



SPRING 2013

TECHTRACKS

MATERIALS SCIENCE AND ENGINEERING
A. JAMES CLARK SCHOOL of ENGINEERING

www.mse.umd.edu

A NEWSLETTER FOR ALUMNI AND FRIENDS OF THE DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING AT THE A. JAMES CLARK SCHOOL OF ENGINEERING, UNIVERSITY OF MARYLAND.

IN THIS ISSUE:

- 2 CHAIR'S MESSAGE
- 2 RESEARCH NEWS
- 6 FACULTY NEWS
- 8 STUDENT NEWS
- 9 EDUCATION NEWS
- 10 RECENT GRADUATES
- 11 ALUMNI NEWS

Air Force Supports Study on Nanopaper for Electronics, Aircraft

Department of Materials Science and Engineering (MSE) assistant professor **Liangbing Hu** has received a U.S. Air Force Office of Scientific Research Young Investigator Program Award (AFOSR YIP) to fund his research group's study of nanopaper, a lightweight, strong, transparent material that can enable a range of new and improved electronic technologies.

Hu, a member of the University of Maryland Energy Research Center and the Maryland NanoCenter, was one of only 40 researchers nationwide to receive the highly selective award, which "foster[s] creative basic research in science and engineering [and] enhance[s] early career development of outstanding young investigators."

Like ordinary paper, nanopaper is made of wood pulp, but reconstructed at the nanoscale to enhance its properties. The fibers that make up a sheet of paper are typically 20 microns in diameter, and each of those fibers is made of a network of even smaller fibers approximately 10 nanometers in diameter. Hu and his team break down the 20-micron fibers into their nanoscale components, then

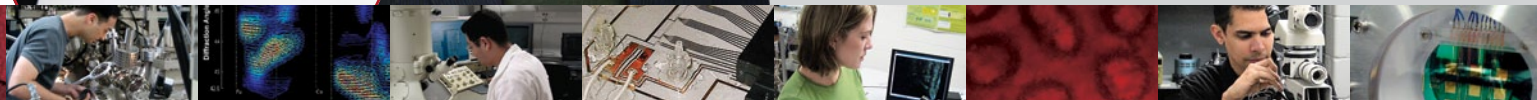
re-create the paper entirely out of them. The nanoscale fiber construction dramatically reduces the paper's ability to scatter light, resulting in a material that is 90-95% transparent. The application of a thin coating of carbon nanotubes makes the paper strong and highly conductive—ideal for use in printed electronics, such as circuit boards.

"Plastic has been used in [printed] electronics for many years," explains Hu, "but there are many problems with it: it's thermally unstable, not as printable as paper, and it's not based on renewable materials. We are trying to replace plastic with renewable nanopaper." Nanopaper, he says, could be manufactured from a renewable wood crop or recycled paper.

The potential benefits aren't only ecological, he adds. The Air Force's Lightweight Materials Program is interested in the development of nanopaper for use in aircraft, which require light, strong materials that can function reliably at various altitudes, temperature, and pressures.

Hu's proposal, "Manipulation of Electrons, Ions and Photons in Lightweight, Multifunctional Nanostructured Paper," will investigate nanopaper's fundamental interactions with electrons, photon and ions, with the goal of producing high-performance electronic devices for Air Force applications.

"WRITING ELECTRONICS" WITH A REGULAR PEN FILLED WITH CARBON NANOTUBE INK IS POSSIBLE ON THE HU GROUP'S NOVEL TRANSPARENT NANOPAPER (SAMPLE IN TWEEZERS), WHICH IS MADE OF NANOCELULOSE FIBERS FROM WOOD PULP. THE NANOFIBERS' DIAMETER OF ONLY ~10nm REDUCES THE PAPER'S ABILITY TO SCATTER LIGHT IN A WAY THAT WOULD OTHERWISE MAKE IT APPEAR OPAQUE AND WHITE.





ROBERT M. BRIBER

I'M PROUD AND EXCITED TO ANNOUNCE SOME OUTSTANDING HONORS AND AWARDS MEMBERS OF OUR FACULTY HAVE RECEIVED SINCE OUR LAST ISSUE:

Liangbing Hu received a U.S. Air Force Office of Scientific Research Young

Investigator Program Award to fund his research group's study of nanopaper, work that was also covered by *C&EN* (see our cover story); while **Ichiro Takeuchi** received a \$2.8M DOE ARPA-E grant for the continued development of an elastocaloric cooling technology (see below). Professor **Ray Phaneuf's** ongoing work with conservation

scientists at the Walters Art Museum to use atomic layer deposition to apply long-lasting, protective coatings to silver artifacts was featured in the March 29 issue of *Science*. **Eric Wachsman** was named a Fellow of ACerS (see p. 7). And at the spring MRS Spring Meeting, a symposium was held in honor of the 80th birthday and distinguished career of **Manfred Wuttig**.

Our current and former students are also doing amazing things, including landing invitations to attend international workshops (see p. 8), winning fellowships (see p. 10), pulling uranium from the sea (see p. 5), educating members of Congress about the importance of solid oxide fuel cells, and, in case of alumnus **S. Pamir Alpay**, becoming the chair of the Materials Science and Engineering Department at the University of Connecticut.

Our faculty is growing once again. We're excited to announce we're in the midst of a new open-rank search, in conjunction with the Department of

Mechanical Engineering, for an expert in computational materials science to add to our roster. We'll tell you all about our newest professor in a future issue of *Techtracks*.

If you are in the Washington, D.C. area, please consider a visiting us to learn about the latest developments in research and education, meet our new faculty and tour the new facilities. If you are an alumnus or alumna, keep us informed of the changes in your career by joining the "MSE UMD" Facebook group or e-mailing us at mse@umd.edu.

Robert M. Briber
Professor and Chair, MSE

NSF AWARD FUNDS NEW SMALL ANGLE X-RAY SCATTERING SYSTEM

The National Science Foundation has awarded a Major Research Instrumentation Grant to a team led by MSE professor and chair **Robert M. Briber**.

Briber and his colleagues received \$345,800 in funding for their proposal, "MRI: Acquisition of a Small Angle X-Ray Scattering System for the Characterization of Nanoscale Structures."

The award will allow for the purchase of a Small Angle X-ray Scattering (SAXS) system for the characterization of nanoscale structures in materials. Nanoscale characterization is a critical step in the design of new materials for applications in areas as diverse as energy, microelectronics, civil infrastructure, defense and health, and for the understanding of the basic science underlying these applications. The new instrument will anchor a state-of-the-art

facility designed to serve the nano- and biosciences research and education needs of both the campus and the region.

\$2.8M DOE GRANT FUNDS CONTINUED DEVELOPMENT OF COOLING TECHNOLOGY

MSE professor **Ichiro Takeuchi** and MSE adjunct professor **Jun Cui** have received a three-year, \$2.83 million Department of Energy (DOE) Advanced Research Projects Agency—Energy (ARPA-E) "plus-up" award to develop a residential-grade air conditioning system that uses no liquid refrigerants and could cut both electric bills and carbon dioxide emissions.

The unit uses an all solid-state cooling technology based on latent heat generated by the martensitic transition (change in crystal structure) of shape memory alloys. Also referred to as elastocaloric cooling, the technology can potentially

replace the vapor-compression based air conditioners and refrigerators, which utilize hydrofluorocarbons and hydrochlorofluorocarbons (such as Freon) that are harmful to the environment and have the potential to increase global warming.

In 2010, Takeuchi and his colleagues received an ARPA-E seed grant to explore the feasibility of thermoelastic cooling systems. Prior to the project, there had only been limited theoretical predictions about the phenomenon of thermoelastic cooling. In 2011, the team developed a 35W water-cooling system, and in 2012 it demonstrated a 1kW thermoelastic air conditioner prototype at the ARPA-E Summit.

The seed project also showed that thermoelastic cooling is one of the most efficient among alternative cooling technologies, with an achievable temperature drop as large as 20 degrees Celsius (68 degrees Fahrenheit).

Thermoelastic cooling won the University of Maryland Office of Technology Commercialization's Physical Sciences Invention of the Year Award in 2011, and has since been licensed by Maryland Energy and Sensor Technologies, LLC, a startup based in the Maryland Technology Enterprise Institute's Technology Advancement Program on campus.

Under the newly funded project, Takeuchi's team will partner with the Pacific Northwest National Laboratory and the United Technology Research Center to develop a 1-ton air conditioning system—a capacity typical of residential window units—based on thermoelastic cooling compression mechanisms. Department of Mechanical Engineering (ME) professor and Center for Environmental Energy Engineering (CEEE) director **Reinhard Radermacher** and CEEE associate director **Yunho Hwang** will conduct extensive modeling and simulation of the heat exchanger and cooling regenerator, the core of the air conditioner. Takeuchi and Cui's collaborators also include ME faculty research assistant **Jan Muehlbauer**, MSE research associate **Yiming Wu**, and MSE professor **Manfred Wuttig**.

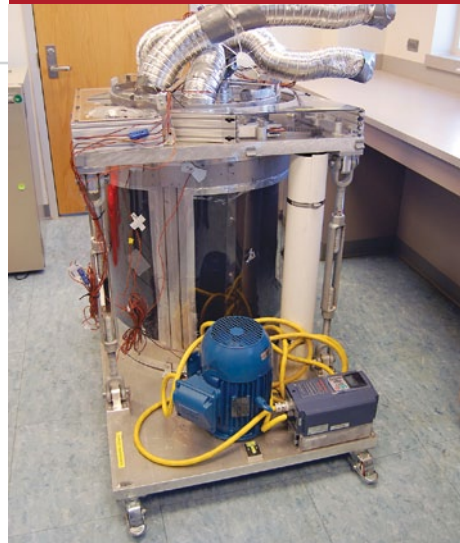
For More Information:

Jun Cui, Yiming Wu, Jan Muehlbauer, Yunho Hwang, Reinhard Radermacher, Sean Fackler, Manfred Wuttig, and Ichiro Takeuchi, "Demonstration of high efficiency elastocaloric cooling with large DT using NiTi wires," Applied Physics Letters 101, 073904 (2012).

MARYLAND HOSTS MID-ATLANTIC SOFT MATTER WORKSHOP

Researchers from throughout the region interested in all things "soft and squishy" gathered to share their ideas at the ninth Mid-Atlantic Soft Matter Workshop (MASM 9), held on the University of Maryland, College Park campus in 2012. The event provided a casual forum for students, faculty and staff from academia, industry and national laboratories to present their latest results, network, and seek out new collaborations.

A wealth of materials can be classified as "soft matter," including polymers, films,



liquid crystals, emulsions, gels, self-assembled structures and systems, cells, tissue, and biomimetic materials. Researchers in the field may be engaged in soft matter's creation, behavioral simulation, manipulation, interfacial properties, biophysics, rheology and hydrodynamics, and replication.

The workshop's goal is to highlight the ways in which scientists from a variety of disciplines—including engineering, biology, chemistry, and physics—approach the study of soft materials and use them in their research. MASM demonstrates how, through a shared interest in soft materials, scientists can discover that their fields and interests may overlap in unexpected ways.

Presentations included formal talks given by invited soft matter experts from regional institutions including Johns Hopkins University, Penn State, the University of Delaware, the University of Maryland, and the University of Pennsylvania. The program also included over 30 three-minute "sound bites," project overviews delivered by undergraduates, graduate students, and postdoctoral research associates.

Clark School professors **Robert M. Briber** (chair, Department of Materials Science and Engineering) and **Srinivasa R. Raghavan** (Department of Chemical and Biomolecular Engineering), College of Mathematical and Natural Sciences professor **Wolfgang Losert** (Department of Physics) and Georgetown University professor **Daniel Blair** (Department of Physics) organized the event.

"We had 110 registrants from across the mid-Atlantic region, including faculty and students from the [A. James Clark] School of Engineering and College of Computer, Mathematical, and Natural Sciences, making this one of the largest MASM workshops to date," says Losert.

"MASM 9 was a great success," Briber adds. "We look forward to holding future workshops at Maryland and providing opportunities for researchers working on soft matter in the region to get together and interact."

Support for MASM 9 was provided by the Clark School's Departments of Chemical & Biomolecular Engineering and Materials Science & Engineering, the University of Maryland–National Cancer Institute Partnership for Cancer Technology, and Georgetown University's Institute for Soft Matter Synthesis and Metrology.

RUBLOFF CO-AUTHORS MAJOR DOE REPORT ON EMERGING ENERGY TECHNOLOGIES

Professor **Gary Rubloff** (joint, MSE and Institute for Systems Research) is the co-author of a major report on mesoscale science commissioned by the U.S. Department of Energy's (DOE) Basic Energy Sciences (BES) Program. Rubloff, the director of the Maryland NanoCenter, was

continues on page 4



ENERGY REPORT, continued from page 3

tapped to serve on the subcommittee that produced the report by **John Hemminger**, chair of the DOE's Basic Energy Sciences Advisory Committee (BESAC).

The DOE's BES Program supports fundamental energy research that develops new technologies and helps fulfill the DOE's missions in the areas of energy, the environment, and national security. The program also operates major research facilities designed to serve the needs of scientists from academia, national laboratories, and other institutions.

For the past ten years, the BES program has published its results in the Basic Research Needs Report Series. Produced by BESAC, which recruits contributors from energy research programs around the world, the reports have outlined the development status of alternative energy technologies and the scientific bottlenecks preventing their implementation.

"The BES reports have laid the foundation for many of the major investments the DOE's Office of Science has made," says Rubloff. "Particularly notable is the \$100 million investment in the nation's 46 Energy Frontier Research Centers (EFRC), including NEES, which is based at the University of Maryland."

The report to which Rubloff contributed, "From Quanta to the Continuum: Opportunities for Mesoscale Science," identified challenges in and refined the definition of the field of mesoscale science, which is generally understood to cover structures and devices that fall somewhere between the nano- and microscales.

But, says Rubloff, "meso" is much more than length scale. "The report recognizes qualitative distinctions in the arrangements of small things, such as atoms, situated somewhere between the 'top down' way we make things like semiconductors—using instruments in clean rooms—and exploitation of the 'bottom up' fabrication that occurs in nature, like self-organizing DNA or the self-

assembly of nanoparticles into regular arrays. Meso is the new science that happens when smaller objects we understand or research are brought together as larger populations."

Rubloff was particularly involved in defining the research directions concerning defects and directed assembly, two areas in which both he and many of his colleagues at the Clark School are active.

"For example, at NEES, we make multicomponent nanowire structures for use in batteries and capacitors," he says. "The directed assembly of billions of these close together is a major challenge." Other examples Rubloff cites include the multiferroic materials systems created by MSE professors **Ichiro Takeuchi** and **Manfred Wuttig**; block copolymer ordering studied by MSE professor and chair **Robert M. Briber**; the study of defects chemistry in solid state ionics by University of Maryland Energy Research Center director **Eric Wachsman**; and connected porous material architectures created by MSE assistant professor **Liangbing Hu**.

"Working on the report was a great experience," says Rubloff. "Besides the new research opportunities mesoscale science represents, I personally believe its societal impact is even greater. We've made large and worthwhile investments in nano, but translating them into economic value requires that we be able to assemble, aggregate and design nanoscale components on a massive scale. In this sense the value of nano will be delivered in large part through science and engineering at the meso scale."



ATTENDEES AT THE 2012 ROBUST WIDE BANDGAP (WBG) SEMICONDUCTOR POWER ELECTRONICS WORKSHOP, CO-HOSTED BY ARGONNE NATIONAL LABORATORY AND THE UNIVERSITY OF MARYLAND.

NEW VIDEO SHOWS HOW MATERIALS SCIENTISTS ARE "SOLVING SOCIETY'S GREAT PROBLEMS"

"Solving Society's Great Problems," a new video about the Clark School's Department of Materials Science and Engineering, premiered at the 2012 Materials Research Society's Fall Meeting & Exhibit. In it, students and faculty discuss their research and how it can make the world a better place, and take us inside their labs and facilities. See the video online at:

<http://ter.ps/msesolves>

WORKSHOP ON WIDE BANDGAP POWER SEMICONDUCTORS STRESSES NEED FOR COMMERCIAL DEVELOPMENT

Argonne National Laboratory and the University of Maryland recently co-organized a workshop on wide bandgap (WBG) power semiconductors that brought together over 60 key industry and government stakeholders to facilitate the rapid development of low-cost manufacturing of WBG power devices in the United States. The event was hosted at the Clark School's Jeong H. Kim Engineering Building by MSE professor **Aris Christou** and **Krishna Shenai**, Argonne's Energy Systems Division's principle engineer.

The event was one of a pair offered by Argonne National Laboratory and the University of Maryland: a workshop held at Argonne, co-sponsored by the Clark School's Center for Advanced Life Cycle Engineering (CALCE), focused on the use of WBG semiconductors for transformative advances in electric utility and transportation infrastructures; while the event at Maryland emphasized WBG products designed to address national security needs. Discussions focused on the key challenges manufacturers face in commercializing WBG power modules, and identifying the nation's strategic military and space application requirements.

Compared to silicon power devices, WBG power semiconductor materials, such as silicon carbide (SiC) and

gallium nitride (GaN), have electronic band gaps significantly larger than one electron volt (eV), and enable power-switching devices to operate at higher temperatures and higher voltages with improved energy conversion efficiency. WBG power electronics converters would be smaller, lightweight, and capable of operating for longer periods of time under the harsh environmental conditions demanded by commercial and national security applications.

According to Christou, one of the workshop's significant outcomes was the recognition that commercial availability and acceptance of WBG power devices have been hindered by high cost, unproven field-reliability, and limited voltage and current ratings.

"[We] concluded that a new WBG manufacturing initiative is required to develop low-cost, reliable technology and novel manufacturing approaches, as well as to enable seamless and transparent interactions among key industry stakeholders in the entire supply chain, from the material manufacturers to end user original equipment manufacturers [OEMs]," Christou explains.

The workshop participants discussed the establishment of an OEM-driven WBG manufacturing consortium in which key industries would collaborate and solve common manufacturing challenges with support from national laboratories, major universities, and community colleges. The goal of the Consortium would be to develop integrated teams to address the challenges identified in the WBG workshop and to rapidly bring WBG power semiconductors to the market and into widespread use.

"MINING" THE SEA FOR URANIUM

Need uranium? Clark School nuclear engineering graduate student **Chanel Tissot** knows where you can find about 1000 times more that you can extract from mined ore: dissolved in seawater. But don't worry about that trip to the beach or fish you had for dinner, she says. Uranium, like many other elements, is found naturally just about anywhere.

"It's all about concentration," she explains. "The uranium is so diluted in such

a vast amount of seawater, it amounts to about 3 parts per billion. That's significantly lower than a uranium-rich part of the earth where you would mine for it."

Despite that very low concentration, collecting uranium from seawater is an attractive alternative to mining: It can be accomplished using a passive process that requires no pumping, electricity, digging or milling. It has virtually no environmental impact, leaves behind no toxic waste, and is far less hazardous for workers.

In a study conducted from 1999 to 2001, a team of Japanese scientists demonstrated that polyethylene fabric treated with a chemical known to bond with uranium ions could be used to filter or "soak up" uranium from seawater. The uranium ions were released by exposing the fabric to an acid bath, and remained in a solution until they could be extracted and enriched for use as fuel.

Unfortunately the material could only be used once or twice before it needed to be replaced, and the process was not efficient enough to offset the cost. Since then, research groups around the world—including Tissot's, led by her advisor, MSE professor **Mohamad Al-Sheikhly**—have been vying to be the first to discover how to turn the concept into a commercial success.

Tissot, Al-Sheikhly and their colleagues may have the solution. Tissot says her team's novel combination of an ultra-high surface area fabric and a specific chemical have enabled them to extract 98 percent of the uranium from a sample of seawater. The chemical is bonded to the fabric using a process called radiation grafting, which keeps it from washing off when exposed to the water.

To date, they have tested the product in the laboratory using small fabric swatches. "Most of the work on this project is optimizing the materials: choosing what [fabric] you're going to use, what chemical you're going to use, the solvents, [radiation] dose rate, total dose, and type of radiation," says Tissot.

The team's next steps involve improving the durability of the fabric so it can be reused, reducing the amount of time it needs to remain in the water, and optimizing the production process so it can be scaled up for

ocean trials and eventual commercial use. The team is also working on a version of the product designed to capture cesium, which can end up in water as a result of a nuclear accident, such as the one that occurred at the Fukushima Daiichi power plant following the 2011 earthquake and tsunami in Japan.

Tissot says the Clark School is an ideal place to work on the project, thanks to its advanced radiation facilities—facilities so good, she adds, that competing research groups come to use them.

Tissot was invited to deliver her findings in a presentation titled "The Extraction of Uranium from Seawater Using Advanced Radiation-Grafted Materials" at the Tenth Meeting of the Ionizing Radiation and Polymers Symposium (IRaP), held in Cracow, Poland in October 2012. Her trip was funded in part by an IRaP Student Grant Award.

The Al-Sheikhly Group conducts this research in collaboration with Professor **Aaron Barkatt** (Department of Chemistry, Catholic University of America) and **Jay A. Laverne** (Department of Physics, University of Notre Dame). Tissot's work is funded by a Nuclear Energy University Programs grant from the U.S. Department of Energy.



CASTING A NET FOR URANIUM: THIS URANIUM-HARVESTING MATERIAL, AN ULTRA-HIGH SURFACE AREA FABRIC WITH A PROPRIETARY CHEMICAL GRAFTED TO IT, IS CREATED USING "GREEN CHEMISTRY" TECHNIQUES, AVOIDING THE NEED FOR ORGANIC SOLVENTS. IN THE MOST RECENT EXPERIMENTS, IT WAS ABLE TO REMOVE 98% OF THE URANIUM FROM A SAMPLE OF SEAWATER, AND FOUND TO BE REUSABLE AT LEAST 16 TIMES WITH LITTLE DEGRADATION OF EXTRACTION CAPACITY. SAMPLES HAVE BEEN SENT TO THE PACIFIC NORTHWEST NATIONAL LABORATORY FOR OCEAN TESTING.

SPINNING ENGINEERED SILK, continued from back cover

Left alone, silk-elastin peptide polymer will naturally self-assemble into a hydrogel in a solution at body temperature. The Seog Group was the first to discover that the AFM's tapping action not only stimulated the formation of SELP fibers, but could also be used to direct them into specific patterns or shapes perpendicular to the microscope's scanning direction. While it has not yet been firmly established why interaction with the AFM's cantilever has this effect on SELP—that's the subject of the group's next study—Johnson's recent paper outlines the scanning conditions that optimize the fibers' growth, the relationship between scanning speed and growth rate, and what is known about the growth mechanism to date.

The three things that affect SELP assembly and direction, Johnson explains, are the AFM's scanning speed, cantilever tip pressure, and how many times the tip is scanned across the width of the sample, a variable known as line density. Johnson and her colleagues found that while using the AFM in tapping mode, lower scanning speeds, higher pressure, and increased line density (particularly once each line equals the width of a SELP molecule) resulted in the fastest and most directed growth. They also discovered that a SELP molecule on a mica substrate must be tapped multiple times to stimulate nucleation, the process that causes the nanofibers to grow. The creation of the miniature letters "UMD," says Johnson, was "the conglomeration of the best conditions [the team] found."

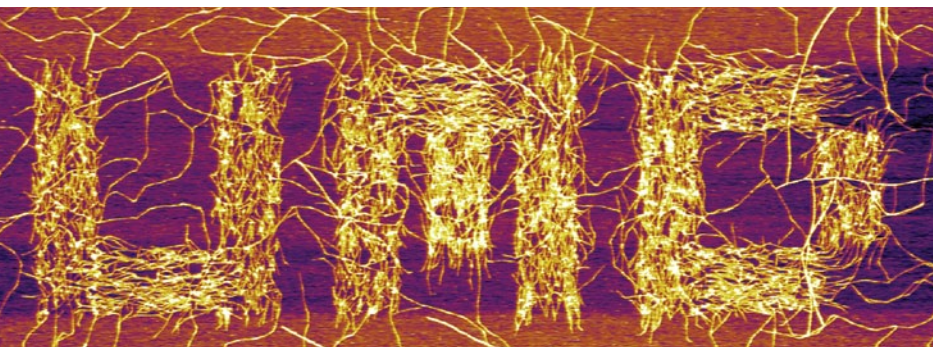
Going forward, the Seog Group hopes to understand the nucleation mechanism that occurs at the cantilever's tip, both why it happens and why the SELP fibers grow in the specific direction they do. Once that knowledge has been perfected, Johnson adds, she and her colleagues can begin to explore practical biomedical applications of structures made out of SELP.

Johnson says working on the project over the past two years and publishing her first paper have been fulfilling, and have inspired her to continue her education. "Coming into the undergraduate program, I didn't have any intent of going on to graduate school," she says. "I just wanted to get out there and make medical devices. Working with grad students and postdocs really allowed me to see that I could obtain [their] level of knowledge. Learning more about the research process can be very challenging, but you also have those exciting moments where you discover something new...and it's pretty rewarding!"

For More Information:

See: "Directed patterning of the self-assembled silk-elastin-like nanofibers using a nanomechanical stimulus." Sara Johnson, Young Koan Ko, Nitinun Varongchayakul, Sunhee Lee, Joseph Cappello, Hamidreza Ghandehari, Sang Bok Lee, Santiago D. Solares and Joonil Seog. *Chem. Commun.*, 2012, 48, 10654-10656.

▼ UNDERGRADUATE SARA JOHNSON AND HER COLLEAGUES IN MSE PROFESSOR JOONIL SEOG'S RESEARCH GROUP USED AN ATOMIC FORCE MICROSCOPE TO MECHANICALLY GUIDE SELP NANOFIBERS, FORMING THE LETTERS "UMD."



CHRISTOU RECEIVES IEEE SERVICE AWARD

MSE professor **Aris Christou** was awarded the Institute of Electrical and Electronics Engineers (IEEE) Electron Devices Society's "Certificate of Service" for his work as editor and co-editor of *Transactions of Devices and Materials Reliability* from 2001–2011. Christou received the award at the IEEE International Devices Meeting, held in San Francisco in December 2012.

As one of the first editors of *Transactions*, Christou helped to make the archival journal one of the most important in the field of devices and material reliability.

FOECKE RECEIVES SCIENCE TEACHING AWARD

Congratulations to MSE adjunct professor Dr. **Tim Foecke**, who received a 2012 Maryland Association of Science Teachers (MAST) Award for Excellence in Science Education. According to the MAST web site, the association's teaching award program "recognizes excellence in science teaching, administration, and outreach in Maryland" at the elementary school, middle school, high school, and college levels.

Foecke, the Deputy Chief of the Metallurgy Division, Leader of the Materials Performance Group, and Director of the Center for Automotive Lightweighting at the National Institute of Standards and Technology, was recognized as the "College Level Teacher showing Excellence in Science Education" for his work with MSE undergraduates in courses such as ENMA 461: Thermodynamics of Materials and ENMA 300: Introduction to Materials Engineering. Foecke was formally presented with his award at the Fall MAST Conference.

"This is a well-deserved honor for Dr. Foecke," says MSE professor and chair **Robert M. Briber**. "Our students think highly of him. He's been doing an excellent job teaching Thermodynamics of Materials and engaging students in a topic that many find difficult to master."

WACHSMAN ELECTED FELLOW

University of Maryland Energy Research Center director **Eric Wachsman** (joint, MSE and Department of Chemical and Biomolecular Engineering) has been elevated to the rank of Society Fellow of The American Ceramic Society (ACerS). He was formally honored at the society's 114th Annual Meeting, held in October 2012 in Pittsburgh, Penn. Society fellowship recognizes individuals "by reason of outstanding contributions to the ceramic arts or sciences; through broad and productive scholarship in ceramic science and technology, by conspicuous achievement in ceramic industry or by outstanding service to the Society."

Wachsman, the William L. Crentz Centennial Chair in Energy Research, is an expert on solid oxide fuel cells (SOFCs), gas separation membranes, solid-state gas sensors, electrocatalytic conversion of CH_4 , and post-combustion reduction of NO_x using advanced ion-conducting materials.

He is frequently tapped to present and advise on economic and technical issues affecting energy research for organizations such as the U.S. Department of Energy, the National Academies, and the U.S. Congress. In 2012, Maryland governor **Martin O'Malley** appointed him to the Board of Directors of the Maryland Clean Energy Center and invited him to participate in a series of roundtable discussions on improving Maryland's electricity distribution system. Later that year, he received the 2012 Fuel Cell Seminar & Energy Exposition Award in recognition of his "significant leadership [role in] promoting the overall advancement of fuel cell technology." Wachsman has also been selected to chair Solar 2013, the American Solar Energy Society's national meeting, which gathers industry leaders to discuss challenges and quick-to-market opportunities in the field of emerging resilient-power technologies.

Wachsman has published over 200 papers—including appearances in *Science* and *Energy and Environmental Science*—holds multiple patents, and serves as the Editor-in-Chief of *Ionics*, and editor of *Energy*

Systems. He is a Fellow of the Electrochemical Society, which recently honored him with an Outstanding Achievement Award. Wachsman is also the co-founder of Redox Power Systems, LLC, a startup company seeking to produce and market the low temperature solid oxide fuel cells designed by his research group.

WACHSMAN PIONEERS TRANSFORMATIONAL ENERGY TECHNOLOGY

By Nancy Grund. Reproduced with permission from E@M, 12(2):21, Fall 2012.

MSE professor **Eric Wachsman**, director of the University of Maryland Energy Research Center, has a lofty goal in mind for his start-up company, Redox Power Systems, LLC: Produce and market a viable energy technology that can help reduce the world's long-term dependency on fossil fuels.

"The rate at which we are consuming fossil fuels has a significant impact on our environment," says Wachsman. "Fossil fuels produce pollutants that contribute to greater weather variations, causing more extreme storms and disrupting power grids and access to electricity. It is all interrelated."

Redox is developing a transformational technology that can address every energy sector from transportation to stationary power plants to private residences. The new power generation technology is based on solid oxide fuel cells (SOFCs), which are fuel-flexible and capable of converting any kind of fuel into electricity—not just hydrogen.

"They can operate on both conventional fuels and future alternative fuels," explains Wachsman. "Through their development, we can attain improved fuel economy, greater gas mileage, and reduced emissions with less impact on the environment."

In the next two decades, the International Energy Agency predicts that global electricity usage will triple from its 1990 base. With no other energy technology demonstrating the versatility of SOFCs, Wachsman believes they can play a major role in deploying renewable power generation into today's energy grid.

In 2012, the technology earned Wachsman and colleague **Bryan Blackburn** a \$7,500 prize at the University of Maryland \$75K Business Plan Competition along with a Warren Citrin Social Impact Award. The award moved development of the technology forward in two ways: It gave Wachsman an opportunity to meet Citrin, an advocate for sustainable engineering solutions, who now serves as chief executive officer for the start-up, and it helped Redox gain entry into the university's Technology Advancement Program (TAP).

TAP is providing the facility to manufacture the prototype and take the company to the next stage. Wachsman's greatest technical challenge is reducing the high operating temperatures of SOFCs. Wachsman and research colleagues published an article last year in *Science* describing SOFCs that operate at temperatures as low as 350 degrees Centigrade with a new design that features high-conductivity electrolytes and a specially nanostructured electrode.

"When cells operate at such high temperatures, there are strong restrictions on the materials you can use," he explains. Below 600 degrees, you can use conventional materials, which improves both cost efficiencies and durability.

Wachsman sees SOFCs as the future of power systems for distributed generation and transportation.

"Distributed generation brings power closer to consumers with less disruption if power lines are down. In the future, you could have power generation within your own home, independent of the power grid."

For more information, visit www.redoxpowersystems.com.



ERIC WACHSMAN

HANRAHAN WINS SILVER MEDAL IN ARL COMPETITION

MSE Ph.D. candidate **Brendan Hanrahan** won a silver medal in the 2012 student symposium research competition at the Army Research Laboratory (ARL). The annual competition gives undergraduates a chance to show the results of their summer work, and graduate students to present an overview of their projects.

In addition to his work as a graduate student in Department of Electrical and Computer Engineering professor **Reza Ghodssi's** MEMS Sensors and Actuators Lab (MSAL), Hanrahan is a full-time ARL employee in its Student Temporary Employment Program. He has been a part of the Sensors and Electron Devices Directorate's Energy and Power Division since 2009.

Hanrahan presented his dissertation work, which deals with the friction, wear, and lubrication of micro-scale ball bearing systems. To reach the final competition, Hanrahan won quarter- and semifinal competitions at the Energy and Power Division and Sensors and Electron Devices Directorate levels.

"Our MSAL group has demonstrated the usefulness of microball bearings in a number of applications in the energy realm, including micro motors, pumps, turbines, and generators," says Hanrahan. "Each of these devices was enabled by the use of microball bearings, but also limited by them in some way. My work takes a step back and focuses on the fundamental sources of friction and wear in these systems. The discoveries related to the reduction of friction and wear in my work are then applicable to all microball bearing systems."

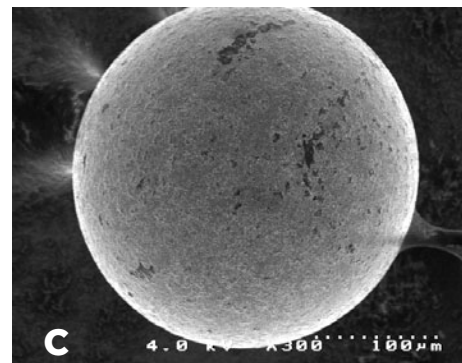
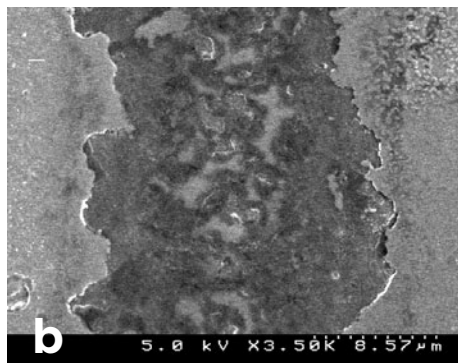
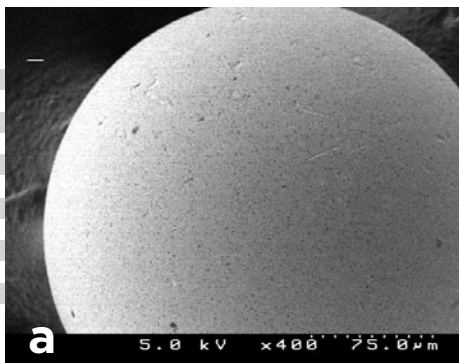
Before the question of "How do you reduce friction in my system?" can be answered, one needs to know where the friction comes from, Hanrahan explains.

On the macro-scale, ball bearing friction comes from a phenomenon called "elastic hysteresis," where energy is lost in the compression and expansion of the ball and raceway during rolling. To solve this problem, engineers use harder materials with less compressibility.

But in microscale systems, Hanrahan has shown friction comes from adhesion—the ball sticking to the raceway. Hanrahan's research shows a reduction in friction in micro-scale systems can be achieved from

a reduction in either or both contact area or adhesion energy. The experiments are described in two upcoming publications: *Microball Bearing Tribology Part I: Friction and Microball Bearing Tribology Part II: Wear.*

LEFT: HANRAHAN RECEIVES THE ARL AWARD.



GORE FEATURED ON GOOD MORNING AMERICA, NPR

Department of Materials Science and Engineering graduate student **Colin Gore** has been featured in segments on ABC's *Good Morning America* and National Public Radio, in which he was interviewed about his role as one of the pilots of *Gamera II*, the Clark School's record-setting human-powered helicopter.

He has also been the subject of a feature in one of his hometown newspapers, the *Reading Eagle*. "Dan Kelly's Korner: Sky's the limit in engineering for Mifflin grad," covers Gore's quest, along with his *Gamera II* teammates, to win the Sikorsky Prize by flying *Gamera II* at a height of 10 feet for at least 60 seconds, with less than a 10-foot drift.

Interdisciplinary research has been important to Hanrahan's graduate school experience. "As a materials scientist in a device group, I have been allowed to take a deep dive into this fundamental friction problem, which will ultimately improve the performance of a family of devices rather than a single device," he says. "I feel like this allows me to have a broad impact on both the science and engineering side of MEMS."

CORNETT, KARKI ATTEND SUSTAINABLE ENERGY WORKSHOP IN ETHIOPIA

MSE graduate students **Jane Cornett** and **Khim Karki** were among only 15 from the U.S. to receive fellowships to attend the first Joint U.S.–Africa Materials Initiative (JUAMI) Materials Research School, held in Addis Ababa, Ethiopia, in December 2012.

Funded by the National Science Foundation and the University of California Santa Barbara's International Center for Materials Research, the program focused on the development of materials for applications in sustainable energy solutions, including

photovoltaics, fuel cells, batteries, and photocatalysis. Fifteen leading instructors and researchers from throughout Africa and the U.S. taught the program's curriculum, which emphasizes problem solving and cultural exchange in addition to scientific topics. The ultimate goal of the school was to help establish collaborations and encourage friendships among approximately 50 students and early-career researchers from top materials science programs on both continents.

"This [was] a prestigious workshop, an important honor for our students, and a positive reflection of our department," says MSE professor and chair **Robert M. Briber**.

Cornett, advised by MSE and Institute for Research in Electronics and Applied Physics assistant professor **Oded Rabin**, studies the thermoelectric properties of nanowires in Rabin's Materials and Interface NanoTechnology Laboratory. Her current and prior work includes studies of waste heat and thermoelectric refrigeration. More recently she and Rabin published an improved model used to calculate the thermoelectric properties of semiconducting nanowires in relation to their radii, which also earned a Best Student Presentation Award from the Materials Research Society. Cornett is an ARCS Scholar and the winner of the 2010 ResearchFest.

Karki, advised by MSE associate professor **John Cumings**, is a member of both the Cumings Group and the Nanostructures for Electrical Energy Storage (NEES) research program, the university's Department of Energy-sponsored Energy Frontier Research Center (EFRC). The goal of his work is to understand the behavior of new nanostructured materials for lithium-ion battery technology using *in situ* transmission electron microscopy (TEM) techniques. Karki's new, fundamental insights about what occurs in individual nanoscale battery components during their operation, and his efforts to create robust nanoscale silicon electrodes, recently earned him NEES' Best Poster and Best Oral Presentation Awards at the group's annual meeting. Outside of the lab, Karki is a member of the Clark School's Future Faculty Program.

HOW TECHNOLOGY CHOICES AFFECT US ALL: I-COURSE EXAMINES CONTEXTS AND CONSEQUENCES

The challenge of making informed decisions about how we develop and implement technology is what inspired MSE professor **Gottlieb Oehrlein** to create ENMA 289A: Bigger, Faster, Better: The Quest for Absolute Technology. The class, offered in Spring semester, is an I-Course, part of the University of Maryland's initiative to expose non-science majors to the roles of science, engineering, math and technology in historical and contemporary issues.

"What I hope to do is stimulate students to think about the technology choices we have as we move forward, and consider the potential benefits and consequences ahead of time," says Oehrlein.

ENMA 289A addresses the applied science and engineering concepts necessary to understand important technological advances and breakthroughs; the motivations behind pursuing technology-based world records; the political, economic, societal and personal decisions that are the driving forces behind major technological advances; historical breakthroughs and failures in the adoption of new technologies; and critical, differentiated evaluations of novel technologies to determine how they will improve or potentially damage our lives.

"I didn't take into account that there was a thorough history of technology and studies on how it actually affects us," says **Chris Ortiz**, a Business Information Systems major who took the course in Spring 2012. "But every new advancement or innovation has a consequence, and it's something that we should all learn and be cognizant of."

"Econ's my major, but economic growth depends on technological growth and change," says **Jay Savage**, who also took the course last year, "I hope to go into hedge fund management or investment banking, [where] we have to make decisions about what's better to fund...the only way to evaluate that is by being tech-literate."

That technical literacy is critical for students of all majors, adds MSE graduate student **Garth Egan**, Ortiz and Savage's TA, because the application of science and technology is inevitably linked to public policy, industry, and the economy. "A lot of the problems that we're going to be facing are going to need more than just scientists to solve," he says.

"MATERIALS OF CIVILIZATION" COURSE FEATURED IN CHRONICLE OF HIGHER EDUCATION

The University of Maryland's revamped general education curriculum, including its innovative I-Series courses, was the subject of a December 2012 story in *The Chronicle of Higher Education*. Among other classes, Chronicle reporter **Dan Berrett** and photographer **Joey Pulone** visited ENMA 150: Materials of Civilization, taught by Department of Materials Science and Engineering professor and Chair **Robert M. Briber**.

ENMA 150, which explores the relationship between advances in materials and advances in civilization, is one of a number of courses designed to expose non-science majors to the roles of science, engineering, math and technology in historical and contemporary events. Like all I-courses, its goal is to engage students in topics outside of their majors, making requirements often viewed as painful necessities more relevant, and placing these subjects in the greater context of students' lives.

"They learn a bunch of science and physics," Briber says of his course in the story, "but it's not dry Physics 101."

JONES, SYED WIN NIST-ARRA FELLOWSHIPS

MSE seniors **Ben Jones** and **Komal Syed** were awarded National Institute of Standards and Technology–American Recovery and Reinvestment Act (NIST-ARRA) Measurement Science and Engineering Fellowships. The two undergraduates spent the Fall 2012 semester at NIST’s Material Measurement Laboratory (MML).

Jones was assigned to the MML’s Polymers Group. Under the guidance of **Dr. Ron Jones**, he worked on simulations and data fitting of neutron scattering of polymer

microstructures. The work was part of efforts by a consortium called nSoft, consisting of members from academia, industry and NIST, to evaluate and polymer macrostructures and improve their properties, making them suitable for use in American industry.

“It’s almost all programming, but my background in materials engineering [gave] me the insight to understand what the code [was] modeling and what the correct answers should be,” says Jones.

Prior to his fellowship, Jones was a member of MSE professor and chair **Robert M. Briber**’s research group, where he worked under research associate Dr. **Xin Zhang** on block copolymer thin film self assembly. He also participated in another project at NIST in which he studied organic semiconductors at the Physical Measurements Lab under Dr. **Michael Walsh**.

Jones, who is interested in polymer physics and processing, scattering theory and crystallography, will attend graduate school this fall at Northwestern University following a summer working at the NIST Center for Neutron Research.

Syed worked with Dr. **Adam Creuziger** in the MML’s Metallurgy Division. She began working for Creuziger in Summer 2012 as a Summer Undergraduate Research Fellow, an experience that inspired her to apply for a NIST-ARRA Fellowship in the hope of continuing her research. Her project involved the statistical analysis of crystallographic texture (the preferred orientation of grains) in polycrystalline materials like steel.

“Crystallographic texture is a result of material processing which can have strong effects on the final product performance,” she explains. “Orientation



BEN JONES

Distribution Function (ODF) is a normalized probability distribution function used to describe crystallographic texture. However...[not] much work [has been] done yet to quantitatively estimate

the measurement uncertainty associated with ODF calculations. I [worked] with Dr. Creuziger...to investigate the bias errors in ODF calculations by analyzing the diffraction data from two independent techniques: neutron diffraction and electron back-scatter diffraction.”

Syed says her MSE coursework helped prepare her for her fellowships, and she was excited about the opportunity to apply what she’d learned to real-world engineering problems. “My [MSE] specialization area is Applications of Materials and Manufacturing,” she explains. “I am really interested in radiation effects of materials, both metals and polymers in general. My work at NIST [was] mainly related to metals, steel in particular, so MSE courses like Physics of Solid materials, Materials Lab, and Macroprocessing [were] specifically useful.”

Prior to joining NIST, Syed was a member of MSE professor **Sreeramamurthy Ankem**’s research group, in which she studied the behavior of titanium alloys. After earning her B.S., Syed would like to continue her work at NIST before applying to graduate school.

The NIST-ARRA program, which is made possible by a \$15 million grant, will bring some 50 fellows per year over

three years to work at NIST laboratories in Gaithersburg, Md., and Charleston, S.C., providing new research collaborations among students, faculty and NIST scientists. The program’s goal is to further develop a future scientific talent pool with extensive training in measurement science and engineering.



KOMAL SYED

recent GRADUATES

AUGUST 2012 PH.D. GRADUATES & DISSERTATIONS

Tsung-Chen Lin: “Nanomechanical Properties and Buckling Instability of Plasma Induced Damaged Layers on Polystyrene.” Advisor: **Ray Phaneuf**

Chuan-Fu Lin: “Directed Self-Assembly of Nanostructures and the Observations of Self-Limiting Growth of Mounds on Patterned Crystal Surface During Epitaxial Growth.” Advisor: **Ray Phaneuf**

Kim Tran: “Microstructural Characterization of Ultrasonic Impact Treated Al-Mg Alloy.” Advisor: **Lourdes Salamanca-Riba**

DECEMBER 2012 B.S. GRADUATES

Komal Syed
Schuyler Lee Fearnis
Sepideh Parvinian

DECEMBER 2012 M.S. GRADUATES

Mollie Powell

DECEMBER 2012 PH.D. GRADUATES & DISSERTATIONS

Lauren Haspert: “Nano-engineering and Simulating Electrostatic Capacitors for Electrical Energy Storage.” Advisor: **Gary Rubloff**

ALUMNUS INTERVIEWED BY THE FINANCIAL TIMES

Arun Luykx (B.S. '07, electrical engineering and M.S. '10, materials science and engineering) was interviewed by the *Financial Times* about his journey from an engineering education at the Clark School to working on a masters degree in general management at the Vlerick Leuven Gent Management School in Belgium while planning to launch his own magazine. In the story, Luykx explains why he feels engineers are good candidates for management positions and entrepreneurial endeavors, and what his business school experience has been like.

ALUMNUS WINS GRADUATE STUDENT MENTORSHIP AWARDS

MSE alumnus **Nagarajan “Nagy” Valanoor** (Ph.D. '01) received the University of New South Wales, Australia's Vice-Chancellor's Award for Excellence in Postgraduate Research Supervision and its Faculty of Science Research and Teaching Excellence Award for his work with masters and doctoral students. Valanoor is an associate professor at the university's School of Materials Science and Engineering.

The competitive awards require candidates be nominated by their department chairs—following a rigorous selection process and their deans' approvals—and to demonstrate their students' past and ongoing success in areas such as publishing, research impact, working with external collaborators, and acquiring positions in academia or industry. Valanoor's candidacy was also bolstered by letters of support from

former students, colleagues who worked with or supervised his students, and his students' current employers.

Valanoor, who studied the synthesis and characterization of ferroelectric thin films under professors **Ramamoorthy Ramesh** and **Alexander Roytburd** during his time at the Clark School, has continued his research in that area at the University of New South Wales. He has also maintained his relationship with MSE, working with Professor **Ichiro Takeuchi** on the development of environmentally friendly piezoelectrics.

Despite what he describes as “radical” changes to his approach over the years, including substantial improvements in materials synthesis, measurement, and data processing, he still finds the work challenging. “[It's] exciting because we still don't know answers to so many basic questions,” he says. “My research involves everything from understanding the chemistry of what makes a ferroelectric material work to how it will be used in a device...I like the fact that we go from basic sciences right to the applications.”

Valanoor thoroughly enjoys his role as a mentor. “I think the greatest joy of [my] job is to have students come in with no clue [about] what a competitive research

program entails, and for them to leave in four years with an entirely different perspective on how to accomplish research,” he says. “...it is fantastic to see the students land amazing new positions or publish in *Science* [or] *Nature*.” But, he adds, he feels particularly proud when they begin to ask questions about their own data.

“When they begin to do that,” he says, “you know that you have done a good job!”



UNIVERSITY OF NEW SOUTH WALES
ASSOCIATE PROFESSOR NAGARAJAN
VALANOOR (PH.D. '01).

JANIAK NAMED KAUFFMAN FELLOW

MSE alumnus and former Fischell Fellow **Dan Janiak** (B.S. '04 and Ph.D. '09) was awarded a Kauffman Fellowship, which includes admission into an elite, two-year program designed to educate the world's most promising, up-and-coming venture capitalists.

Fellows continue to work full time at their respective venture firms while participating in an apprenticeship that includes mentoring, professional coaching, networking, and a curriculum of quarterly classes in industrial leadership.

After completing their fellowships, participants become lifetime members of the Society of Kaufmann Fellows. Society members make up a global network of expert venture capitalists who continue to share insights, opportunities and resources while mentoring the next generation of the best and brightest in the field.

Janiak became interested in entrepreneurship during his tenure as one of the Fischell Department of Bioengineering's (BioE) Fischell Fellows. Together with his advisor, BioE professor **Peter Kofinas**, he developed molecularly imprinted hydrogel polymers capable of filtering viruses from the blood into a marketable product with applications in hemodialysis, vaccine production, and diagnostics. In 2008 the pair received the university's Office of Technology and Commercialization's Outstanding Invention of the Year award in the life sciences category for the product, which was later licensed by Link Plus Corporation.

Janiak is currently an investment team associate at DFJ Mercury, where he specializes in the development of biomedical- and bioscience-based startup companies.





A. JAMES CLARK
SCHOOL OF ENGINEERING

Department of Materials Science and Engineering
2135 Chemical and Nuclear Engineering Bldg.
University of Maryland
College Park, MD 20742-2111

ABOUT THE COVER IMAGE

THE ATOMIC FORCE MICROSCOPY (AFM) IMAGE USED ON THE COVERS SHOWS A “UMD” LOGO CREATED BY EXERTING NANOMECHANICAL FORCE ON A SUBSTRATE COATED WITH A SILK-ELASTIN PROTEIN POLYMER (SELP). THE TAPPING FORCE OF THE AFM TIP ON THE SELP-COATED LAYER CAUSED THE NUCLEATION AND GROWTH OF AMYLOID NANOFIBERS. THE FIBERS TEND TO GROW PERPENDICULAR TO THE AFM SCAN DIRECTION, INDICATING THAT NANOMECHANICAL FORCE ALSO CONTROLS THE DIRECTION OF GROWTH. THIS IS THE FIRST EXAMPLE OF USING MECHANICALLY INDUCED NUCLEATION OF AMYLOID TO CREATE A PATTERN COMPOSED OF ALIGNED NANOFIBERS. FOR MORE INFORMATION, SEE BELOW.

TECHTRACKS is published for alumni and friends of the Department of Materials Science and Engineering at the A. James Clark School of Engineering. Your alumni news and comments are welcome. Please send them to:

Materials Science and Engineering
2135 Chemical & Nuclear Eng. Building
College Park, MD 20742
Or call: (301) 405-5207
Or e-mail: mse@umd.edu

Department Chair: Dr. Robert M. Briber
Editor: Faye Levine

Spinning Engineered Silk Into Tiny Designs—With A Microscope

If someone says they use a microscope in their research, most people would assume it's because they need to observe something very small.

Sara Johnson, a Clark School senior, uses one to write messages.

Johnson, a member of MSE assistant professor **Joonil Seog's** research group, is part of a team investigating how an atomic force microscope (AFM) can be used to grow and weave threads of silk-elastin-like peptide polymers (SELPs) into specific patterns or shapes—such as the letters “UMD” at only one thousandth of a millimeter wide. She is the first author of

a recent paper about the work published in *Chemical Communications*, one of the premiere journals in its field.

SELP is a polymer made out of alternating segments of genetically engineered spider silk and elastin, the protein responsible for giving skin and blood vessels their flexibility. SELP is studied because of its similarity to amyloid fibers, the suspected culprit behind certain neurological disorders such as Alzheimer's disease, and because of its potential applications in tissue engineering.

AFM employs a cantilever with a pointed tip—something like a very tiny

diving board or the tone arm of a record player—to “see and feel.” While the cantilever either taps or skims the surface of a sample, a laser tracks the location of its tip. As the tip's location changes, it deflects the laser, which is in turn detected by a photodiode. Ultimately, data collected about motion of the tip are translated into a three-dimensional surface map. The cantilever can also be used to measure mechanical properties at the single molecule level by pulling on a sample and characterizing force profiles.

continues page 6