

Keywords: Polylactide, Eggshell powder, Fatty acid, Composite
Session: Naturally Derived Composites
Comp-12-P06

The Preparation, Performance and Application of Starch/Sugarcane Bagasse Based Biodegradable Composites
Huayan Shen*, Mingzhou Chen, Youjun Yang, Dong Xie, Fayong Li, Huiping Zhang, and Xuhua Gao
Guangdong Biomaterials Engineering Technology Research Center, Guangdong Provincial Bioengineering Institute (Guangzhou Sugarcane Industry Research Institute)

*Email: 18814123150@163.com

Abstract
The polylactic acid (PLA)/starch (St)/Sugarcane bagasse (SCB) composites were prepared through extrusion molding with the complex plasticizer. The rheological properties, thermal stability, mechanical properties and biodegradable behavior of the PLA/St/SCB composites were characterized by torque rheometer, thermal gravimetric analysis, tensile tests and soil burial tests. The results indicated that the PLA/St/SCB composites had good rheology behavior and thermal stability, which was beneficial for the melt-processing of the composites. The obtained PLA/St/BF (2/4/4 in mass ratio) composites showed good mechanical property, with the tensile strength of 32.7 MPa and the bending strength of 55.0 MPa. The degradation test in soil showed that the degradation ratio of the PLA/St/BF (2/4/4 in mass ratio) composites was ~54.87% after two months. Compared with the pure PLA, the PLA/St/SCB composites exhibited remarkable improvement in biodegradability. The PLA/St/SCB composites could be injected into seeding containers with thickness of 0.4mm, which could be used for the seeding of sugarcane, pepper, tomato and some specific flowers.

Keywords: Sugarcane bagasse, Composites, Soil burial, Seeding container

Fig. 1 Application of PLA/St/SCB composites in biodegradable seeding container.
Preparation and Characterization of Fast-Curing Powder Epoxy Adhesive at Middle Temperature

Shenyuan Fu*, Jie Xu, Xiaohuan Liu, Fapeng Wang, Pingan Song

Department of Materials, School of Engineering, Zhejiang A &F University, Hangzhou, China

*Email: fshenyuan@sina.com

Abstract

In recent years, how to reduce the curing temperature of powdered epoxy adhesive and decrease curing time was the concern of the epoxy industry. Powdery epoxy adhesive was characterized by long storage period, convenient transportation and low cost et al. In this paper, a series of fast-curing powder epoxy adhesive were prepared by melt blending method with epoxy resins, 4,4’-Diaminodiphenyl sulfone (DDS) as curing agent, 2-methylimidazole (2-MI) as accelerant. The effects of the amount of E-12/DDS/2-MI system on mechanical properties and the optimal conditions were determined. The structure and properties of the E-12/DDS/2-MI system were characterized by FTIR, TGA, DSC and XRD. The kinetic equation was fitted based on Kissinger and Crane equations. The results indicated that the mechanical properties of E-12/DDS/2-MI system were first increased and then decreased with the increasing amount of 2-MI. Fast-curing powder epoxy adhesive containing 23wt% DDS and 0.2wt%2-MI (based on the mass of E-12) had a rather low curing temperature and their cured samples present the best mechanical performance after curing at 135°C for 20 min.

Keywords: Powder epoxy adhesive ; 4,4’-Diaminodiphenyl sulfone ; 2-Methylimidazole, Mechanical properties

Fig. 1 Preparation and properties of epoxy composites
A Bulk Superhydrophobic Conductive Material Fabricated by Mechanical Abrasion Method

Lie Shen*, Zhiming Cai

MOE Key Laboratory of Macromolecular Synthesis and Functionalization, Department of Polymer Science and Engineering, Zhejiang University, Hangzhou 310027, China

*Email: shenlie@zju.edu.cn

Abstract

Weak resistance to mechanical abrasion is one of the stones that stops superhydrophobic materials from daily use. Bulk superhydrophobic materials show better resistance to mechanical abrasion. If we make use of mechanical abrasion to create roughness on hydrophobic material surface, mechanical abrasion will no longer reduce superhydrophobicity of materials. Herein, we report a facile approach to fabricate superhydrophobic conductive Ketjen black-Vapor grown carbon fiber/polyethylene (KB-VGCF/PP) bulk materials by pressing mixed KB, VGCF, PP in a mold and then processing the surface with abrasive paper. Because of different mechanical resistivity of KB, VGCF and PP, surface roughness will be created during the process. The prepared material shows a water contact angle (WCA) as high as 167.5° and a sliding angle (SA) below 1°, and the material is also highly conductive, which could be applied to anti-icing. The material maintained stable superhydrophobicity under the range of mechanical abrasion and the WCA also remained over 160° after water impacting 5 minutes or left it indoor for 2 months, displaying a good stability. The whole fabrication process is easy to scale up for large application, which contains no fluoride, no organic solvent, and environment friendly.

Keywords: Superhydrophobicity, Conductivity, Mechanical abrasion, Anti-icing, Self-clean

Fig. 1 Morphology of bulk superhydrophobic material. a) and b): pure PP. c) and d): KB-VGCF/PP composites.
A Novel High-Temperature-Resistant EVA Composites With Foamable and Ceramifiable Capacity

Tingwei Wang\textsuperscript{1,2,*}, Yucai Shen\textsuperscript{1,2}

\textsuperscript{1}Advanced Materials Research Institute of Nanjing Tech University in Suqian, Suqian, China
\textsuperscript{2}College of Materials Science and Engineering, Nanjing Tech University, Nanjing, China

*Email: syctomson@163.com

Abstract

A novel high-temperature-resistant ethylene-vinyl acetate (EVA) composite with foamable and ceramifiable capacity was prepared through incorporating silicate glass frit (SGF), ammonium polyphosphate (APP), and organically modified montmorillonite (OMMT) into the EVA. To evaluate the foaming capacity, the dimensional changes of the composite before and after expansion were tested. The effect of APP and OMMT on the foaming capacity and mechanical property was investigated. Results show that the addition of APP and OMMT increases the foaming capacity of the composites and improves the structure of the foamed ceramics. Furthermore, with the improvement of the structure of the foamed ceramics, the mechanical property of the ceramic residues enhances, and its heat insulation performance and the smoke suppression are improved.

Keywords: EVA, Ceramifiable, Glass frits, Ammonium polyphosphate

Fig. 1 Bending angles of sample ES, ESA-1 and ESA-2 fired at different temperatures.
Switchable Surface Water Adhesive State based on Fast Water-Responsive Shape Memory PU-CNFD Nano-Composite

Yongzhen Wang1, Zhongjun Cheng2, Yuyan Liu1*

1 MIIT Key Laboratory of Critical Materials Technology for New Energy Conversion and Storage, School of Chemistry and Chemical Engineering, Harbin Institute of Technology, Harbin, China.

2 Natural Science Research Center, Academy of Fundamental and Interdisciplinary Sciences, Harbin Institute of Technology, Harbin, China.

*Email: liuyy@hit.edu.cn

Abstract

Shape memory composites have gained much attention due to wide applications in actuators, smart devices, etc. Herein, by incorporating cellulose nanofiber (CNF) into a thermoplastic polyurethane (PU) matrix, we report a water-responsive shape memory nanocomposite (PU-CNFD) with high Rf, Rr (>90%) and fast responsivity (<1min), ascribing to the reversible formation and destruction of rigid CNF percolation network in the polyurethane elastomer matrix.1 Then we design a shape memory bilayer film comprised of a pillar micro-structured PU thin functional layer and PU-CNFD thick substrate layer (Fig. 1ab), to switch the water droplet adhesion on s-PU surface between super-hydrophobic pinning and sliding state with sliding angle switching from 180° to 35°, which is resulted from the reversible change of pillar space followed by corresponding switching of solid-liquid contact friction (0.15-0.07) in the process of stretch-recovery shape memory (Fig. 1a). Benefit from the shape memory of PU-CNFD, the film can be fixed at a certain or desirable stretch strain without continuous external force, which overcomes the limit of previous reports about switchable water adhesion based on elastomer substrate rely on the continuous mechanical stress 2-5 and may provide a platform for remote manipulation, droplet transfer (Fig. 1c), etc.

Keywords: Water-responsive shape memory, Super-hydrophobicity, Water adhesion, Droplet transfer

Fig. 1 The dynamic switch of surface water adhesion based on the s-PU/PU-CNFD bilayer composited film. (a) The schematic drawing and sliding angle of switch process. (b) The SEM images of pillar micro-structured s-PU layer surface with pillar diameter, height and space of about 5 μm, 10 μm, 10 μm and the cross-section of the bilayer structure. (c) The droplet transfer by the s-PU/PU-CNFD film with different stretch strain.
**A Novel Strategy for Recycling Thermoset Resin used to Fabricate Composites**

Xiong-Lei Wang¹,², Wen-Li An², Yang Yang², Zai-Yin Hu¹,², Shimei Xu², Wang Liao², and Yu-Zhong Wang*,²

¹College of Chemical Engineering, Sichuan University, Chengdu 610064, China
²Center for Degradable and Flame-Retardant Polymeric Materials, College of Chemistry, National Engineering Laboratory of Eco-Friendly Polymeric Materials (Sichuan), Sichuan University, China

*Email: yzwang@scu.edu.cn

**Abstract**

Thermosetting unsaturated polyester is one of important polymer used to fabricate fiber-reinforced polymer composites. Its insoluble and infusible properties make waste thermosetting unsaturated polyester resin (WTUPR) and its composites very difficult to recycle and thus have caused environmental concerns. The traditional decomposition processes of WTUPR are usually carried out at severe conditions which usually result in the complex products and even lead to secondary pollution¹, ². In this work, we developed a facile method to transform of WTUPR into high-performance gel material (GM) taking advantages of WTUPR using environmentally benign catalyst system composed of base, alcohol and water at a mild reaction condition (scheme 1). During reaction, the partial ester bond in the cross-linked structure was selectively cleaved, and the thermosetting polymer was successfully converted to GM without gas products. When the GM was used as adsorbent for water purification, the GM showed distinguished adsorption performance when absorbing methylene blue (MEB): fast dye uptake, high adsorption capacity of more than 700 mg·g⁻¹ and good reusability (no efficiency decay after 20 adsorption/desorption cycles, Fig.1). This work opened up a novel avenue to recycle waste thermosetting material into high value-added products.

**Keywords:** Thermosetting unsaturated polyester resin, controllable degradation, gel material, wastewater remediation

![Fig. 1 One-pot fabrication protocol for the GM.](image-url)
Effect of the Heat Process on the Piezoelectric Property of the PLLA/ BaTiO3 Fiber Sensor

Hyun Ju Oh, Do-Kun Kim, Wan Gyu Hahm*, Byeong-Jin Yeang*

Technical Textile R&D Group, Korea Institute of Industrial Technology, Ansan, Republic of Korea

*Email: yeang777@kitech.re.kr

Abstract
The crystal transformation from $\alpha$-phase to $\beta$-phase is key factor in developing PLLA materials as a piezoelectric sensor. Many researchers have been made to increase the $\beta$ phase crystal by controlling the post process such as drawing temperature/ratio and annealing. In this work, we have investigated the effect of the post process such as drawing temperature, drawing ratio on the piezoelectric property of the Poly(L-lactic acid) PLLA/BaTiO3 fiber in the melt-spinning process. The temperature of drawing process was conducted by the range from 90°C to 130°C at draw ratio 3. Then, the various drawing ratio was performed at the optimized temperature. The crystal transition behavior of PLLA/BaTiO3 at various drawing conditions was investigated by the 2D wide angle X-ray diffraction(2D-WAXD) and the differential scanning calorimetry(DSC) measurements. The mechanical property was also performed by the universal mechanical test. Prior to piezoelectrical test, the PLLA/BaTiO3 filament was hot pressed at 100°C for 1 hour and poled by corona charging process at 2 kV for 30 min. The piezoelectric property of PLLA/BaTiO3 filament sensor was characterized by the thickness directions(d33). Those results indicated that increase of the drawing temperature and ratio in PLLA/BaTiO3 fibers could be enhanced the piezoelectric property in the melt-spun process and it could be promising materials for the fiber type piezoelectric sensor.

Keywords: Piezoelectric, PLLA, Fiber sensor, Melt-spinning, Post process

![SEM images of the PLLA fiber at a various drawing temperature.](image)

Fig. 1 SEM images of the PLLA fiber at a various drawing temperature.
Abstract
The graphene is used to enhance the thermal conductivity, but it is difficult to obtain uniform dispersion and low dielectric property. We fabricate the polyimide composite with high thermal conductivity and low dielectric property. It changes the filler contents, and examines curing time and dispersion. The dispersion characteristics were quantifies by absorbance measurement. The graphene 0.1wt% and BN 0.5wt% polyimide composites show a thermal conductivity of 6.6 W/m•K by LFA and a dielectric constant of 4.6 by SPDR @ 10GHz.

Keywords: Dielectric property, Thermal conductivity, Polyimide composite, Flexible PCB

Fig. 1 Measuring of Viscosity by dielectric curing monitoring (a) PI @100°C (b) PI @200°C (c) PI composite @100°C (d) PI composite @200°C
Fluorinated Phthalonitrile Resin with Good Processing Characteristic and Outstanding Dielectric Properties

Ying Guo, Heng zhou*, Tong Zhao*

Institute of Chemistry, Chinese Academy of Sciences, China

*Email: zhouheng@iccas.ac.cn, tzhao@iccas.ac.cn

Abstract

A series of high performance fluorinated phthalonitrile resins were prepared from 2,2-bis[4-(3,4-dicyanophenoxy)phenyl]hexafluoropropan (FAPN), 2-allyl- (3,4-dicyanophenoxy)phenyl (XDCN) and 3-amino-(3,4-dicyanophenoxy)phenyl (2P). The quartz fiber reinforced phthalonitrile resins were also prepared through molding process. Highly efficient allyl and amino synergistic catalytic cyano polymerization was studied in detail. The effect of the fluorinated groups on the thermal stability, mechanical and dielectric properties was also studied. Dielectric constant of the fluorinated phthalonitrile resins was 3.35-3.49 and the dielectric loss could reach 0.0073-0.0079 at 10GHz, which were dramatically improved compared with the reported data. The fluorinated phthalonitrile also exhibited good mechanical properties, with flexural strength of composite above 500 MPa. Their 380 oC flexural strength was 396-488 MPa, retaining above 70% of their room temperature strength. Meanwhile, the fluorinated phthalonitrile resins showed excellent thermal stability, with a high glass transition temperature above 450 oC and 5% weight loss thermal decomposition temperature (Td5) exceeding 500 oC. This work suggested that the fluorinated phthalonitrile resin had great potential to be used as the matrix of high temperature wave-transparent composites.

Keywords: Phthalonitrile, Dielectric property, Processing property, Wave-transparent material

Fig. 1 The rheological properties and dielectric constant of fluorinated-phthalonitrile resins
Study on Radiation Thermal Insulation of SiO2 Coating Composites
Xinyang Zhang\textsuperscript{1,*}, Zhaofeng Chen\textsuperscript{1,*}, Hao Ma\textsuperscript{2}, Runjun Ma\textsuperscript{2}, Chenchen Sun\textsuperscript{1}

\textsuperscript{1}International laboratory for Insulation and Energy Efficiency materials, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, P. R. China
\textsuperscript{2}Suzhou Junyue New Material Technology Co., Ltd, Suzhou 215164, P. R. China
*Email: xinyang_zh@nuaa.edu.cn, zhaofeng_chen@163.com

Abstract

In order to reduce the infrared heating effect of materials on sunlight and increase the barrier property of the film, a atmospheric transparent window of 8 to 14 micrometres in the atmosphere is used. Therefore, coating of silicon dioxide micro-spheres is coated on the surface of transparent films and films with reflective screen. The infrared absorption spectrum of the film structure was measured in the frequency band by using Fourier transform infrared spectrometer (FTIR), the emissivity of films was measured by an infrared emissivity indexer, the microscopic appearance of the surface structure of the film was observed by Scanning Electron Microscope (SEM), and the barrier effect to sunlight was tested by using a temperature recorder in practical applications. The results show that the film with silicon dioxide miro-spheres has a high emissivity and its infrared emissivity is greater than 0.7; The temperature of the indoor space is 10.8 °C lower than the outdoor environment between the film with silicon dioxide miro-spheres and the film without in practical applications, which can significantly reduce the temperature of the interior space. This study has practical value and reference significance for thermal insulation.

Keywords: Sunlight, SiO2 micro-spheres, Radiation, Emissivity

Fig. 1 Cures of the comparation for the different films
Preparation of Open-Porous Stereocomplex PLA/ PBAT Scaffolds and Correlation between their Morphology, Mechanical Behavior, and Cell Compatiblility

Yuan Kang¹, Xuetao Shi¹, Guangcheng Zhang¹, and Chaoli Wang²

¹School of Science, Northwestern Polytechnical University, Xi’an, China
²Department of Pharmaceutical Analysis, Fourth Military Medical University, Xi’an, China

*Email: shixuetao@nwpu.edu.cn, zhangguc@nwpu.edu.cn

Abstract

For tissue engineering applications, it is essential that biodegradable scaffolds have accessible mechanical properties, high porosity, and good biocompatibility to support the formation of new tissues. In this study, we have prepared stereocomplex polylactide (sc-PLA) incorporated poly (butylene adipate-co-terephthalate) (PBAT) scaffolds by non-solvent induced phase separation (NIPS). Also, we have characterized and compared the morphology, thermal, mechanical, and wettability properties as well as preliminary biocompatibility of scaffolds. The developed sc-PLA/PBAT scaffolds possess high porosity (>94%), well-connected open porous micropores structures, available mechanical properties, and excellent water permeability. As the content of PBAT increased, the average diameter of the sc-PLA/PBAT scaffolds decreased while the mechanical properties improved. The tensile strength was improved to 3.8 MPa while the neat PLA scaffold was 0.3 MPa, and the elongation of the scaffold was six times higher than neat PLA scaffold. Fibroblasts cells seeded on the structure maintained phenotypic shape, and the developed scaffold structure was observed to be highly capable of supporting the cell attachment and proliferation.

Keywords: sc-PLA, PBAT, porous scaffold, biocompatibility, cells

Fig. 1 Schematic of the preparation of biomimetic PLA/PBAT scaffolds by NIPS process.
Session: Functional Polymer Composites  
Comp-7-P11

**Thermosensitive Au-Pluronic® F127 Hybrid Micells for Raman-enhancing Detection**

Yu-Hsuan Lin¹, Ting-Yu Liu¹*, Yuh-Lin Wang²

¹Department of Materials Engineering, Ming Chi University of Technology, Taiwan  
²Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei 10617, Taiwan  
*Email: tyliu0322@gmail.com

**Abstract**

The thermosensitive and high efficiency surface-enhanced Raman scattering (SERS) micells was successfully fabricated by consisted of Pluronic® F127 and gold nanoparticles for rapid bio-detection. Two terminal hydroxyl groups of Pluronic® F127 were thiol-functionalized to form self-assembling Pluronic® F127 micelles in aqueous solution with exposed -SH groups in the outer shell layers. The gold nanoparticles then were synthesized through NaBH4 reduction and captured by the outer thiol groups to form AuNPs-Pluronic® F127 micelles. The critical micelle temperature of the AuNPs-Pluronic® F127 micelles are about 26.5°C. The volume of the micelles showed 10 times decrease from low temperature (15°C, swelling) to high temperature (37°C, shrinkage), due to Pluronic® F127 turned from hydrophilic to hydrophobic by dynamic light scattering (DLS) analysis. The reversible swelling/shrinkage behaviours of the micelles produced a good potential to capture the biomolecules and control the interparticle gap of the gold nanoparticles to induce strong “hot-junctons” for enhancing the SERS sensitivity. The great sensitivity and stability of AuNPs-Pluronic® F127 micelles are great potential in rapid SERS detecting biomolecules by adsorbed the biomolecules at low temperature and encapsulated the biomolecules into the micelles at high temperature (Fig. 1).

**Keywords:** thermosensitive micells, gold nanoparticles, pluronic® F127, SERS, bio-detection

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**Fig. 1** Diagram of thermosensitive AuNPs-Pluronic® F127 micelles for SERS detection
Improved Dielectric and Mechanical Properties of Cyanate Ester Wave-Transparent Laminated Composites Reinforced by PDA/KH-560 Functionlized PBO Fibers

Ping Song, Wencai Dong, Junwei Gu

MOE Key Laboratory of Materials Physics and Chemistry under Extraordinary Condition, Shaanxi Key Laboratory of Macromolecular Science and Technology, Department of Applied Chemistry, School of Science, Northwestern Polytechnical University, Xi’an, China.

*Email: gjw@nwpu.edu.cn

Abstract

Cyanate ester (CE) resins are considered as the best candidate polymeric matrix for wave-transparent composites. However, the cured pristine CE resins are brittle, and the present dielectric constant (ε) and dielectric loss tangent (tanδ) can’t meet the requirements for ideal broadband and high performance radar domes. In our present work, functionlized poly (p-phenylene-2, 6-benzobisoxazole) fibers/modified bisphenol A dicyanate ester (f-PBO fibers/m-BADCy) wave-transparent composites were fabricated by optimized method of impregnation-winding followed by lamination-molding. m-BADCy was prepared from the copolymerization between 2-(3-trifluoromethyl) phenoxy) methyl) oxirane and BADCy matrix, and f-PBO fibers was obtained by the combining method of poly dopamine (PDA)/silane coupling agent KH-560. PDA was coated onto the surface of PBO fibers and KH-560 was also grafted onto the PBO fibers successfully, the corresponding single fiber pull-out strength for f-PBO fibers was also increased. The interlaminar shear strength (ILSS) and flexural strength of the f-PBO fibers/m-BADCy composites was enhanced to 49.5 MPa and 652.2 MPa. The corresponding ε and tanδ was decreased to 2.86 and 5.7×10^-3, decreased by 6.5% and 23.0%, compared with that of PBO fibers/BADCy composites (ε of 3.06 MPa and tanδ of 7.4×10^-3), respectively. However, the Tg and THRI values of the f-PBO fibers/m-BADCy composites were also decreased slightly.

Keywords: Cyanate ester (CE) resins; Wave-transparent laminated composites; Poly (p-phenylene-2, 6-benzobisoxazole) fibers; Surface functionlization.
PVDF/PMMA/GO Blend Composite Membrane with High Water Flux and Oil Adsorption

Dan-feng Liu, Jing-hui Yang*, Yong Wang

School of Materials Science & Engineering, Key Laboratory of Advanced Technologies of Materials (Ministry of Education), Southwest Jiaotong University, China

*Email: yangjinghui_84@163.com

Abstract

Polymer porous membranes have been widely applied as water purification to remove suspended particles, polluted oil, etc. In this work, we prepared porous PVDF/PMMA/GO blend via solution blend-hot compressure-etching. The effect of GO on the water flux and oil adsorption has been systematically investigated. It can be clearly seen that the incorporation of GO can enlarge the pore size of PVDF/PMMA membrane when the loading of PMMA is fixed. On the other hand, the water flux was greatly improved when the GO was incorporated into the polymer blends due to the enlarged pore size and hydrophilic GO. On the other side, the oil adsorption has also been enhanced because of the variation of pore structure induced by GO incorporation. It should be mentioned, although such a high porosity has been achieved, the membrane still remains to be flexible.

Keywords: PVDF/PMMA, Graphene oxide, Water flux, Oil adsorption

Fig. 1 (a) the water flux of PVDF/PMMA/GO membrane; (b) the oil adsorption property of PVDF/PMMA/GO membrane.
Multiple Impact Loading Resistance of Concrete Mixed with Rubber Particles

Andre Towi, and Wuman Zhang*

School of transportation science and engineering, Beihang University, Beijing, China

*Email: wmzhang@buaa.edu.cn

Abstract

The impact loading resistance of roller compacted concrete (RCC) mixed with 0, 5%, 10% and 15% rubber particles was investigated. The experimental through repeated impact load on the RCC concrete, the dynamic elastic modulus, the ultrasonic pulse velocity, and mechanical properties of RCC were measured. The results show that the dynamic elastic modulus of RCC with 0, 5%, 10% and 15% rubber particles decreases 0.39%, 0.38%, 2.55% and 0.04%, respectively. The ultrasonic pulse velocity increase 0.24%, 1.68%, 3.93% and 0.86% when the specimens are subjected to 30 thousands flexural impact loading.

Keywords: Roller compacted concrete, Impact loading, Dynamic modulus of elasticity, Rubber

Fig. 1 Strength of RCC at 28 days.
Comparative Analysis of Geopolymers with C-S-H and N-A-S-H Gels

Wang Qing, Li Tianru, Zhang Qiang*, Ding Zhaoyang

School of Materials Science and Engineering, Shenyang Jianzhu University, Shenyang, 110168

*Email: 863261770@qq.com

Abstract

C-S-H and N-A-S-H gels were synthesized with laboratory reagents, using the sol-gel procedure. Geopolymers were prepared using slag, fly ash and metakaolin as raw material. All the gels and matrices were characterized with FTIR, XRD, SEM, TG-DSC and the volume of Chemically bound water were detected. After comparing these results, it shows that the XRD and FTIR spectra of high calcium system converge with the spectra of C-S-H gels. However, in low calcium system the spectra of matrices were more similar with the spectra of N-A-S-H gels. There was no chemical bonding water in no-calcium system of geopolymers through the TG-DSC analysis. But the chemical bonding water gradually increased with the increase of calcium content, which caused by formation of C-S-H gels. SEM analysis illustrated that low-calcium geopolymer system has obvious three-dimensional network structure, with tetrahedral monomer whose size in the range of 90nm-120nm. N-A-S-H and C-S-H coexist in high-Calcium geopolymer system, C-S-H gels dispersed in the boundary and defects of N-A-S-H gels. Through this study, it can be proved that there were two kinds of gels in geopolymers. In high calcium system, matrices were constituted main by C-S-H gels. In low calcium system, matrices were constituted mainly by N-A-S-H gels.

Keywords: Geopolymers, Sol-gel, C-S-H gels, N-A-S-H gels, CaO content

Fig. 1 FTIR analysis of gels and geopolymer.
Effect of Magnesium Oxide Activity on Hydration and Morphology of Magnesium Oxychloride Cement

Ma Lingfei*, Wang Cheng and Sheng Hao
Zhejiang Agriculture and Forestry University, Lin’an 311300, Zhejiang, China
*Email: malingfei@zafu.edu.cn

Abstract

Magnesium oxychloride cement is a new kind of cementing material, which prepared by light burning MgO, MgCl2 and H2O [1-2]. In this study, the content of active MgO were 38%, 45%, 54%, 62% and its effect on the crystallization and morphology of cement was analyzed. The mechanism of affecting the mechanical properties of magnesium oxychloride cement was analyzed. The results show that the main hydration products formed in MOC specimen for 28 days are 5 phase (5Mg(OH)2·MgCl2·8H2O), 3 phase (3Mg(OH)2·MgCl2·8H2O) and Mg(OH)2 and there are residual unreacted MgO and impurity MgCO3. When the active MgO content in the specimen increases, the increase of 5 phase content can be clearly observed from the XRD. The content of Mg(OH)2 increased with the increase of free MgO. The SEM results show that when the structure with lower MgO activity was loose, the pore size was large, and the crystal length increased with the increase of the activity. The contact growth between the crystals formed a relatively stable crystal network and a large number of tabular crystals. With the increase of MgO activity the shrinkage rate and the flexural strength of MOC increased.

Keywords: Magnesium oxychloride cement, Activity, Morphology, 5 Phase

Fig. 1 X-ray diffraction (XRD) patterns of the H38 (38%), H45(45%), H54(54%), H62(62%) specimens.
The Effect of SiC Particle on Compressive Property and Energy Absorption Capacity of SiC/2024Al Composite Foams

Li, A.B.*, Wang, G.S., Zhang, X.X., Yi Y.F, Du Y., Geng, L

*Email: aibinli@hit.edu.cn

Abstract

The metallic foams have triggered considerable research interests due to the exceptional performance on structural protection, sound absorption and thermal insulation. 2024Al/SiC composite foams and 2024Al foams were fabricated by ball milling and sintering followed by hot extrusion with foaming agent CaCO₃. Among them, 1vol.% SiC nanoparticles with 40nm and 10vol.% SiC microparticles with 10μm were selected as the reinforcements. The fabrication technology, compression behavior and energy absorption capacity of the composite foams were researched. The foam morphologies were characterized by SEM (FEI Quanta F200). The pore size and porosity were determined by Magiscan-2A image analysis and Archimedes' principle, respectively. The Quasi-static compression experiments of SiCp/2024Al composite foams were tested on Gleeble 1500 thermal simulation testing machine. The compression properties and energy absorption were calculated from the compressive curves. Figure 1 and Figure 2 show the compressive stress–strain curves and energy absorption capacity curves of nano- and micro-SiC/2024Al composite foams and pure 2024Al foams, respectively. Obviously, the addition of both nano- and micro-SiC can enhance compression properties and energy absorption of 2024 metals. It is worth noting that the replacement of higher content microparticles with small amount nanoparticlesc can significantly strengthen the metal and enhance energy absorption.

Keywords: Composite foams, SiC particle, Compressive property, Energy absorption capacity

Fig. 1 The compressive stress–strain curves of reinforced and unreinforced 2024Al composite foams.
Session: Metal Matrix Composites
Comp-10-P02

Interface Evolution of Graphene Nano Platelets Reinforced Al Composites during Heat Treatment
Shijiang Zhong$^1$, Jianchao Li$^2$, Xuexi Zhang$^2$, *, and LinGeng$^2$

$^1$School of Environment, Harbin Institute of Technology, Harbin, China
$^2$School of Materials Science and Engineering, Harbin Institute of Technology, Harbin, China

*Email: zhongshijiang@hit.edu.cn, xxzhang@hit.edu.cn

Abstract
The interfacial characteristics of graphene and aluminum in GNP/Al composites are critical to their physical and mechanical properties. Here, 3vol.% GNP/Al composites were synthesized and followed by heat treatments to reveal the interface characteristic evolution at elevated temperature. The results showed that the interface characteristics are strongly affected by the heat treatment temperature. Clean interface of GNP/Al was observed in as-extruded composites. After heat treated at 600°C for an hour, a small fraction of GNP reacted with Al can be found, while most GNP possess good structural integrity. With increasing temperature, the interfacial reaction become much more obvious. Both fully and partly reacted GNPs were observed in composites heat treated at 660°C for an hour. During the heat treatment process, the Al4C3 phase firstly formed on the out layer and grew towards the inner layers of GNP. The (006) atom planes of Al4C3 phase were well bonded to both GNP and Al matrix.

Keywords: GNP/Al composites, Interfacial characteristics, Heat treatment, Interfacial reaction

Fig. 1 TEM micrographs showing the interface in as-extruded and heattreated composites. (a and d) as-extruded composites, (b and e) 600°C for 1 hour, (c and f) 660°C for 1 hour. The insert in (e) shows the FFT image of GNP, the insert image in (f) shows the select area diffraction pattern of Al4C3 phase.
Multiferroic Properties of Sol-Gel Derived
(Ba$_{0.90}$Ca$_{0.10}$)(Zr$_{0.25}$Ti$_{0.75}$)O$_3$/LaNiO$_3$ Herostructures


$^1$Laboratory Teaching Center, Guangdong University of Technology, Guangzhou Higher Education Mega Center, Guangzhou 510006, China. E-mail: jianglili@gdut.edu.cn

$^2$School of Physics & Optoelectric Engineering, Guangdong University of Technology, Guangzhou Higher Education Mega Centre, Guangzhou 510006, China

*Email: xgtang@gdut.edu.cn

Abstract

This work reports the effect of the buffer-layer LaNiO$_3$ (LNO) on the multiferroic properties of the (Ba$_{0.90}$Ca$_{0.10}$)(Zr$_{0.25}$Ti$_{0.75}$)O$_3$ (BCZT) thin films. BCZT/LNO heterostructure were grown on Pt(111)/Ti/SiO$_2$/Si(100) substrates by a sol-gel process. The microstructural, ferroelectric, and magnetic properties of the BCZT thin films were investigated using the X-ray diffractometer (XRD), field emission scanning electron microscopy (FE-SEM), ferroelectric test system, and vibrating sample magnetometer (VSM). The remnant polarization (Pr) and coercive electric field (Ec) of the BZCT thin film without and LNO buffer layer are 1.97 μC/cm$^2$ and 72 kV/cm, 12.18 μC/cm$^2$ and 127 kV/cm, respectively. Using LNO as a buffer-layer enhanced the ferroelectric properties. On the contrary, the corresponding saturation magnetizations were 0.1066 and 0.0626 emu/cm$^3$, respectively. The ferromagnetic properties of the BCZT thin films can be correlated to the mixed valence ions and the effects of the grain boundary.

Keywords: Multiferroic properties, Polarization, Magnetization, Oxygen vacancies
Room Temperature Shear Performance Test of C/SiC Pins

Donglin Zhao, Xiaoying Liu*, Laifei Cheng, Jing Zhang, Dan Li and Fen Li
Science and Technology on Thermostructural Composite Materials Laboratory, Northwestern Polytechnical University, xi‘an, 710072
*Email: liuxiaoying5987@nwpu.edu.cn

Abstract

With the extensive use of carbon/silicon carbide composite materials(C/SiC) in aircraft and spacecraft, it was applied gradually to the large complex structures such as leading edge and control wing. The connection technology of C/SiC materials is the key research for application. C/SiC pin riveting technology is one of the most important connection technology of C/SiC large complex structures because of reliable connection, good heat matching and no increase the weight et al. The C/SiC pins were prepared by chemical vapor infiltration (CVI). The shear strength of Φ3 and Φ4.5 C/SiC pins were investigated. The results indicated that the average shear strength of Φ3 C/SiC pins was 107.17MPa and the average shear strength of Φ4 C/SiC pins was 97.7MPa. These results are helpful for the design of C/SiC materials bolting in Aerospace Structures.

Keywords: C/SiC, C/SiC pin, Shear strength
Oxidation Effects on Mechanical Behaviors of 2D C/SiC Z-Pinned Joints Prepared by Chemical Vapor Infiltration

Chao Chen, and Yi Zhang*

Northwestern Polytechnical University, West Youyi Rd., No. 127, Xi’an, Shaanxi 710072, PR China

*Email: zhangyit@nwpu.edu.cn

Abstract

Although Z-pinned joints have been shown effective in improving delamination resistance in adhesively bonded and co-cured joints, they were rarely reported in composite structures made of Ceramic Matrix Composites (CMCs). In this paper, a Z-pinned joint with all 2D C/SiC was successfully prepared by chemical vapor infiltration (CVI) and the effects of oxidation on its mechanical behaviors (shearing and bending) were studied because of CMCs’ oxidation sensitivity. According to the oxidation mechanisms of 2D C/SiC, the oxidation temperature 700 oC was chosen under which the material properties were degraded most significantly. The oxidation results showed the shear strength and the bending strength were decreased by 59.8% and 50.5% respectively, which were almost the same as the oxidation degradation of the tensile strength of 2D C/SiC about 51.3%. An important phenomenon was discovered that substantial softening region in shearing tests and large sliding plateau in bending tests were found after oxidation when compared with the pseudo-plastic behaviors as received.

Keywords: Oxidation effects, Mechanical behaviors, 2D C/SiC z-pinned joints
Structural, Dielectric and Energy-Storage Properties of (Pb0.97La0.02)(Zr0.95Ti0.05)0.97O3-BiFeO3 Composite Ceramics

Zhong-Hua Niu, Yan-Ping Jiang*, Xin-Gui Tang, Qiu-Xiang Liu, and Wen-Hua Li

School of Physics & Optoelectric Engineering, Guangdong University of Technology, Guangzhou Higher Education Mega Centre, Guangzhou 510006, PR China

*Email: ypjiang@gdut.edu.cn

Abstract

The antiferroelectric, magnetic and magnetoelectric properties of (1-x)(Pb0.97La0.02)(Zr0.95Ti0.05)0.97O3+xBiFeO3 composites, where (x=0, 0.02, 0.04, 0.06 and 0.08) synthesized via double sintering ceramic method were studied. Subsequently, the effects of addition of BFO on the structural, dielectric and energy-storage properties of PLZT have been investigated. X-ray diffraction analysis indicated that a perovskite structure was obtained for all compositions. The ceramics with BFO additions of 0-0.06 undergo two phase transitions during heating from 120 to 240 oC: antiferroelectric-ferroelectric and ferroelectric-paraelectric phase transitions. An enhancement in dielectric constant was achieved as BFO additions increasing from 0 to 0.04, then decreased when x=0.06 and 0.08. Observation of well saturated antiferroelectric hysteresis loops for PLZT phase and their composites, and magnetic hysteresis loops for BFO and composites samples confirms the antiferroelectric and magnetic nature of the samples. A maximum recoverable energy-storage density was about 1.04 J/cm3 with efficiency of 76.5 % was obtained in (Pb0.97La0.02)(Zr0.95Ti0.05)0.97O3 ceramics at 60 kV/cm.

Keywords: Compositie ceramics, PLZT, Dielectrics, Energy storage density

Fig. 1 Temperature dependence of dielectric constant of (1-x)PLZT-xBFO composites with x=0, 0.02, 0.04, 0.06 and 0.08. The insert are the maximum dielectric constant and the corresponding temperatures of these composites.
Session: Energy and thermoelectric materials
Comp-5-P01

Boosting the Thermoelectric Performance of n-type Bi2-xTaxO2Se Nanocomposites: Carrier Engineering and Hierarchical Microstructure

Xing Tan, Yuan-Hua Lin*

State Key Laboratory of New Ceramics and Fine Processing, School of Materials Science and Engineering, Tsinghua University, Beijing 100084, China
*Email: linyh@tsinghua.edu.cn

Abstract

N-type Bi2O2Se possesses intrinsically high Seebeck coefficient and low thermal conductivity due to its distinctive layered structure. However, the low carrier concentration of Bi2O2Se (~1015 cm-3) severely limits its thermoelectric performance. Partial substitution of Bi3+ with pentavalent Ta5+ can markedly increase the carrier concentration of Bi2O2Se by several orders of magnitude and relatively high carrier mobility can still be retained. Meanwhile, hierarchical microstructure of Bi2-xTaxO2Se nanocomposites composed of point defects, grains boundaries from nanoscale to mesoscale and Ta2O5 secondary phase effectively shortens the phonon mean free path, leading to continuously decreased lattice thermal conductivity. Therefore, the synergistically optimization of electrical and thermal transport properties significantly enhances the thermoelectric performance of Bi2O2Se-based materials.

Keywords: Layered structure, Carrier concentration, Hierarchical microstructure, Phonon mean free path

Fig. 1 The temperature-dependent ZT values for Bi2-xTaxO2Se.
Experimental and Numerical Investigation on the Performance of an Automotive Thermoelectric Generator with Exhaust-Module-Coolant Direct Contact

Yulin Tang¹, Yiping Wang¹,²*, Yadong Deng¹, and Chuqi Su¹

¹Hubei Key Laboratory of Advanced Technology for Automotive Components, Wuhan University of Technology, 430070, Wuhan China
²Hubei Collaborative Innovation Center for Automotive Components Technology, Wuhan University of Technology, Wuhan 430070, China
*Email: wangyiping@whut.edu.cn

Abstract

The waste heat of automotive exhaust gas would be directly transferred into electricity by thermoelectric generator (TEG). In conventional automotive TEG, the thermoelectric modules (TEMs) do not contact the hot exhaust and coolant, which leads to low heat transfer efficiency. In current research, a direct contact thermoelectric generator (DCTEG) is proposed, and a test bench is constructed to evaluate its performance. In the experiment system, the exhaust is replaced by hot gas which is produced by a hot-air blower. The coolant is replaced by water which is driven by a water pump. In order to analyze the characteristics of the DCTEG insightfully, three experimental parameters, that are exhaust inlet velocity, exhaust inlet temperature and coolant inlet velocity, are selected to be changeable. In addition, numerical simulations are also conducted to investigate the heat transfer and pressure characteristics of the DCTEG and the conventional indirect contact thermoelectric generator (ICTEG). Comparing the results of experiment and numerical simulation, the better overall performance of DCTEG can be verified.

Keywords: Thermoelectric generator, Directly contact, Experiment, Overall performance
Session: Energy and thermoelectric materials
Comp-5-P03

A Large Energy-Storage Density and Giant Electrocaloric Effect in Anti-Ferroelectric (Pb0.97La0.02)(Zr0.95Ti0.05)O3 Ceramics

B.Li, Q.X. Liu*, X.G. Tang, Y.P.Jiang

School of Physics and Optoelectric Engineering, Guangdong University of Technology, Guangzhou
Higher Education Mega Center, Guangzhou 510006, PR China

*Email: liuqx@gdut.edu.cn

Abstract

The(Pb0.97La0.02)(Zr0.95Ti0.05)O3 (PLZT2/95/5) ceramics were successfully synthesized by a solid state mixed oxide technique[1]. Temperature dependence of dielectric permittivity and loss for PLZT2/95/5 ceramics was shown and the phase transitions were characterized. P-E loops of the samples were measured at different temperatures with the maximum applied field 60 kV/cm. The energy storage density of ceramics were calculated at different temperatures. Using the Maxwell relationship, the entropy change $\Delta S$ and adiabatic temperature change $\Delta T$ was obtained at different electric field ranged from 40 kV/cm to 60 kV/cm.

The temperature dependence of dielectric permittivity and loss for PLZT2/95/5 ceramics was shown in Fig.1(a) and (b) at various frequencies, respectively. It shows that there are two phase transitions, one at 155 °C, corresponding to the phase transition from ferroelectric (FE) to antiferroelectric (AFE), and the other at 225 °C, corresponding to AFE and paraelectric phase transition.

Keywords: PLZT2/95/5 ceramics, Dielectric analysis, Energy storage density, Electrocaloric effect

Fig. 1 (a) Temperature dependences of dielectric permittivity $\varepsilon_r$ and (b) dielectric loss tan$\delta$ for PLZT2/95/5 ceramics samples at various frequencies.
A Bio-based Composite Gel Polymer Electrolytes for Lithium Dendrite Suppressing and Manganese Ions Trapping

Ming Zhu*, Gang Sui*, and Xiaoping Yang*

State Key Laboratory of Organic-Inorganic Composites, College of Materials Science and Engineering, Beijing University of Chemical Technology, China

*Email: 15201243452@163.com, suigang@mail.buct.edu.cn, yangxp@mail.buct.edu.cn

Abstract

Lithium (Li) dendrites in Li anodes, and dissolution and migration of manganese (Mn) ions in LiMn2O4 (LMO) cathodes, have hindered these extraordinary electrode materials to be efficiently applied in high performance Li batteries.1,2 Here, a composite gel polymer electrolyte (c-GPE) was proposed to simultaneously address the two critical issues. As shown in Fig 1, the skeleton of c-GPE is constructed from a sandwich structure composed of porous polydopamine spheres and two layers of the environmentally friendly soy protein isolate-based nanofiber membranes, and the carbonized polydopamine spheres are coated without any binder on the surface of the membranes. Consequently, the c-GPE has been demonstrated to possess significant functions of effectively mitigating the dissolution of Mn ions and chelating the fleeing Mn ions, as well as dramatically suppressing Li dendrites growth. Moreover, in Fig 2, the cell based on the c-GPE delivered a higher capacity retention (71.3%) after 200 cycles and reversible capacity (65.5 mA h g\(^{-1}\)) at 2 C than those of LMO/Celgard 2400/Li (58.5%, 9.8 mA h g\(^{-1}\)). This structure design will be quite promising to meet the distinct requirements from Li batteries and provide a high-efficiency and safe bio-based GPE for next generation energy storage systems.

Keywords: Gel polymer electrolyte, Lithium dendrites, Manganese ions, Lithium metal

Fig. 1 The cycle (a) and rate (b) performance of the cell based on neat gel polymer electrolyte, composite gel polymer electrolyte and Celagard 2400.
The Visible-Light-Driven Type III Heterojunction  
\( \text{H}_3\text{PW}_{12}\text{O}_{40}/\text{TiO}_2-\text{In}_2\text{S}_3 \) : A Photocatalysis Composite with Enhanced Photocatalytic Activity

Huimin Heng\(^1\), Qiang Gan\(^2\), Pengcheng Meng\(^1\), and Xia Liu\(^1\)*

\(^1\)College of Science, China Agricultural University, China.
\(^2\)State Key Laboratory of Explosion Science and Technology, Beijing Institute of Technology, China

*Email: liuxia6680@sina.com

Abstract

\( \text{H}_3\text{PW}_{12}\text{O}_{40}/\text{TiO}_2-\text{In}_2\text{S}_3 \), a visible-light-driven Type III photocatalysis composite heterojunction, is synthesized by typical sol-gel method. The X-ray diffraction (XRD) results show that the introduction of \( \text{H}_3\text{PW}_{12}\text{O}_{40} \) and \( \text{In}_2\text{S}_3 \) brings negative effect on the crystallinity of \( \text{TiO}_2 \). Inductively coupled plasma atomic emission spectrometer (ICP-AES), X-ray photoelectron spectroscopy (XPS) and energy dispersive X-ray spectra (EDS) analysis confirm the existence of each component in \( \text{H}_3\text{PW}_{12}\text{O}_{40}/\text{TiO}_2-\text{In}_2\text{S}_3 \). UV-Vis diffused reflection spectra (UV-Vis DRS) and photoluminescence (PL) spectra are applied to investigate the optical properties of synthesized composites. The results indicate that the lattice defects of TiO\(_2\) lead to the existence of oxygen-vacancies and impurity energy levels which make TiO\(_2\) respond to visible light. And the type-III heterojunction restrains the recombination of photo-generated carriers effectively. In addition, the photocatalytic activity of composites are tested via degradation of imidacloprid under visible light (\( \lambda \geq 400\text{nm} \)). Compared with \( \text{H}_3\text{PW}_{12}\text{O}_{40}/\text{TiO}_2, \text{TiO}_2-\text{In}_2\text{S}_3 \) and \( \text{TiO}_3, \text{H}_3\text{PW}_{12}\text{O}_{40}/\text{TiO}_2-\text{In}_2\text{S}_3 \) displays higher photocatalytic activity. Moreover, the mechanism of the photoexcited process and the photocatalytic degradation process are deduced. The photogenerated holes and \( \cdot \text{OH} \) radicals are proved as the main active species in degradation process.

Keywords: Visible-light-driven, Type III heterojunction, H3PW12O40/TiO2-In2S3, Photocatalysis composite
Scalable Solution Synthesis of Tin Chalcogenide Nanomaterials for Thermoelectric Applications

Guang Han\textsuperscript{1*}, Duncan Gregory\textsuperscript{2}

\textsuperscript{1}College of Materials Science and Engineering, Chongqing University, Chongqing 400044, China
\textsuperscript{2}School of Chemistry, University of Glasgow, UK

*Email: guang.han@cqu.edu.cn

Abstract

Single crystalline SnSe combines a high ZT with a relatively low toxicity and high Earth-abundance of the component elements.\textsuperscript{[1]} Unfortunately the synthesis of SnSe bulk materials is protracted and energy-intensive. Bottom-up solution synthesis is a cost-effective method for inorganic nanostructure synthesis. However, solution syntheses of SnSe nanostructures, only yielding milligram quantities of materials, have required organic surfactants and exert no effective control on doping.

In our study, we demonstrate versatile aqueous solution approaches, including surfactant-free direct precipitation,\textsuperscript{[2]} in-situ ligand replacement,\textsuperscript{[3]} and topotactic anion exchange,\textsuperscript{[4]} towards the 10 gram-scale preparation of orthorhombic SnSe-based nanomaterials with controllable morphology, chlorine doping and tuneable sulphur concentration, respectively. These nanomaterials were spark plasma sintered or hot press into textured, dense, nanostructured compacts that exhibit tuneable conducting type (p- and n-type) and excellent thermoelectric performance. In particular, p-type SnSe has obtained power factors significantly higher than equivalent materials prepared using citric acid as the surfactant,\textsuperscript{[2]} and SnS0.1Se0.9 has achieved an excellent ZT of 1.16 at 923 K via microstructure texturing control;\textsuperscript{[4]} power factors of n-type SnSe have been optimised via control of Cl dopant concentration,\textsuperscript{[3]} These approaches provide versatile, scalable and low-cost routes to p- and n-type layered tin chalcogenides with controllable composition and competitive thermoelectric performance.

Keywords: Thermoelectric, Metal chalcogenide, Nanomaterials, Solution synthesis
Realizing High Thermoelectric Performance in n-Type Highly-distorted Sb-doped SnSe Microplates via Structure Engineering

Xiaolei Shi\textsuperscript{1}, Jin Zou\textsuperscript{1}, and Zhi-Gang Chen\textsuperscript{2*}

\textsuperscript{1}Materials Engineering, the University of Queensland, Brisbane, QLD, Australia
\textsuperscript{2}Centre for Future Materials, University of Southern Queensland, Springfield, QLD, Australia
\textsuperscript{*}Email: zhigang.chen@usq.edu.au

Abstract

Considering the requirement of both p-type and n-type thermoelectric materials for composing the thermoelectric modules, it is highly needed to synthesize high-performance n-type polycrystalline SnSe.[1] However, due to the nature of SnSe (large amount of Sn vacancies in SnSe system), SnSe always presents an intrinsic p-type behavior, making it hard to realize n-type, as well as a high thermoelectric performance. Halogens, such as Cl, Br, and I, are potential candidates to realise n-type doping because the valence state of halogens is -1 in most compounds. In this study, we report a record high figure of merit ($zT$) of $\sim 1.1$ at 773 K in n-type highly-distorted Sb-doped SnSe microplates via a facile solvothermal method. The pellets sintered from the Sb-doped SnSe microplates show a high power factor of $\sim 2.4 \ \mu W \ cm^{-1} \ K^{-2}$ and an ultralow thermal conductivity of $\sim 0.17 \ W \ m^{-1} \ K^{-1}$ at 773 K, leading a record high $zT$. Such a high power factor is attributed to a high electron concentration of $3.94 \times 10^{19} \ cm^{-3}$ via Sb-enabled electron doping, and the ultralow thermal conductivity derives from the enhanced phonon scattering at intensive crystal defects, including severe lattice distortions, dislocations, and lattice bent, observed by detailed structural characterizations. This study fills in the gaps of fundamental doping mechanisms of Sb in SnSe system, and provides a new perspective to achieve high thermoelectric performance in n-type polycrystalline SnSe.

Keywords: Thermoelectric materials, Tin selenide, Solvothermal synthesis, n-Type doping, Sb

Fig. 1 Comparison of $zT$ for n-type SnSe thermoelectric materials.
Tuning the Thermal Conductivity of Strontium Titanate by Introducing Mesoporosity

Al Jumlat Ahmed1*, Md. Shahriar A. Hossain2, Yusuke Yamauchi2, and Xiaolin Wang1*

1Institute for Superconducting and Electronic Materials, University of Wollongong, Australia
2Australian Institute for Bioengineering and Nanotechnology, University of Queensland, Australia

*Email: jumlat@gmail.com, xiaolin@uow.edu.au

Abstract

Strontium titanate (SrTiO3) is a well-known n-type thermoelectric material because of its thermal and chemical stability in air at high temperature, non-toxic and low cost. However, the thermoelectric figure of merit (ZT) of SrTiO3 is still low because of its relatively high thermal conductivity. Here we report that the thermal conductivity of SrTiO3 can be reduced effectively by introducing mesoporosity (2-50 nm porosity) into the bulk sample. Mesoporosities are successfully introduced into the SrTiO3 bulk samples by polymeric micelle assembly method followed by spark plasma sintering process. The thermal conductivity of mesoporous SrTiO3 is 0.88 Wm-1K-1 at 900 K which is almost half of the thermal conductivity of pure SrTiO3 (1.61Wm-1K-1) at the same temperature. This work suggests a promising means of improving thermoelectric figure of merit of SrTiO3.

Keywords: Strontium titanate, Polymeric micelle assembly, Spark plasma sintering, Mesoporosity, Thermal conductivity

Fig. 1 (a) Thermal diffusivity, \( \alpha \) (cm2/s) (b) Specific heat, \( C_p \) (J/gk) of pure and mesoporous STO bulk samples.
Interfacial Characteristics and Mechanical Properties of Ti6Al4V-TiAl Metal-intermetallic Laminate (MIL) Composites

Fantao Kong*, Wei Sun, Xiaopeng Wang and Yuyong Chen

School of Materials Science and Engineering, Harbin Institute of Technology, Harbin, China

*Email: kft@hit.edu.cn

Abstract

Ti6Al4V-TiAl metal-intermetallic laminate (MIL) composites with a uniform interfacial microstructure and no discernible defects at the interfaces has been prepared successfully by hot-pack rolling, and the interfacial microstructures and mechanical properties were investigated respectively. Characterization of the interfacial microstructure shows that there was an interfacial region of uniform thickness of about 250µm which consisted of four layers, as showed in Fig.1. The microstructure of the interfacial region is the result of the inter diffusion of Ti element from Ti6Al4V alloy layer into the TiAl alloy layer and Al element from the TiAl alloy layer into the Ti6Al4V alloy layer. The shear strength measurement (Fig.2) demonstrated that the bonding strength between the TiAl alloy and Ti6Al4V alloy layers in the laminate composite was very high. This means that the quality of the interfacial bonding between the two layers achieved by the multi-path rolling is high. Compared with TiAl alloys, fracture toughness of the MIL composites increased obviously due to the beneficial effects of both titanium alloys layer and the interface layers. Especially, the interface between the TiAl layer and titanium layer is very effective in transferring loading, causing significantly improved toughness of the Ti6Al4V-TiAl MIL composites.

Keywords: TiAl alloy, Laminate composite, Interface, Mechanical property

Fig. 1 The structure of the interfacial region of the MIL composite.
Evaluation of Thermoplastic Prepreg for Automated Fibre Placement on Polymer Substrates

Nahaad Vaheed, Rajkumar Velu*, and Felix Raspall

*Email: rajkumar7.v@gmail.com

Abstract

In the recent years, there has been increased demand for Out-Of-Autoclave (OOA) prepregs or prepregs that only require in-situ consolidation. The industries like automotive and aerospace are focusing towards OOA thermoplastic (TP) composite materials due to lower processing temperature and pressure requirements, while maintaining excellent mechanical properties1,2. Appropriately, automated fibre placement (AFP), are also of interest to these industries due to a combination of unique advantages3. In general, metal plates or moulds are used for consolidation during fibre placement process. To eliminate the complication in producing metal moulds, 3D printed polymer moulds have been selected and the current homemade 3D printing system has the capabilities of printing elevated temperature polymer materials. This study investigates the compatibility of different polymer substrates to assist as moulds in the consolidation of TP prepregs suited for AFP. The paper will present the adopted research methodology and test setup, as well as discussed the quality of consolidation and influential parameters. Consolidation of carbon fibre reinforced polyamide (PA) uni-directional (UD) prepreg tapes on different polymer materials at varying temperatures and pressures will be conducted. Results from tests to determine intimate contact, autohesion and fibre/void volume fraction will be presented.

Keywords: Automated fibre placement, Polymer composites, Design methodology
Acoustic Emission Measurements in Structures Using Packaged Fibre Bragg Grating Sensors

Sagar Jinachandran¹, Abheek Basu², Huijun Li², Jiangtao Xi², and Ginu Rajan¹*

¹School of Electronics, Computer and telecommunication Engineering, University of Wollongong, Wollongong, Australia
²School of Mechanical, Materials and Mechatronic Engineering, University of Wollongong, NSW, Australia
*Email: ginu@uow.edu.au

Abstract

Structural health monitoring (SHM) of engineering structures plays an important role in ensuring the safety and integrity of the structures. Acoustic emissions (AE) can be one of the several ways to monitor the structural health. Fibre Bragg grating (FBG) based AE measurement technique is emerging as a solution to monitor cracks in structures remotely and has advantages such as less bulky, low noise, high bandwidth and ease of implementation. In this paper a study on the impact of AE signals on FBGs attached to a substrate focusing on the directional sensitivity using different configurations is presented. For ease of installation the FBG sensors are packaged metallically similar to PZT sensors, where it can withstand temperatures up to 250 oC. The directional AE sensitivity of the packaged FBG sensor device is studied and compared with that of a surface attached FBG. Experimentally the AE signals are generated using an AE transducer for a frequency range of 1-400 kHz and is measured using a high sensitivity commercial FBG AE interrogation system. A numerical simulation of the design is carried out using ANSYS/LS-DYNA and lamb wave propagation in the structure using the attached packaged FBG sensor is analysed and is experimentally verified.

Keywords: Fibre Bragg gratings, Acoustic emission, Directional sensitivity, Finite element modelling, Structural health monitoring

Fig. 1 (a) the packaged FBG sensor (b) schematic of the AE measurement setup.
Weak Bonds, Strong Materials: a Rigid and Healable Polymer Cross-Linked by Abundant Zn(II)-Carboxylate Interactions

Jian-Cheng Lai*, Cheng-Hui Li*, and Jing-Lin Zuo*

School of Chemistry and Chemical Engineering, Nanjing University, Nanjing, China.
*Email: jiancheng.lai@outlook.com, chli@nju.edu.cn, and zuojl@nju.edu.cn

Abstract
Achieving a desirable combination of solid-like properties and fast self-healing is a great challenge due to slow diffusion dynamics. In this work, we describe a design concept that utilizes weak but abundant coordination bonds to achieve rigid and healable materials. The new PDMS polymer PDMS-COO-Zn, crosslinked by abundant Zn(II)-carboxylate coordination interactions, is very strong and rigid at room temperature, with flexural Young's modulus 480 MPa and breaking strain smaller than 4% (Fig 1a). As the coordination equilibrium is sensitive to temperature, the mechanical strength of this polymer rapidly and reversibly changes upon heating or cooling. The soft–rigid switching ability, defined as G’max /G’min, can reach 8000 when dT = 100 °C (Fig 1b). Based on these features, this polymer not only exhibits fast thermal-healing properties (Fig 1a), but is also advantageous for various applications. For example, it can be used in orthopedic immobilization to replace traditional plaster casting with the advantages of removable and recyclable (Fig 1c). It can also be used for 3D printing which combine the advantages of modern 3D-printing processes and traditional brick-and-mortar operation (Fig 1d). Moreover, it can be used to prepare conductive composites and adhesives that are reshapable, healable, and 3D printable (Fig 1e).

Keywords: Healable, Rigid, Polymer, Coordination interaction

Fig. 1 (a) Flexural stress-strain curves of PDMS-COO-Zn before and after healing at 80 °C for different time. (b) Cyclic temperature-sweep rheology measurements of PDMS-COO-Zn polymer. (c) A rigid flaky sample can be reshaped and adapted into an orthosis upon heating. (d) 3D object printed from the PDMS-COO-Zn polymer. (e) An electrical circuit based on the PDMS-COO-Zn/graphene composite could be printed on paper.
The Layer of Kevlar Angle-Interlock Woven Fabric Effect on the Tensile Properties of Composite Materials

Shangyong Zhang*, Wanchen Xie, and Tatyana Merkulova

School of Textile Science and Engineering, Wuhan Textile University, Wuhan, China

*Email: shangyong.zhang@wtu.edu.cn

Abstract

This article describes the experimental study of three-dimensional angle-interlock longitudinal fabric structure with the 1500D Kevlar fiber twist filament. The relationship between the number of layers in Kevlar angle-interlock woven fabrics and the tensile properties of composite materials has been explored and analyzed. Eight different three-dimensional woven fabric composites were prepared and tested respectively. The 3-layer, 5-layer, 7-layer and 9-layer of angle-interlock 3D fabrics were woven on the sample weaving machine respectively produced by United States DuPont. At the same time, Kevlar plain weave fabric was woven, and three, five, seven and nine layers’ fabrics were compared. In the process of vacuum assisted resin transfer molding (VARTM) composite technology - epoxy resin was used as matrix material, acetone is diluent, triethylene tetramine is curing agent and the five different fabrics represented the reinforced materials respectively. Finally, it is concluded that the five-layer composite angle-interlock woven fabric prepared with Kevlar fiber shows the best tensile property.

Keywords: Composite material, Tensile property, Kevlar, 3D angle-interlock woven fabric

Fig. 1 The draw-in draft into the angle interlock (a) 3 layers; (b) 5 layers; (c) 7 layers; (d) 9 layers.
A Stable and Highly Efficient Visible-Light Photocatalyst of TiO₂ and Heterogeneous Carbon Core-Shell Nanofibers

Jing Cheng, Yan Xing, and Wei Pan

School of Materials Science & Engineering, Tsinghua University, Beijing, China

*Email: panw@mail.tsinghua.edu.cn

Abstract

Nowadays, increasing concerns of energy consumption and environmental problems have driven a demand for cost-effective clean energy. Here, a novel core-shell heterostructure of TiO₂ nanofibers with carbon quantum dots embedded in an amorphous carbon shell has been successfully prepared via a simple electrospinning and impregnation process. The composite nanofibers exhibit a stable and highly efficient photocatalytic activity, and the apparent quantum efficiency can reach as high as 52%, which is about 10 times that of pure TiO₂ nanofibers. Structural analyses show that the enhanced photocatalytic activity is attributed to the synergistic effect of TiO₂, the amorphous carbon thin shell and the CQDs embedded inside. The photogenerated electrons can be easily transferred from the CQDs to TiO₂ resulting in a longer lifetime of the electron-hole pairs and a higher photocatalytic activity. In addition, the unique up conversion properties of the CQDs enable the nanofibers to utilize more solar energy and increase the photocatalytic activity. Also, the carbon shell can induce more oxygen vacancies on the surface of the nanofibers, which can further enhance the photocatalytic activity. The results in this work may be beneficial to the future study of exploring new carbon-based heterostructured materials for visible-light-driven photocatalysts.

Keywords: Carbon quantum dots, Amorphous carbon, Heterostructure, Photocatalyst

Fig. 1 Schematic illustration of the photocatalytic mechanism of the C/TiO₂ heterostructure.
Study on Electromagnetic Parameter Characterization Technology of Structural Honeycomb Absorbing Materials

Huimin Sun*, Le Chen and Zhaozhan Gu

College of Electronic Science and engineering, Nanjing University, Nanjing, China

*Email: sunhuimin@nju.edu.cn

Abstract

Honeycomb structure absorbing material is a structural material of anisotropy. According to the different size of honeycomb, the absorbing properties is different after honeycomb structure is dipped the absorbing materials. In this paper, it is electromagnetic parameter characterization technology that Equivalent Media theory and Free Space method are used to calculate and test to verify the electromagnetic parameters of the honeycomb absorbing materials. Honeycomb absorbing materials are measured using the Free Space method in this paper. By CST simulation model (as Fig 1) inversion the electromagnetic parameters of honeycomb absorbing structure, the measured results and the inversion results of electromagnetic parameters are consistent. The reflectivity of honeycomb absorbing materials is calculated and simulated, and it is verified based on the measured results. It is demonstrated that this calculated method is feasible. Through the study on absorbing properties of honeycomb, the results have showed that the radar absorbing properties of honeycomb were related to electromagnetic parameters, as well as different dip-coating thickness of honeycomb absorbing materials. With the increase of the dip-coating thickness of the materials, the radar absorbing capability was significantly increased. It is worth noting that the resonance peak moved to the low frequency with the increase of the thickness.

Keywords: Honeycomb absorbing materials, Electromagnetic parameters, Dipping coat

Fig. 1 Structure of the cell repeating unit and periodic structure model for obtaining the equivalent electromagnetic parameters.
Optical Properties of Compositionally Graded Pb(Zr$_{1-x}$Ti$_x$)O$_3$
Thin Films on Pt-Coated Si Substrates Studied by Spectroscopic Ellipsometry

Zhen-Xun Tang$^1$, Li-Li Jiang$^2$, and Xin-Gui Tang$^1$*

$^1$School of Physics and Optoelectric Engineering, Guangdong University of Technology, Guangzhou, Higher Education Mega Center, Guangzhou, China

$^2$Laboratory Teaching Center, Guangdong University of Technology, Guangzhou Higher Education Mega Center, Guangzhou, China

*Email: xgtang@gdut.edu.cn

Abstract

Compositionally graded ferroelectric lead zirconate titanate Pb(Zr$_{1-x}$Ti$_x$)O$_3$ (PZT) thin films were grown on Pt/Ti/SiO$_2$/Si substrates by using a sol-gel process. The final structure consists of six layers, up-graded graded films starting from PbZrO$_3$ on the Pt electrode to the top PZT(50/50) layer, it consists of no Ti, 10%Ti, 20%Ti, 30%Ti, 40%Ti, and 50%Ti respectively. Whereas films with opposite gradient are called down-graded graded films. Structure, surface morphologies, root mean square (RMS) roughness, and optical properties of the graded thin films were studied by X-ray diffraction (XRD), atomic force microscopy (AFM), Auger electron spectroscopy (AES) and spectroscopic ellipsometry (SE). The refractive index $n$, the extinction coefficient $k$, RMS roughnesses and thickness of the up-graded and down-graded PZT thin films thin films were obtained by spectroscopic ellipsometry as a function of the wavelength in range from 235 to 1700 nm. The rms roughnesses and thickness of the up-graded and down-graded PZT thin films are 0.097 and 197.24, 5.901 nm and 232.37nm, respectively. At 633 nm, the refractive index $n$, the extinction coefficient $k$ of the up-graded and down-graded PZT thin films are 2.4691 and 0.01526, 2.4817 and 0.01997, respectively. The refractive index value of the down-graded PZT thin films is slightly higher than that of the up-graded thin films in the range from 235 to 1700 nm, based on the various first layers. The absorption coefficient $\alpha$ and direct bandgaps $E_g$ of the up-graded and down-graded PZT thin films are calculated from the results of the spectroscopic ellipsometry.

Keywords: Thin films, Graded structure, Optical properties, Spectroscopic ellipsometry
Vorticity Alignment of Flowing Polymer Blends Induced by Anisotropic Particles

Yajiang Huang¹,²*, Chaoying Mao¹,², Miqiu Kong³, Qi Yang¹,², and Guangxian Li¹,²

¹College of polymer science and engineering, Sichuan University, Chengdu, China
²State key laboratory of polymer materials engineering of China, Chengdu, China
³School of Aeronautics and Astronautics, Sichuan University, Chengdu, China
*Email: hyj@scu.edu.cn

Abstract

Although the role of particle surface chemistry and concentration on the microstructure formation of immiscible polymer blends has been explored extensively, the crucial influence of particle shape on the morphological deformation of flowing polymer blends is far from being fully elucidated. In this study, the influence of particle shape on the droplet deformation of polyisobutylene (PIB)/polydimethylsiloxane (PDMS) blends in the presence of polystyrene (PS) microparticles with different aspect ratios is examined by using rheo-optical technique and confocal microscopy. During slow shearing, droplets are found to become elongated and rotate periodically about their major axes while aligning along the vorticity direction in ellipsoid-filled emulsions. However, similar behavior is not observed in the pristine, microsphere-filled or ellipsoid-filled inverse systems. Based on the Jeffery orbits theory, the formation of anisotropic droplets with extremely small Reynolds number due to arrested coalescence in Newtonian matrix and strong confinement effect are suggested to be responsible for the vorticity alignment of droplets during slow shearing. The vorticity orientation behaviour of droplets is found to be closely related to the particle parameters (such as aspect ratio and concentration) and flow conditions (such as confinement degree and flow rate), which determine the microstructure of particle-laden droplets. It is believed that the results reported here may pave a way for the fabrication of anisotropic functional materials with novel microstructures and properties.

Keywords: Particles, Polymer blends, Anisotropy, Morphology, Flow

Fig. 1 Schematic diagram illustrating the influence of particle parameters and flow condition on the morphology of immiscible PIB/PDMS blends under simple shear flow.
Improved Thermal And Mechanical Properties of Tri-Functional Epoxy Resins through Controlling Molecular Network

Miqiu Kong1*, Chengjun Liu1, Mengxue Zhao1, Qi Yang2, Yajiang Huang2, and Guangxian Li2

1School of Aeronautics and Astronautics, Sichuan University, Chengdu, China
2College of polymer science and engineering, State key laboratory of polymer materials engineering of China, Sichuan University, Chengdu, China

*Email: miqiukong@scu.edu.cn

Abstract

In this work, the molecular network of tri-functional epoxy resins is designed by two-step polymerization to improve the toughness and thermal properties without sacrificing the modulus and strength. Epoxy resin is pre-mixed with ionic liquid (IL), then the pre-reacted epoxy/IL is added into epoxy with curing agent and finally the obtained mixture is cured. It is found that the fracture toughness of designed epoxy resin is significantly improved by 156% comparing with neat epoxy, as shown in Fig 1. This is attributed to the parts of highly cross-linked epoxy-ionic liquid networks, which can change the path of the cracks (Fig 2). Meanwhile, 45.9% and 74.8% increase in the tensile strength and elongation at break is found, respectively. Moreover, thermal stability and heat resistance of designed epoxy resin are also enhanced, possibly due to the existence of highly cross-linked epoxy-ionic liquid networks. This work proposes a strategy to obtain epoxy with relatively high toughness and thermal stability.

Keywords: Thermoset polymer, Designed molecular network, Mechanical properties, Thermal properties

Fig. 1 Fracture toughness of pure TDE-85 and TDE-85 with designed network by [EMIM]BF₄.
In Situ Preparation of Polyurethane-Imide/Graphene Oxide Nano-Composite Foam with Gradient Structure and Its Thermal Mechanical Stability

Chengjie Li, Bing Hui, and Lin Ye*

State Key Laboratory of Polymer Materials Engineering, Polymer Research Institute of Sichuan University, Chengdu, China
*Email: yelinwh@126.com

Abstract

The poor thermo-stability of polyurethane foam restricted its wide application. In this work, a series of polyurethane-imide/graphene oxide (PUI-GO) nano-composite foam were fabricated via prepolymer method. An efficient grafting of PUI molecules onto GO surface was realized by formation of hydrogen bonding, resulting in partly exfoliation and uniform distribution of GO in the matrix. Compared with neat PUI foam, the composite foam exhibited a closed circular cellular structure with smaller cell size, narrower cell size distribution, thicker cell walls, and higher apparent density. By addition of GO, the decomposition temperature and activation energy increased, the compressive strength and modulus were improved. At 100 oC, the storage modulus of PUI/1wt% GO foam reached as high as 284MPa, increasing by 49.3% compared with PUI foam. The reinforcing and thermal oxidative stabilizing mechanisms of PUI/GO nano-composite foams were explored. Furthermore, Fe3O4@ GO hybrid was prepared, and under an external magnetic field, GO particles presented gradient distribution in the matrix, leading to the formation of gradient cell structure and thermal mechanical properties of the composite foam, which showed potential application prospective in the aerospace and defense area.

Keywords: Polyurethane-imide (PUI), Graphene oxide (GO), Nano-composite foam, Gradient cell structure, Thermal mechanical property

Fig. 1 The gradient structure of PUT/GO nano-composition foam.
Preparation and Characterization of Shape Memory Epoxy Composite for Space Deployable Structure

Hongjun Kang\textsuperscript{1}, Huifeng Tan\textsuperscript{2}, Wu Wang\textsuperscript{1}, and Yuyan Liu\textsuperscript{*}

\textsuperscript{1}MIIT Key Laboratory of Critical Materials Technology for New Energy Conversion and Storage, School of Chemistry and Chemical Engineering, Harbin Institute of Technology, Harbin, China.

\textsuperscript{2}National Key Laboratory of Science and Technology on Advanced Composites in Special Environments, Harbin Institute of Technology, Harbin, China.

\textsuperscript{*}Email: liuyy@hit.edu.cn

Abstract

Shape memory composites have attracted much interest in aerospace applications, such as small structural parts and deployable structures, due to the combination of mechanical and functional properties. However, there are some drawbacks with low deformation ability and brittleness for thermoset shape memory epoxy. Herein, during curing process, n-octylamine was used as a toughening agent to increase the toughness of thermoset shape memory epoxy, which is ascribed to the introduction of the soft segment in the system. The effect of mass ratio of n-octylamine and m-xylylenediamine curing agents on the shape memory resin performances was investigated in detail. The results show that the as-prepared shape memory epoxy processes moderate glass transition temperature ($T_g=60^\circ\text{C}$), good shape memory performances ($R_f>96\%$, $R_r>98\%$) and toughness (Fig. 1) with the mass ratio of 3:1. Furthermore, a round support tube covered with S-type electric heating wire was prepared with aramid fabric reinforced shape memory epoxy composite, which can be easily folded into $Z$ shape or deployed into original shape above $T_g$, owing to the good shape memory performance of shape memory epoxy matrix, which provides a good perspective for shape memory epoxy composite in application of space deployable structures.

Keywords: Shape memory epoxy, Composite, Preparation, Characterization, Deployable structure

Fig. 1 The performances of the as-prepared shape memory epoxy. (a) DMA (b) SEM (c) shape memory process.
Intelligent and Controllable Adhesive Based on Thermal Response
Haiyang Zhang¹, Yuyan Liu¹*, and Zhongjun Cheng²
¹MIIT Key Laboratory of Critical Materials Technology for New Energy Conversion and Storage, School of Chemistry and Chemical Engineering, Harbin Institute of Technology, Harbin, China.
²National Key Laboratory of Science and Technology on Advanced Composites in Special Environments, Harbin Institute of Technology, Harbin, China.
*Email: liuyy@hit.edu.cn

Abstract
The gecko is widely known because it can quickly go through rough, smooth, vertical and inverted surface and so on. Recent studies have revealed that this extraordinary ability was attributed to the unique hierarchial micro/nanostructures and the function of self-crimping on the gecko’s feet. To realize the special dry adhesion, we design a new smart surface simulating gecko toes function by integrating PU fiber arrays and shape memory polymers. PU fiber array biomimetic gecko toes array as dry adhesion layer. The thermal response shape memory polymer was used as the actuator to control adhesion of PU fiber arrays and through this special control, the contact area could be decreased (Fig. 1a). And the shear adhesion force could be changed from 0.32 N/cm² to 0 N/cm² by heating (Fig. 1b). The new smart dry adhesive surfaces with wide range of potential applications, such as wall-climbing robots, clamp systems for antiterrorism, reconnaissance and aerospace applications.

Keywords: Thermally response, Controllable, Gecko, Adhesive

Fig. 1 (a) Thermal response intelligent and controllable adhesive. (b) Average shear adhesion force for smart surface after several consecutive attach and detach cycles.
Advanced Macroporous Mxene Films for Electromagnetic Interference Shielding

Zhimin Fan¹, Youshan Wang², and Yuyan Liu¹*

¹MIIT Key Laboratory of Critical Materials Technology for New Energy Conversion and Storage, School of Chemistry and Chemical Engineering, Harbin Institute of Technology, Harbin, China.
²National Key Laboratory of Science and Technology on Advanced Composites in Special Environments, Harbin Institute of Technology, Harbin, China.

*Email: liuyy@hit.edu.cn

Abstract

Flexible MXene film is an advanced electromagnetic interference (EMI) shielding material due to their favourable flexibility and excellent conductivity¹. Unfortunately, when the MXene was applied in a humid environment, its surface is easily oxidized to titanium dioxide, unavoidably sacrificing its conductivity², ³. Meanwhile, the ultrahigh density of MXene film also limits its application in the field of EMI. Herein, we employed a simple strategy to prepare a lightweight, hydrophobic and flexible MXene film with macroporous structure by incorporating a spherical template into MXene film and then sacrificing the spherical template, obtaining MXene film with increased porosity. The macroporous MXene film surprisingly displays a low density (0.4 g cm⁻³), fantastic flexibility and hydrophobic surfaces combined with high conductivity (Fig 1). When the macroporous MXene film was used for EMI in a humid environment, it is able to achieve an improved EMI-shielding effectiveness as compared to that of pure MXene film because of its outstanding water resistance and effective wave attenuation in the abundant macroporous structure. As a result, the macroporous MXene film is a very promising EMI material for applications in smart electronics and aerospace.

Keywords: Macroporous MXene film, Flexibility, Low density, Water resistance, Electromagnetic interference shielding

Fig. 1 Digital images of the flexible and macroporous MXene film (a) and EMI shielding mechanism (b).
Fabrication of a Shear Thickening Fluid Hybrid Composite and Its Mechanical Characteristics
Jaehyeong Lim and Sang-Woo Kim*
*Department of Mechanical Engineering, Hankyong National University, Gyeonggi-do, South Korea
*Email: swkim@hknu.ac.kr

Abstract
A shear thickening fluid (STF) is one of non-Newtonian fluids. It has a capability of a reversible liquid-solid phase transition; that is, a shear thickening of the STF is generally observed at the critical shear rate. We developed STF hybrid composites (STFHCs) with the improved damping and impact characteristics due to the shear thickening effect. The silica nanoparticles with 12 nm were dispersed in polyethylene glycol (PEG) using methanol; it was used as a diluent to improve the rheological properties of the STF and to enhance the dispersion of silica nanoparticles. Then, the rheological properties of the STF was measured using a rheometer after the fabrication of the STF. The kapton tubes filled with STF which have an internal diameter of 0.4 mm were embedded with 4 mm intervals into the carbon fiber reinforced plastic (CFRP) composites with a stacking sequence of [0°2/90°2/0°2/90°2/0°2/STF/0°2/90°2/0°2/90°2/0°2]T. The STFHCs were cured by autoclave process. The damping and impact characteristics were investigated by performing low velocity impact and vibration tests, respectively.

Keywords: Shear thickening fluid (STF), STF hybrid composite (STFHC), Carbon fiber reinforced plastic (CFRP), Damping, Impact

Fig. 1 Schematic diagrams of the STF hybrid composite (STFHC).
Multifunctional Structural Cell Using Glass Fabrics as a Separator and a Packaging Layer Reinforcement

Hyun-Wook Park, Joo-Seung Choi, Jung-Min Lee, and Chun-Gon Kim*

Korea Advanced Institute of Science and Technology, South Korea
*Email: cgkim@kaist.edu

Abstract
Transportations using electrical energy have been developed continuously due to the problem of energy depletion. The key to their use is energy storage technologies. One of the studies related to energy storage technologies is structural battery research which is intended to store energy in a structure. In the concept of structural batteries, separators that are vulnerable to mechanical load need to be improved. Glass fabrics not only have high mechanical strength but also excellent thermal stability. These advantages have shown that glass fabric can be used as a separator for a battery. In this study, a multifunctional structural cell using glass fabrics as a separator and packaging layer reinforcement was fabricated. For this experiment, epoxy films and glass fabrics were laminated and polymer films, electrodes, and micro tubings were inserted between the layers. The laminated specimen was fabricated as composite and then injected through micro tubings. The fabricated structural battery showed 150.8mAh/g under C/20 condition at first discharge capacity.

Keywords: Structural battery, Separator, Glass fabric, Load support

Fig. 1 Schematic of the structural battery.
Abstract

The aim of this work was to examine the gradient mechanical properties of natural tooth and fabricate polymer-infiltrated-ceramic to simulate natural tooth and its mechanical behaviors. The elastic modulus and Vickers hardness of enamel and dentin were examined through nano indentation, which showed gradient characteristics. The gradient change of mechanical properties was realized through gradually changing the ceramic component of resin infiltrated partially sintered ceramics. The one is nano glass phase aluminum silicate sodium-micron α alumina laminated composites. The sintering temperature of ceramic green body is 700 °C. The holding hours are 2, 4 and 6 hours respectively. Flexural strength, fracture toughness, elastic modulus and hardness of the composite were tested, which show that elastic modulus and hardness of the aluminum silicate sodium-alumina composite exhibited gradient characteristics. Another is 3Y-PZT-micron α alumina laminated composites. The sintering temperature of green body is 1150 °C and 1200 °C, with holding time of 2 hours. The results showed that both elastic modulus and hardness exhibited gradient characteristics. Different from those of ordinary homogeneous materials, composites prepared in this study have anisotropy. And therefore, the mechanical properties of the composites are more close to the primary teeth.

Keywords: Dental restoration, Gradient material, Polymer infiltrated ceramic network, Mechanical properties
Session: Composites Repair and Self-healing
Appl-4-P01

Polyether-Urethane/Mwcnts Composites Based on Multiple Hydrogen-Bonding: Preparation and Self-Healing Behaviors
Cheng-Jie Fan, Zi-Chun Huang, Bei Li, and Yu-Zhong Wang, and Ke-Ke Yang*

Center for Degradable and Flame-Retardant Polymeric Materials, National Engineering Laboratory of Eco-Friendly Polymeric Materials (Sichuan), State Key Laboratory of Polymer Materials Engineering, Sichuan University, Chengdu, China
*Email: kkyangscu@126.com

Abstract
Self-Healing material has attracted considerable interests since it shows improved safety, lifetime, energy efficiency and environmental impact. Supramolecular interactions have been highly concerned in the field of self-healing material owing to its excellent reversibility and sensitive responsiveness to the environmental stimuli. However, it still a big challenge to achieve a polymeric material with good mechanical performance as well as self-healing capacity. Herein, we report a PPG-UPy multiblock copolymer with desirable self-healing capacity as well as good mechanical performance by coupling PPG diol and UPy with isophorone diisocyanate. As illustrated in Scheme 1, the UPy groups were embedded into the soft phase of the block copolymer to endow it with desirable self-healing properties, meanwhile, the hard phase promise the material a good mechanical performance. Because of the carbon conductive fillers such as GO and MWCNTs, can absorb the near-infrared (NIR) light and the transform it into thermal energy to access self-healing effects. So we introduced MWCNTs into the material to achieve the remote control of the self-healing processes of the material by using solution mixing and solvent casting processes, successively.

Keywords: Polyether-urethane, Self-healing, Hydrogen-bonding, MWCNTs

Fig. 1 Schematics of preparation of Polyether-urethane PPG-UPy/MWCNTs composites and the UPy dimer contribute to self-healing properties.
Multilayer Composite Microcapsules Synthesized via One-Part Strategy and Their Application in Self-Healing Coatings

Nan Zheng¹,³*, Jie Liu²,³, Qing Liu³, and Qiuyu Zhang³*

¹ School of Chemical and Environmental Science, Shaanxi Province Key Laboratory of Catalytic Foundation and Application, Shaanxi University of Technology, Hanzhong, Shaanxi, China.
² School of Materials Science and Engineering, Shaanxi University of Technology, Hanzhong, Shaanxi, China.
³ MOE Key Laboratory of Material Physics and Chemistry under Extraordinary Conditions, School of Science, Northwestern Polytechnical University, Xi’an, Shaanxi, China.

*Email: 32895610@qq.com, and qyzhang1803@gmail.com

Abstract

Phenol-formaldehyde/polyurea multilayer composite microcapsules loaded with dicyclopentadiene (DCPD) as core materials were prepared via one-part strategy of interfacial polymerization and in situ polymerization in PGMA nanoparticle-stabilized Pickering emulsions. Thickness of shell were conducted by varying the isophorone diisocyanate (IPDI) content of oil phase. By scanning electron microscopy (SEM), optical microscopy (OM), and Soxhlet extraction, the resultant microcapsules were multilayers with polyurea inner shell and phenol-formaldehyde outer shell surrounding by PGMA nanoparticles outside, and had shell thickness of 1-5μm, diameters of 50-200μm, the mass of the core content were 62%-74%. Chemical structure and reaction heat of the capsules were studied by fourier transform infrared spectranuclear (FTIR), nuclear magnetic resonance (NMR) and differential scanning calorimetry (DSC), it was found that phenol-formaldehyde/polyurea shell were synthesized, and encapsulated core materials still kept high chemical reactivity. The resistant properties against thermal and solvent attacks were assessed by using thermogravimetric analysis (TGA) and the immersion test.

Keywords: Microcapsules, Multilayer shell, Self-healing, Coatings

Fig. 1 SEM images of PF/PU multilayer microcapsules: a, b outer shell fractured.