Top Story

Composites and Nanotechnology: Atoms to Applications

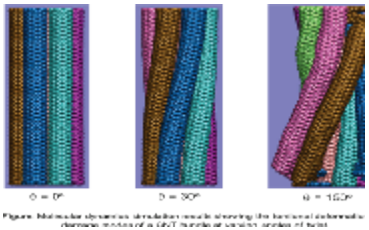
Researchers are studying fundamental material behavior at the micro- and nano-scales that will have future applications ranging from fuel cells to ultra-lightweight structural materials.

University of Delaware
Center for Composite Materials

COMPOSITES UPDATE
May 2014

Recent research in materials engineering has targeted the development of multi-fuctional materials with adaptive, sensory and enegry storage capabilities.

Molecular Modeling of Nanotube Bundles



The novel mechanical, electrical and thermal properties of carbon nanotubes has stimulated interest in using these materials as structural and functional reinforcement in composite materials. Drs. Jack Gillespie, Bazle Haque and Sanjib Chowdhury are investigating the properties of nanotube bundles where axially aligned nanotubes are packed together creating a yarn. Understanding the nanoscale mechanical behavior and failure mechanisms will lay the groundwork for future multifunctional high-performance composites.

The research team studied the mechanical response of the nanotube bundles under tensile,

TOP STORY *Continued*

compressive and torsional loadings using molecular dynamics simulations. Simulation results revealed that the stiffness and load carrying capacity increases with bundle diameter for the three modes of loading. While nanotube-nanotube van der Waals interactions do not have a significant effect on tensile behavior, these interactions combined with lateral boundary conditions alter the compressive behavior by changing the buckling mode shape.

Multi-Scale Modeling of the Fiber-Matrix

Continuing their molecular modeling efforts, Gillespie, Haque and Chowdhury are also studying the fiber-matrix interface/interphase in advanced composites. The interface in composites is not just a boundary, but rather a complex nanoscale region near the fiber surface with graded material properties (interphase). This area between the fibers and polymer matrix in advanced composites is of fundamental importance since that is the region of stress transfer and affects the overall composite performance.

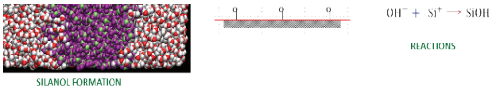


Figure: Formation of silanol on the silica glass surface in presence of water.

The research team is using molecular dynamics modeling to examine the formation of the interphase during composite processing and also to develop mixed-mode traction laws based on bond breakage. This predictive capability will enable researchers to design the chemistry of the fiber surface for maximum strength and energy absorption. The molecular dynamics models provide the input for modeling at higher length scales.

Transitioning Basic Research into Future Applications

Collaborative partnerships enable the rapid transition of basic research and discovery in the laboratory to future applications. In cross-disciplinary research professors Gillespie and Shridhar Yarlagadda (CCM, Electrical Engineering) received a $3-million DARPA grant to develop rapid prototyping techniques to manufacture ankle-foot orthoses for injured soldiers.

Advanced, lightweight composites offer advantages over conventional materials, which are too thick and heavy to meet design requirements, including the ability to tailor stiffness to an individual patient's needs while remaining thin enough to be worn with a shoe. Gillespie and Yarlagadda are further collaborating with Steven Stanhope (BADER Consortium, Kinesiology & Applied Physiology). This unique collaboration between researchers in composite materials along with health sciences builds on expertise in manufacturing and design of composites combined with the ability to implement the orthoses in clinical trials.

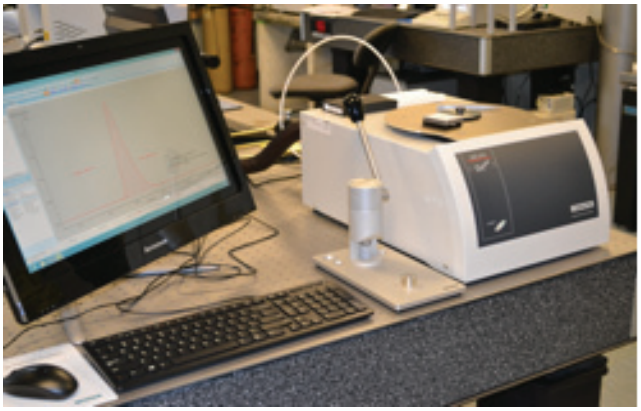
Article by Erik T. Thostenson

OTHER NEWS

NETZSCH Joins the University of Delaware Center for Composite Materials Industrial Research Consortium

NETZSCH North America is one of the newest members of the University of Delaware Center for Composite Materials (UD-CCM) Industrial Consortium. NETZSCH brings new and diverse types of thermal analytical instruments to the Materials Characterization Laboratory at UD-CCM. Most recently, NETZSCH has provided UD-CCM with their newest differential scanning calorimeter (DSC), the Polyma DSC, which can be used to determine the glass transition and melting temperatures as well as measuring the curing reactions for thermosetting materials. This instrument was just commercially introduced in November of 2013. What makes the Polyma DSC unique is that it comes with "intelligent" software that enables automated data reduction and material identification. The Polyma DSC matches new DSC scans with a library of previous DSC scans and the software reports the best library fits with a confidence percentage. Users can also add new materials to the library of scans in the software. NETZSCH has also given UD-CCM their advanced kinetics software, which will allow users to better model the curing reaction for all thermoset formulations. The unique aspect of this software is its flexibility in dealing with both isothermal and non-isothermal cure models. This flexibility gives the user a very useful tool for predicting the degree of cure that can be expected for a given temperature program. The temperature programs can be a very simple ramp up and down in temperature or a more complex time-temperature set of data recorded from a wide variety of Composites processing techniques (RTM, Pultrusion, Compression molding, etc.). Output from this software can be easily incorporated into the wide range of Composite processing software that has been developed by UD-CCM over the years.

"Through our new partnership with the NETZSCH Corporation, UD-CCM continues to maintain our materials characterization facility at the forefront of the industry. The new suite of equipment expands and complements our existing capabilities, providing our students with exposure to the state of the art in Thermal Analysis techniques and enabling us to better serve our Industrial and Governmental partners. We look forward to a long and fruitful collaboration with NETZSCH," said Dr. Joseph Deitzel, staff Scientist with the Center.



Netzsch Polyma DSC

OTHER NEWS

CCM Joins Strategic Partnership with ANSYS

The Center for Composite Materials has joined into a strategic partnership with ANSYS, a simulation software company providing engineering tools used to predict how real world products behave. The mutually beneficial partnership provides CCM researchers access to the state of the art tools ANSYS delivers, and provides ANSYS access to CCM researchers to participate in how these tools are, or can be used to further the state of the art in composites.

Robert Harwood, Ph.D., Aerospace and Defense Industry Director at ANSYS, Inc. said "ANSYS is very excited to have established a strategic partnership with the Center for Composite Materials and its world class faculty. Collaborations like this are key to advancing state of the art technology for modeling and simulating composite materials. Joint customers and the larger engineering community will certainly benefit from the knowledge and insight gained from this partnership."

A core group of CCM researchers are participating in the partnership, each using different ANSYS tools to meet the needs of the different aspects of their composites research. The researchers and the tools are highlighted in the table below.

ANSYS Tool	CCM Researcher
ANSYS Academic Research and Academic Research HPC	Dr. Bazle Haque Dr. John Tierney
ANSYS LS-DYNA and ANSYS LS-DYNA HPC	Dr. Bazle Haque
ANSYS Polyflow	Dr. Jack Gillespie Dr. John Tierney
ANSYS AutoDYN	Dr. Bazle Haque
ANSYS Composites Prepost	Dr. Bazle Haque Dr. John Tierney
ANSYS Computational Fluid Dynamics	Dr. Suresh Advani Dr. Pavel Simacek Dr. John Tierney
ANSYS Spaceclaim	Dr. Bazle Haque
ANSYS Electromagnetics &High Frequency Electromagnetics	Dr. Erik Thostenson Dr. Bazle Haque

Article by Jim Byrnes

OTHER NEWS

CCM Receives Silver Boeing Supplier Performance Award

Boeing Performance Excellence Award

The Center for Composite Materials has received a 2013 Boeing Performance Excellence Award. The Boeing Company issues the award annually to recognize suppliers who have achieved superior performance. CCM maintained a Silver composite performance rating for quality and delivery each month of the 12-month performance period, from 1 October 2012, to 30 September 2013.

This year, Boeing recognized 582 suppliers who achieved either a Gold or Silver level Boeing Performance Excellence Award. CCM is one of only four recognized academic institutions worldwide to receive the Silver level of recognition.

This award enhances CCM's longstanding relationship with Boeing as CCM expands its research and development activities into multi-functional materials. Current programs focuses on evaluating new sensing applications using Carbon Nano Sheets with Boeing Philadelphia leading to a joint patent application and evaluation of electrical properties with Boeing BRT Seattle.

In addition to the research & development activities, CCM recently participated in the Boeing E-Week University Day Celebration in Philadelphia. At this National Engineers Week celebration, CCM research and UD College of Engineering educational opportunities were showcased.

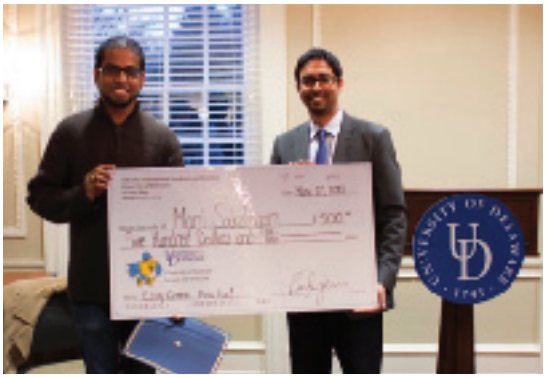

Boeing E-Week Hockey Demonstration

Highlights of CCM's contributions were the integration of the patented sensor technology in a composite hockey stick demonstration. According to CCM Assistant Director Dirk Heider, "we had a fabulous event with a great number of people interested into our smart composite hockey demonstration. It is always exciting to engage the engineering staff but this time we "hit it" with our display. Most people took a shot (the record velocity was measured at 50mph), but discussions often included our Boeing sponsored nano-sensor technology which was integrated into the stick and through wireless transfer displayed on our laptop.

John Lyons, the University of Delaware Executive Focal for The Boeing Company, wrote in an email, "The University of Delaware's CCM team contributed to another successful Engineer's Week celebration at Boeing. The UD team was able to create a display that was fun and interactive, while tying in their current nano-sensor technology research. It's always exciting to see what the University presents during Engineer's Week."

OTHER NEWS

CCM Student wins First Place in OISS International Student Essay Contest



First place International Student Essay Contest winner Mani Sockalingam accepts his prize from OISS Director Ravi Ammigan.

Subramani (Mani) Sockalingam, Ph.D.MEEG was the First Place winner of the $500 prize of the Office for International Students and Scholars (OISS) first annual international student essay contest. The purpose of this contest is to give interested applicants an opportunity to tell their stories and share their experiences of being an international student with the larger University community. **Click here to read Mani's essay.**

NEW PUBLICATIONS

Journals

Chowdhury, S. C., B. Z. (Gama) Haque and J. W. Gillespie Jr., "Molecular Simulations of the Carbon Nanotubes Intramolecular Junctions under Mechanical Loading," Computational Materials Science, 82, pp. 503–509, 2014, http://dx.doi.org/10.1016/j.commatsci.2013.10.025.

Gangloff Jr., J. J., W. R. Hwang, S. G. Advani, "Characterization of Bubble Mobility in Channel Flow with Fibrous Porous Media Walls, International Journal of Multiphase Flow, 60, pp. 76-86, April 2014, ISSN 0301-9322, http://dx.doi.org/10.1016/j.ijmultiphase-flow.2013.12.003.

Kelly, G. S., M. S. Just, S. G. Advani, and J. W. Gillespie, Jr., "Energy and Bond Strength Development during Ultrasonic Consolidation," Journal of Materials Processing Technology, 214, pp.1665 – 1672, 2014, http://dx.doi.org/10.1016/j.jmatprotec.2014.03.010.

NEW PUBLICATIONS

Continued

Journals

Khattra, N.S., Z. Lu, A. M. Karlsson, M. H. Santare, F. C. Busby, T. Schmiedel, "Time-Dependent Mechanical Response of a Composite PFSA Membrane," Journal of Power Sources, 228, pp. 256-69, 2013 http://dx.doi.org/10.1016/j.jpowsour.2012.11.116.

Lopatnikov, S. L. and J. W. Gillespie, Jr., "Simple Analytical Model for Fiber Tensile Failure Due to Droplet Impact," Journal of Applied Physics, 115, 063511, 2014. DOI: 10.1063/1.4863207, http://link.aip.org/link/?JAP/115/063511&aemail=author.

Lu, Z., M. H. Santare, A. M. Karlsson, F. C. Busby, P. Walsh, "Time-Dependent Mechanical Behavior Proton Exchange Membrane Fuel Cell Electrodes," Journal of Power Sources, 229, pp. 543-52, 2014 http://dx.doi.org/10.1016/j.jpowsour.2013.07.013.

Sockalingam, S., M. Dey, J. W. Gillespie Jr, and M. Keefe. "Finite Element Analysis of the Microdroplet Test Method using Cohesive Zone Model of the Fiber/Matrix Interface." Composites Part A: Applied Science and Manufacturing 56, pp. 239-247, 2014 http://dx.doi.org/10.1016/j.compositesa.2013.10.021.

Sockalingam, S., J. W. Gillespie, Jr., and M. Keefe, "On the Transverse Compression Response of Kevlar KM2 using Fiber-level Finite Element Model," International Journal of Solids and Structures, doi: http://dx.doi.org/10.1016/j.ijsolstr.2014.03.020, 2014.

Conferences

Reno, K. H., J. F. Stanzione, III, T. H. Epps, III, and R. P. Wool, "Tackling Toxicity: Designing a BPA Alternative from Lignin" 247th ACS National Meeting, Dallas, TX, March 16-20, 2014.

Chowdhury, S. C., G. R. Swenson, B. Z. (Gama) Haque, and J. W. Gillespie, Jr., "Molecular Modeling and Characterization of Carbon Nanospring," 10th International Conference on Mechanical Engineering, ICME 2013, Bangladesh, Dec. 20-22, 2013.

CONSORTIUM MEMBER NEWS

We would like to thank **Block Engineering, Inc., Marlborough, MA,** Damian Andrisani, MD, **Wilmington, DE**, **Fenner Precision, Manheim, PA**, and **NETZSCH Instruments North America Inc., Burlington, MA** for becoming our newest consortium members. In addition, we thank **Honeywell Advanced Fibers and Composites**, **Fort Mill, SC**, **Pratt and Whitney, Middletown, CT**, and **The Boeing Company, Berkeley, MO,** for renewing their memberships and continuing to participate in CCM's research and development activities.

To learn more about the benefits of becoming a member, please visit us on the web at **www.ccm.udel.edu/Consortium/benefits.html**

Celebrating 40 years of significant contributions to composites science and technology, the education of students, and the creation and transfer of technology to industry.

40th Anniversary
Celebrating 40 years of significant contributions to science and technology, the education of students, and the creation and transfer of technology to industry
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