



SPRING 2011

# TECHTRACKS

MATERIALS SCIENCE AND ENGINEERING

A. JAMES CLARK SCHOOL of ENGINEERING

[www.mse.umd.edu](http://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
- 3 FACULTY NEWS
- 5 RESEARCH NEWS
- 6 FEATURED RESEARCH
- 10 STUDENT NEWS
- 10 ALUMNI NEWS
- 12 SCHOLARSHIP WINS

## Cumings, Seog: NSF CAREER Awards for Nanotechnology Research

Proposals to study misbehaving crystals and peptides that spin themselves into nanofibers have earned two Department of Materials Science and Engineering professors National Science Foundation (NSF) Faculty Early Career Development (CAREER) Awards.

Assistant professors **John Cumings** and **Joonil Seog**, who were recognized by the NSF as outstanding junior faculty who most effectively integrate research and education, will each receive a grant of at least \$500,000 to support their research.

Cumings received his award for a proposal titled "Frustration on Nanomagnetic Lattices." When liquids become solids, their atoms usually lock into a perfect, repeating pattern—a unique crystal configuration known as a ground state. However, some materials can simultaneously settle into many possible crystal structures, resulting in an imperfect solid made of disordered arrangements of different patterns. Materials with these unusual properties are referred to as "frustrated."

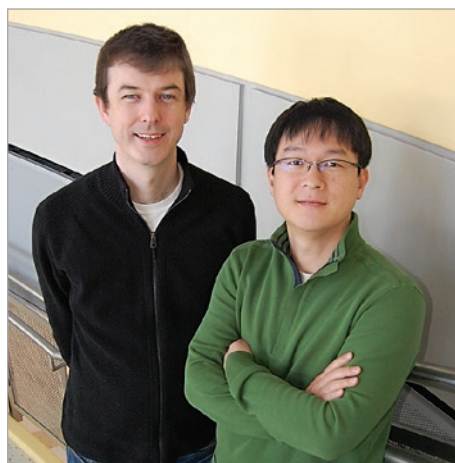
Cumings' goal is to study the fundamental aspects and causes of frustration in artificial materials, and to determine if nanoscale magnets with frustrated molecular structures can be encouraged to overcome

their nature and align themselves into repeating patterns.

"One of the interesting things about this project is that even if we can't overcome these materials' frustration, it would be very good news for magnetic memory technology, which relies on the fact that certain patterns of magnetic bits do not find a unique ground state," he

explains. "Our custom-designed magnetic nanomaterials could potentially achieve much higher information density than conventional memory because we could pack more bits into the same space."

Cumings' CAREER award will also fund a team of early career scientists, a postdoctoral researcher and a graduate student to work on the project, as well as a pre-college student recruited from an area high school. The



PROFESSORS **JOHN CUMINGS** (LEFT) AND **JOONIL SEOG** (RIGHT).

*continues next page*





ROBERT M. BRIBER

## WE HAVE A LOT TO BE PROUD OF!

This year, two of our junior faculty, **John Cumings** and **Joonil Seog**, received NSF CAREER awards for their work in nanotechnology. Their accomplishments reflect the level of excellence in education and research ongoing in the Department, as well as the future of the field.

Professor **Ichiro Takeuchi** became the latest member of the faculty to be elected a Fellow of a national scientific society, in this case the American Physical Society. Our students also continue to win awards, scholarships and fellowships. You can read about some of the most recent on pages 10-12.

I'd like to let you know about a few other great things we didn't have room to include in this issue:

Professor **Mohamad Al-Sheikhly** was the Chair of the 9th meeting of the Ionizing Radiation and Polymers Symposium (IRaP 2010), hosted at the University and at which Professor Emeritus **Joseph Silverman** received a Lifetime Achievement award.

The Department continues to strengthen its ties to NIST, with over \$30 million in new funding to support two separate programs, one at the Center for Neutron Research (for which I serve as the PI) and one with the Center for Nanoscale Science and Technology (for which Professors **John Cumings** and **Oded Rabin** serve as co-PIs).

Assistant Research Scientist **Hui Wu** received the Pittsburgh Diffraction Society's 2010 Sidhu Award for her "outstanding expertise [in] neutron and x-ray diffraction to solve key structural problems which are central [to] the understanding and development of novel...porous framework materials for hydrogen storage." Her work has resulted in over 40 publications in high-impact journals spanning disciplines including chemistry, materials science, and physics.

Please encourage the potential future scientists and engineers you meet to think about materials science and engineering as a career. If they choose MSE, they will be at the center of some of the most exciting developments that we will see in the next decade. The future of engineering depends on the underlying materials that form the building blocks of our modern society.

If you are in the Washington, D.C. area, please consider visiting us to learn about the latest developments in research and education. If you are an alumnus or alumna, please keep us informed of the changes in your career by e-mailing us at [mse@umd.edu](mailto:mse@umd.edu).

Robert M. Briber  
Professor and Chair, MSE

## NSF-CAREER AWARDS, CONTINUED FROM PAGE 1

research will be conducted in the Nanoscale Imaging, Spectroscopy, and Properties Laboratory (NISPLab).

Seog (joint, Fischell Department of Bioengineering) received his award for a proposal titled "Direct Observation of Dynamic Self-Assembly at the Single Molecule and Nanoscale Level," which outlined the use of a novel technique to study the self-assembly behavior of peptides. Peptides—polymers made out of amino acids that are found in every cell—perform some of the most crucial biochemical and physiological functions required to sustain life.

At the molecular level, Seog will use a combination of optical mini-tweezers and a novel single molecule construct to provide fundamental information about the behavior of two particular peptides, amyloid beta and tau, which self-assemble into a nanofiber that can be used as a platform to create bioinspired materials. At the nanoscale level,

his group will use atomic force microscopy to examine the growth of the nanofibers, the optimal conditions for their creation, and the effects of nanomechanical forces on their properties and assembly. The research will be conducted in Seog's Molecular Mechanics and Self-Assembly Laboratory.

The implications of the work extend beyond Seog's lab. "The experimental approaches we've developed are general and can be readily extended to answer questions about other self-assembling molecular systems," he says.

Seog's award will also support several educational objectives inspired by his research, including the development of an atomic force microscopy model for blind students, new and existing biomaterials and nanomechanics courses at the undergraduate and graduate level, as well as undergraduate research opportunities in his lab.

Since joining the department in 2005, Cumings has twice been invited to present research on artificial spin ice at the American Physical Society's March Meeting; developed a new form of microscopy used test nanoscale devices in real-time while they are observed in a transmission electron microscope; and was selected to lead the University of Maryland Energy Frontier Research Center's nanowires team. Recently, he received a Department of Energy grant to study thermal resistance of carbon nanotubes.

Seog, who joined the department in 2007, established the Molecular Mechanics Laboratory, home to one of the relatively few installations of optical mini-tweezers, which are used to study single molecules in nanomedicine and nanobiotechnology research. He is currently collaborating with MSE professor **Gottlieb Oehrlein** to characterize the effects of plasma on biological molecules at the monolayer level (*see related story, p. 8*).



## TAKEUCHI ELECTED APS FELLOW

Professor **Ichiro Takeuchi** was elected to Fellowship in the American Physical Society (APS). The Council of the APS cited Takeuchi “for pioneering contributions to the creation of novel classes of materials using combinatorial synthesis and probing their properties with novel probes.”

Founded at Columbia University in 1899, the APS has 46,000 members and is the publisher of *Physical Review Letters*, the top physics journal in the nation. APS Fellows constitute no more than one half of one percent of the total membership.

Takeuchi is one of the relatively few scientists worldwide who specializes in combinatorial materials science (also known as “combi”), which allows for the rapid screening of a large number of compositionally varying samples to determine if any have the characteristics the researchers desire, saving time and money in the process. Only a handful of facilities capable of this kind of work exist throughout the world,

and the one Takeuchi manages, the Keck Laboratory for Combinatorial Nanosynthesis and Multiscale Characterization, is unique among American universities.

One of Takeuchi’s highest-profile combi projects was the discovery of a new, lead-free piezoelectric material whose properties are comparable to PZT, a lead-based compound currently widely used in electronics.

His other research interests include the fabrication and characterization of novel multilayer thin-film devices, development of scanning probe microscopes, thin-film deposition and characterization, device fabrication, and low temperature measurements.

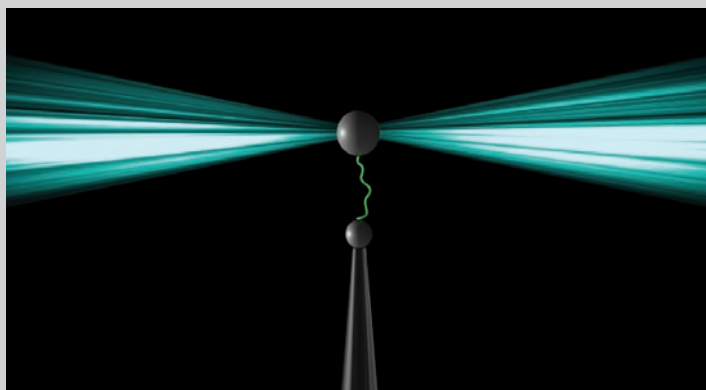
Takeuchi’s work has won him numerous grants and honors, including the ONR Young Investigator Program Award in 2000, the NSF-CAREER Award in 2001, and being selected to attend the National Academy of Engineering’s 2008 U.S. Frontiers of Engineering Symposium. He was named a University Research Leader for his success in bringing millions of sponsored research dollars to campus, including its first Department of

Energy Advanced Research Projects Agency—Energy (ARPA-E) grant to develop a smart alloy that could make cooling systems up to 175% more efficient, and a U.S. Defense Advanced Research Projects Agency (DARPA) grant that funds the exploration of new ways to construct highly-sensitive magnetometers.

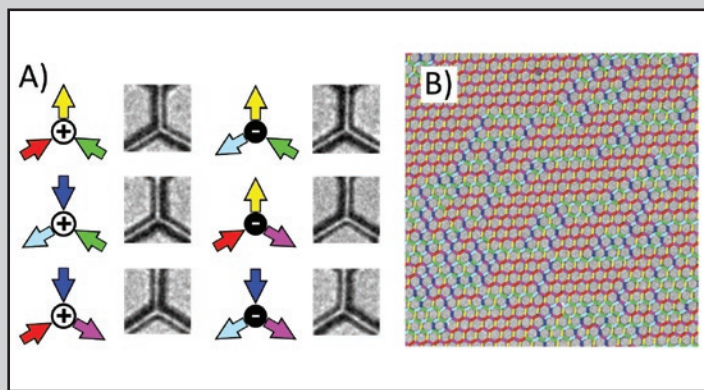
Takeuchi earned his Ph.D. in physics at the University of Maryland, College Park in 1996. After working as a postdoctoral fellow at the Lawrence Berkeley National Laboratory, he returned to campus to join the MSE faculty in 1999. He has been a visiting professor at institutes, laboratories and universities in Germany and Japan (*see p. 5*), and has been a guest researcher at the National Institute of Standards and Technology since 2002.

Takeuchi is the fourth member of the MSE faculty, and the second in the past three years, to become an elected fellow of the APS, joining Professor and Chair **Robert M. Briber**, Associate Professor **Luz Martínez-Miranda**, and Maryland NanoCenter director Professor **Gary Rubloff**.

## nsf-careerRESEARCH



From Professor **Joonil Seog**’s Molecular Mechanics and Self-Assembly Laboratory: Stretching and relaxing a single biological molecule using optical tweezers. The top bead is “tweezed” by a laser light and the bottom bead is fixed onto a pipette tip. A biological molecule (e.g. DNA) is tethered between the two beads and can be repeatedly pulled and relaxed, revealing the mechanical properties of the biomacromolecules at the single molecule level. This method can also provide very useful information about dynamic properties of biomolecules, which can shed light on protein folding, self-assembly, and protein-protein interactions. *Illustration by postdoctoral research associate Chenyang Tie.*



From Professor **John Cumings** and the Nanoscale Imaging, Spectroscopy, and Properties Laboratory: Electron microscopy shows the interaction of artificial magnetic atoms on an experimentally-defined lattice: A) various configurations of the interacting vertices, showing magnetic monopoles at the intersections. B) Under the influence of a magnetic field, monopoles move through the lattice, producing reversal patterns that will be studied in the course of Cumings’ research project.

## OEHRLIN RECEIVES IBM FACULTY AWARD



GOTTLIEB OEHRLEIN

Professor **Gottlieb Oehrlein** (joint; Institute for Research in Electronics and Applied Physics) received the 2010 IBM Faculty Award in recognition of his research program's achievements in the area of nanostructure fabrication, a field important to the computer and electronics industries.

The award came with a cash prize of \$10,000.

Oehrlein is the director of the Laboratory for Plasma Processing of Materials. His research interests include low-temperature plasma science and technology, plasma and process diagnostics, plasma-surface interactions, physics and chemistry of micro- and nanostructure fabrication, novel materials, and surface physics and chemistry. In 2007, he spent his sabbatical at the Max-Planck Institut für Plasmaphysik, where he participated in research on plasma-materials interactions for fusion reactor design. Earlier this year, he was recognized as being among the 250 most highly cited authors in his discipline over the past three decades by Thomson Reuters' **ISI HighlyCited.com** web site, and a new course he designed, "Bigger, Faster, Better: The Quest for Absolute Technology" was designated for the University's "I" series, the pilot of the proposed General Education program that represents the evolution of the traditional CORE course requirements. He has been listed among the university's Research Leaders for bringing sponsored research dollars to campus. His research group is currently hosting Feodor Lynen Fellow Dr. **Evelina Vogli**, from the University of Dortmund, Germany, and Professor **Lijun Wang** from Xi'an Jiaotong University, China.

Oehrlein also has a history of cultivating successful young plasma scientists in his research program, and two of his recent

alumni have gone on to work for IBM's Advanced Plasma Processing Group at the T.J. Watson Research Center in Yorktown Heights, New York: Dr. **Bobby Bruce** (Ph.D. '10) won the 2009 American Vacuum Society Student Merit award and was also one of six finalists for the AVS's highly prestigious John Coburn and Harold Winters Student Award in Plasma Science and Technology. Dr. **Sebastian Engelmann** (Ph.D. '08) published a book based on his dissertation titled *Plasma-Surface Interactions of Advanced Photoresist Systems*. While at Maryland, both Bruce and Engelmann were involved in research aimed at improving the quality of plasma etching techniques used by the electronics manufacturing industry.

## GOVERNOR APPOINTS WACHSMAN TO CLEAN ENERGY BOARD

Maryland governor **Martin O'Malley** has appointed William L. Crentz Centennial Chair in Energy Research and University of Maryland Energy Research Center (UMERC) director **Eric Wachsman** (joint, MSE and Department of Chemical and Biomolecular Engineering) to the Board of Directors of the Maryland Clean Energy Center. According to a press release from the governor's office, Wachsman, along with fellow new board member **George Ashton**, co-founder and CFO of Sol Systems, Inc., will help facilitate the adoption and generation of clean energy along with the new jobs, consumer savings and reduction of greenhouse gas emissions that come with it.

"I am so proud to announce the appointment of two very talented individuals to the Board of the Maryland Clean Energy Center," said O'Malley. "As Maryland continues to emerge as a national leader in clean energy, their leadership will help us move toward a better and more sustainable future for our children. I'd like to thank them for their willingness to step up and serve the people of our State as we work to find innovative ways to reach our clean energy goals in the toughest of times."

"We are privileged to have two such high-caliber and forceful clean energy

advocates join us as we move into our second year of operation," said **I. Katherine Magruder**, Executive Director of the Maryland Clean Energy Center.

Wachsman will serve through June 2015. More information is available at [www.MDCleanEnergy.org](http://www.MDCleanEnergy.org).

## CUMINGS TAPPED FOR NATURE PHYSICS NEWS & VIEWS COLUMN

Assistant Professor **John Cumings**, a recognized expert in the use of artificial spin ice in studies of thermodynamics and crystal lattices, was invited to introduce readers of *Nature Physics* to the topic in the journal's op-ed "News & Views" column.

"Frustrated magnets: Artificial ice goes thermal" explains how artificial spin ice, a metamaterial that simulates the behavior of real ice, is being used to study why water and certain magnetic materials can simultaneously settle into many possible disordered crystal structures, a behavior known as "frustration" that seems to be in conflict with a fundamental law of physics. That law, Third Law of Thermodynamics, states that as the temperature of a pure substance moves toward absolute zero the disorderly behavior of its molecules also approaches zero, and the molecules should line up in a perfectly ordered fashion. Researchers have been using artificial spin ice to study real ice and other frustrated materials because it allows for highly controlled simulations under relatively easy conditions—the study of real ice's crystal lattice, by contrast, requires precise maintenance of temperatures below that of liquid nitrogen over extended periods of time.

Cumings introduces and comments on a paper in the same issue, "Thermal ground-state ordering and elementary excitations in artificial magnetic square ice," which presents the design of the first artificial spin ice material that can reach a ground state (that of its least possible energy and complete order) like real materials do, making it a prime candidate for use in studies that seek to discover the ground states of frustrated materials that seem to defy the Third Law of Thermodynamics.

## LLOYD LEADS PROGRAM FOR COMMUNITY COLLEGE FACULTY

Associate Professor **Isabel Lloyd** will lead a new three-year summer program for regional community college faculty designed to increase the success of students with associate degrees who transfer into engineering at the University of Maryland. Lloyd's co-PI on the project is Clark School Director of STEM Education Dr. **Leigh Abts**.

The Research Experiences for Teachers (RET) program, set to begin in 2011 and funded by a \$450,000 grant from the National Science Foundation, will develop strategies for implementing new curricula in science, technology, engineering and math (STEM) courses at the 100-200 levels.

Participants will attend a six week workshop in which they will conduct research with Clark School faculty and discuss ways to bring technological innovation into their existing courses. Other activities include the development of curriculum elements; lectures on ethics, safety, entrepreneurship and intellectual property; and round-table discussions about promoting interest in STEM majors to new undergraduates and ensuring a smooth transition for those who transfer to the university.

An academic year follow up program will include monthly online discussions about curriculum implementation, outside evaluations, and two half day workshops for participants to discuss their results and exchange course materials. In the long term, the Clark School will track the number and success of students transferring from participating schools.

"This is a wonderful opportunity," says Lloyd. "RETs for community college faculties have rarely been done—typically the focus is on middle and high school educators. The participating schools not only provide most of the Clark School's transfer students, but they also serve large numbers of students from underrepresented groups. It's a win-win situation: a larger and more diverse group of students will be engaged in STEM majors and better prepared to succeed, and the community colleges and university will retain and graduate more of them thanks to an increased awareness of their needs and better transfer experiences."

## INTERNATIONAL COLLABORATION'S PAPER ON COVER OF *ADVANCED FUNCTIONAL MATERIALS*

The research groups of MSE **Professor Ichiro Takeuchi** and Professor **Alfred Ludwig** of Ruhr University Bochum, Germany (RUB) are enjoying a unique partnership that has seen the exchange of faculty, students and ideas used to advance and publish new materials research.

Takeuchi, an expert in combinatorial materials science (in which large numbers of samples of new materials are rapidly discovered, developed and analyzed), came to know Ludwig, a prominent figure in Europe's combinatorial materials science community, through various professional events. After collaborating on a number of projects, Takeuchi was invited to serve as a visiting professor at RUB in November 2009.

"We worked so extensively and so productively during that visit that we've already published a paper," says Takeuchi.

The journal article, "Identification of Quaternary Shape Memory Alloys with Near-Zero Thermal Hysteresis and Unprecedented Functional Stability," was featured on the cover of the June 2010 issue of *Advanced Functional Materials*. It describes minimizing temperature-cycle-induced fatigue in shape memory alloys by using combinatorial materials science to screen the properties of alloys under development to discover which will have the longest functional lifespan. The group was also able to discover alloy compositions whose behavior remains consistent whether they are being heated or cooled, a quality known as near-zero thermal hysteresis.

Takeuchi and Ludwig's success has inspired a more formal collaboration between the A. James Clark School of Engineering and RUB, established by a memorandum of

understanding signed in April 2010. Takeuchi will serve as the program's coordinator in Maryland. The partnership is not limited to materials science—research groups from other disciplines are encouraged to pursue collaborations as well.

The first official project under the agreement began in May 2010, when RUB Materials Research Department graduate student **Matthias Wambach** joined the Takeuchi Group.

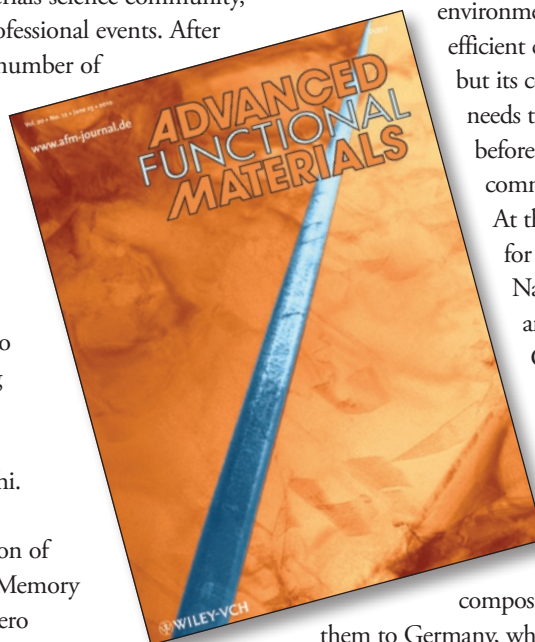
Wambach is studying ferromagnetic shape memory alloys, which change their shape when exposed to magnetic fields. This new class of material has the potential to be used in magnetic field sensors as well as

environmentally friendly, highly efficient cooling technologies, but its composition needs to be optimized before it can be used in commercial products. At the Keck Laboratory for Combinatorial Nanosynthesis and Multiscale Characterization, Wambach is creating libraries of hundreds of ferromagnetic shape memory alloy samples of varying chemical compositions. He then sends

them to Germany, where fellow RUB graduate student **Steffen Solomon** measures their properties.

"The project allows our groups to leverage their respective expertise in the discovery and development of new materials," says Takeuchi. "I'm really looking forward to seeing what other collaborations grow out of our relationship with RUB."

*For more information, see "Identification of Quaternary Shape Memory Alloys with Near-Zero Thermal Hysteresis and Unprecedented Functional Stability," Robert Zarnetta, Ryota Takahashi, Marcus L. Young, Alan Savan, Yasubumi Furuya, Sigurd Thienhaus, Burkhard Maaß, Mustafa Rahim, Jan Frenzel, Hayo Brunken, Yong S. Chu, Vijay Srivastava, Richard D. James, Ichiro Takeuchi, Gunther Eggeler, and Alfred Ludwig, Adv. Funct. Mater. 2010, 20, 1917–1923.*





## Materials Scientists and Museum Conservators Join Forces to Preserve Silver Artifacts & Art

Where there's silver, there's tarnish. While getting the tarnish off your flatware might be an occasional inconvenience, to museum curators and conservators, it's a threat to irreplaceable works of art.

To protect these objects for generations to come, scientists from the A. James Clark School of Engineering at the University of Maryland, College Park, have teamed up with conservators from the Walters Art Museum in Baltimore, Md., to develop and test a new, high-tech way to protect silver art objects and artifacts, using coatings that are mere nanometers thick.

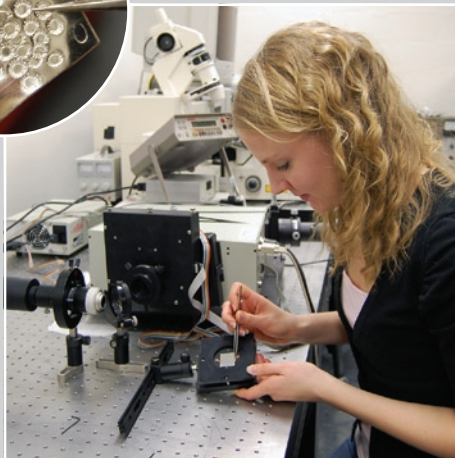
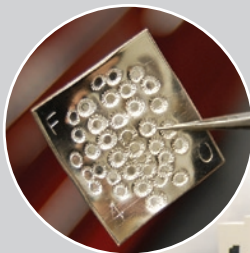
The technique, called atomic layer deposition (ALD), will be used to create nanometer-thick, metal oxide films which, when applied to an artifact, are both transparent and optimized to reduce the rate of silver corrosion. The films are created when an object is exposed to two or more gases that react with its surface.

"ALD gives us an exquisite level of control, literally at the atomic level," says MSE Professor **Ray Phaneuf**, one of the investigators working on the project. "It's an effective, low-cost strategy to reduce corrosion that preserves artifact appearance and composition while complying with the rigorous standards of art conservation practice."

**Eric Breitung**, a scientist who runs E-squared Art Conservation Science, proposed the collaboration after conducting preliminary investigations into the use of ALD on silver at New York's Metropolitan Museum of Art.

"I approached members of the Clark School faculty because of their expertise and the university's extensive ALD facilities at the Maryland NanoCenter," he says, adding that the faculty members' previous collaborations with museums made them a good match for the Walters and its silver collection.

Walters Art Museum Conservation Scientist **Glenn Gates** explains the goals the new coating has to achieve.



MSE GRADUATE STUDENT **AMY MARQUARDT** LOADS A SILVER SAMPLE INTO A REFLECTANCE SPECTROMETER, WHICH IS USED TO QUANTIFY CHANGES IN THE COLOR BALANCE OF THE SILVER SAMPLES AND DETERMINE THE ACCEPTABILITY OF THE ALD OXIDE FILMS' APPEARANCE.

AMY BRINGS HER PREVIOUS EXPERIENCE AT THE SMITHSONIAN'S MUSEUM CONSERVATION INSTITUTE TO THE SCIART GRANT TEAM (SEE SIDEBAR, P. 7)

INSET: A TEST SAMPLE OF FINE SILVER, STAMPED USING SILVERSMITHS' METHODS, TO CREATE THE KIND OF COMPLEX SURFACE THE NEW PROTECTIVE COATINGS WOULD ENCOUNTER ON ARTIFACTS.

"First, its appearance must be acceptable for display in a museum context. It has to be tough enough to endure transport and handling, but not so tough that it can't be removed. It needs to be completely removable so an object can be re-treated to meet future standards of conservation and aesthetics. And finally, it should not cause any harm to a piece, even if it breaks down."

Gates, who works with the Walters' world-class silver collection, is well acquainted with the battle against tarnish. He points out the project's figurative mascot, **Antoine**

**Louis Barye's** 1865 *Walking Lion* sculpture, as exactly the sort of piece that could one day benefit from the new treatment. It has been cleaned and lacquered twice since 1949, but in both cases ultimately experienced deterioration problems with its coatings. It is currently unlacquered but must be kept in a special exhibition case to ward off tarnish.

"The *Walking Lion* represents a complex shape that, being difficult to coat with traditional lacquer, might benefit from ALD protection," he says.

The team will test the new technique, first on small samples of fine and sterling silver, and then on objects from Gates' own collection, such as 19th century demitasse spoons and Morgan silver dollars. While the Walters does not expect any pieces from its collection to receive the experimental treatment during the course of the study, once it has been proven effective and safe, the *Walking Lion* would be a prime candidate for the procedure.

The three-year project is one of the first to be funded by the National Science Foundation's Chemistry and Materials Research at the Interface between Science and Art (SCIART) grant program, which supports research in the field of cultural heritage science through the funding of collaborations among conservation experts in museums and scientists in academia.

The project's other team members include the Walters' Director of Conservation and Technical Research **Terry Drayman-Weisser**, a recognized metals expert; and, from the University of Maryland's Department of Materials Science and Engineering, Professor **Gary Rubloff**, Research Associate **Laurent Henn-Lecordier**, and Graduate Assistant **Amy Marquardt**, who brings to the project her previous experience working on bronze

**ANTOINE-LOUIS BARYE, WALKING LION; STRIDING LION (RACING TROPHY), 1865, SILVER ON MARBLE PLINTH, 19.5 X 26.75 X 8.75 IN., THE WALTERS ART MUSEUM, BALTIMORE. THIS SCULPTURE, WHOSE DETAILED SURFACE MAKES IT DIFFICULT TO PROTECT FROM TARNISH, WOULD BE A PRIME CANDIDATE TO RECEIVE A NEW, NANOMETERS-THICK COATING BEING DEVELOPED BY MATERIALS SCIENTISTS AND CONSERVATORS AT THE WALTERS ART MUSEUM AND THE A. JAMES CLARK SCHOOL OF ENGINEERING. IMAGE COURTESY OF THE WALTERS ART MUSEUM.**



patinas with the Smithsonian's Museum Conservation Institute (*see sidebar*).

Since its announcement, the project has been covered by the *Baltimore Sun*, *Materials Performance*, and the University of Maryland's *Terp* magazine. When the NSF SCIART program was highlighted at the March 2011 national meeting of the American Chemical Society, the team was invited to a special symposium sponsored by the Getty Conservation Institute (GCI). According

to Phaneuf, the team's presentation was enthusiastically received, drawing questions from the audience, including GCI director **Giacomo Chiari**.

In April 2011 the National Science Foundation's *Science Nation* web site, which highlights scientific discoveries for the public, debuted a video segment about the project called "Silver Saver," narrated by former CNN chief technology and environment correspondent **Miles O'Brien**. To watch the video online, visit [www.nsf.gov/news/special\\_reports/science\\_nation](http://www.nsf.gov/news/special_reports/science_nation) or our department's YouTube channel at [www.youtube.com/materialsatumd](http://www.youtube.com/materialsatumd).

## MARQUARDT STUDIES PATINAS AT SMITHSONIAN INSTITUTION

MSE graduate student **Amy Marquardt**, advised by Professor **Ray Phaneuf**, spent the summer of 2010 at the Smithsonian Institution's Museum Conservation Institute (MCI), where she worked with Smithsonian research scientist Dr. **Edward Vicenzi** and MSE adjunct professor Dr. **Richard Livingston** (NIST) on a project that could help museums better analyze, clean and preserve their bronze artifacts.

The research focused on patinas, the greenish films that form on untreated metal surfaces (typically copper, bronze, and brass) after years of exposure to the elements—for example, a patina is what gives the Statue of Liberty its minty color. Patinas help protect metal against further corrosion, and may increase an object's value. An artificial patina can also be applied to an object to accelerate the process, produce a desired look, or restore a patina after cleaning. Artificial patinas, however, are not as stable and long lasting as the real thing.

"In the field of conservation, cleaning and repatination of bronze statues is an active area of research," Marquardt explains, "but the chemistry and mineralogy of the artificial patinas used by artists and conservators have not been systematically and quantitatively investigated. The purpose of our research was to understand, at the molecular and microstructural level, the relationship between the application of artificial patination to bronze and the resulting appearance and stability of the patina. Understanding both the process and its result is important for the conservation and restoration of bronze objects."

Marquardt and her colleagues used scanning electron microscopy, electron probe microanalysis, and Raman spectroscopy to determine patina color, mineralogy, stability and interactions with protective coatings for different artificial bronze patina recipes.

Marquardt also worked with corrosion samples taken from **Auguste Rodin's Eve**, a sculpture belonging to the Philadelphia Museum of Art. Her goal was to characterize the corrosion in order to aid conservators in the restoration and cleaning of the piece.

"The best thing about the internship was that the nature of the project required an interdisciplinary collaboration between

materials science, conservation, art history, and

mineralogy," she says of the experience.

"It was very interesting and I enjoyed meeting and working with the scientists and conservators at the Smithsonian and NIST."



PARIS 30 AVRIL 1865

FILLE DE L'AIR



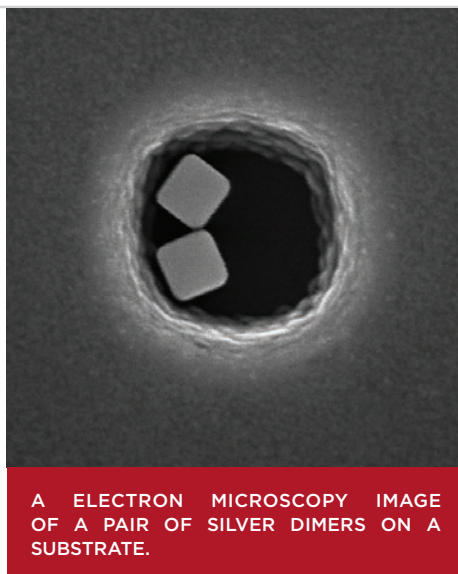
## NANOCUBE PAIRS ARE KEY TO IMPROVED SENSORS

Pairs of nanoscale silver cubes can enhance the effectiveness of surface-enhanced Raman scattering (SERS), paving the way for a finer level of spectroscopy that can be used to improve sensor design and fabrication, according to a recent paper published in *ACS Nano* by MSE assistant professor **Oded Rabin** and Alford L. Ward Professor and Distinguished Scholar-Teacher **Isaak Mayergoyz** (Department of Electrical and Computer Engineering). Their findings could translate into improved equipment used in environmental monitoring, medical diagnostics, and security.

The paper, titled “Dispersion in the SERS Enhancement with Silver Nanocube Dimers,” demonstrates how the orientation of and gaps between pairs of silver nanocubes, called dimers, enhance the signals generated by SERS, allowing researchers to detect the presence of target molecules—dangerous or benign—in much smaller quantities.

“This is a significant advance in spectroscopy,” Rabin explains. “Using the nanocubes has allowed us to detect radiation from the presence of only a few thousand molecules, whereas with Raman alone, we would need as many as ten billion molecules to get a positive test result.”

In Raman spectroscopy, light is scattered by the presence of molecules, providing a spectrum that is unique to the molecule being probed. When light from a laser probe floods a sample in a sensor, it is not strong enough to detect target molecules present in only very small quantities. If the silver dimers



A ELECTRON MICROSCOPY IMAGE OF A PAIR OF SILVER DIMERS ON A SUBSTRATE.

are present, however, they focus and intensify the probe’s light in their immediate vicinity. These localized, intense spots of light hit the target molecules and scatter in a unique way, alerting the person using the equipment to their presence.

The paper explains how the team’s technique of assembling and simultaneously testing many groups of dimers in varying configurations allows them to quickly determine how to best construct a sensor for a specific type of molecule.

Rabin’s team creates the cubes from silver ions that are reduced to silver atoms, which in turn form crystals of a specific shape. Using a patterned substrate (surface) that guides their placement, the team can drive the nanocubes to self-assemble into pairs at predetermined locations. Viewed under an electron microscope, the cubes, which are 80 nanometers in size, look something like pairs of dice in bowl-shaped indentations.

The nanocubes’ shape determines with what wavelength of light they will interact. When probed with a beam of light, the electrons in the silver begin to oscillate, causing them to scatter some wavelengths while absorbing others, reflecting a color back. How the electrons are distrib-

uted and behave across the surface of the nanocubes is determined by the nanocubes’ proximity to other nanocubes and the wavelength of light to which they are exposed.

Mayergoyz’s team has created computer simulations that efficiently model the optical response and predict its enhancement.

“Other research groups have used single nanocubes in these types of experiments, but the dimers are more effective, because their electromagnetic fields are more intense at their junctions [where they nearly touch],” says Rabin. “Our assembly technique allowed us to carry out a systematic study of these dimers. The cubes in the pairs could be aligned face to face, edge to edge, or edge to face. We’ve found that each configuration is effective in different conditions, and the more surface area contact they have, the greater the intensity of the field.”

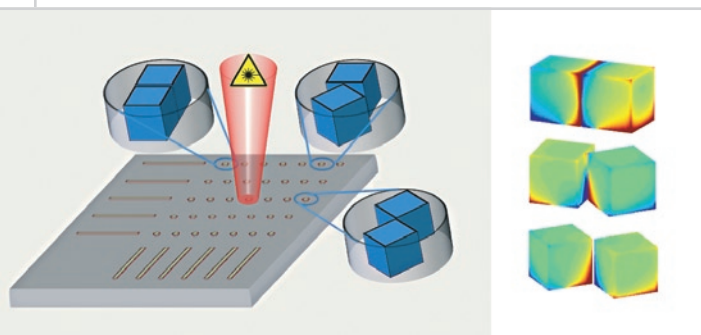
“The work also reflects on the interdisciplinary environment that is fostered on campus,” he adds. “Our research groups learned a lot from each other, and achieved a higher quality of work by collaborating. And we had fun in the process.”

## PLASMA FOR DISINFECTION STUDY WINS DOE GRANT

A new study that seeks to explain how and why plasma (a gas containing charged, reactive molecules) is so effective at deactivating toxic proteins and biomolecules could lead to its broader use in the medical community. The project, a unique blend of plasma science and bioengineering, will be the first to explore the mechanistic effects of plasma on bacteria at the monolayer level.

MSE professors **Gottlieb Oehrlein** (joint, Institute for Research in Electronics and Applied Physics) and **Joonil Seog** (joint, Fischell Department of Bioengineering) have received a three-year, \$330,000 grant from the Department of Energy’s Office of Science for Fusion Energy Sciences for their proposal, titled “Fundamental Science of Low Temperature Plasma-Biological Material Interactions.”

Plasma is commonly used in the production of electronic devices at low pressure.



▲ A SCHEMATIC OF THE RAMAN SCATTERING EXPERIMENT SHOWING THE PATTERNED SUBSTRATES WITH CAVITIES IN WHICH THE NANOCUBE DIMERS WERE ASSEMBLED. THE RIGHT SIDE SHOWS SIMULATIONS OF THE ELECTRIC FIELD MAGNITUDES ON THE SURFACE OF THE NANOCUBES AS A FUNCTION OF THE RELATIVE ARRANGEMENT. RED AND BLUE CORRESPOND TO AREAS OF STRONG FIELDS (“HOT SPOTS”).



Plasma at room temperature and atmospheric pressure, however, is used to sterilize surgical equipment and to disinfect clothing or surfaces. Its antibacterial and antimicrobial properties also mean it can be used for wound care, a treatment that has been tested but is not widespread. Exactly why and how these treatments work, however, it not yet understood.

Conventional plasma treatment of surgical instruments and biomedical devices completely removes biomolecules, but the harsh reaction conditions may also remove surface layers from the equipment, degrading their performance. Oehrlein is developing a “gentle and selective” means of plasma application that will allow Seog, who specializes in molecular mechanics, to observe exactly which reactive plasma molecules interact with individually targeted biomolecules in a biological assay designed specifically for this research.

“If we understand exactly how plasma deactivates biomolecules we’ll have many opportunities to extend and customize the technology,” says Seog. “It could be used in a variety of laboratory and hospital procedures, target different kinds of toxins from bacteria or viruses, and possibly facilitate tissue regeneration. Using this technique, we may be able to deactivate toxic molecules by altering their molecular structure in a selective manner.”

“Researchers have been excited by the potential advantages of plasma-based treatments over traditional disinfection methods,” Oehrlein adds. “The plasma approach only requires electrical energy and simple gases, like air. Working at low temperature and atmospheric pressure means the devices used in treatment could be small, portable, and easy to operate. It may also help in cases where an infection is resistant to antibiotics.”

Oehrlein and Seog will collaborate with professors **Jihj Wei Chu** and **David Graves** (Department of Chemical and Biomolecular Engineering, University of California–Berkeley), who have received a similar grant to perform complimentary experiments and model and interpret the data. The study is also funded in part by the National Science Foundation.

## SALAMANCA-RIBA SILICON CARBIDE RESEARCH HIGHLIGHTED BY NIST

The National Institute of Standards and Technology’s Center for Nanoscale Science and Technology highlighted one of MSE professor **Lourdes Salamanca-Riba**’s research projects in the Fall 2010 issue of its newsletter, *CNST News*.

The article, titled “University-Army Collaboration Investing SiC-based MOSFET Treatments,” describes a collaboration among researchers at the University of Maryland, Auburn University, and the Army Research Laboratory. The team is investigating performance and reliability-enhancing treatments for silicon carbide (SiC)-based devices used in communications.

SiC is a semiconductor capable of operating at high temperatures, frequencies, and power. This makes it a good candidate for use in metal-oxide-semiconductor field-effect transistors (MOSFETs). However, it has been found that in MOSFETs fabricated with layers of SiC and silicon dioxide (SiO<sub>2</sub>), carbon atoms make their way into the SiO<sub>2</sub>, blurring the distinction between the two materials where they touch. Electrons move less efficiently through these muddled areas, resulting in a loss of energy and poor device performance.

“The high temperature at which devices made of silicon carbide operate causes the carbon to diffuse into the silicon dioxide,” Salamanca-Riba explains. “Why exactly this happens is not well understood, but it’s possible that it’s because the two materials expand at different rates when the temperature increases.”

Salamanca-Riba and her colleagues were able to create a sharper interface between the layers of SiC and SiO<sub>2</sub>, as well as substantially increase performance, by treating the materials with nitrogen plasma in one experiment, and focused ion beam bombardment in another. The team is planning on testing two other possible treatments, annealing and ion implantation, in order to determine which yields the best results and could be implemented in the manufacturing process.

## BREAKTHROUGH IN SOLID OXIDE FUEL CELL RESEARCH

MSE research associate Dr. **Yuri Mastrikov** and adjunct professor Dr. **Maija Kuklja** (National Science Foundation [NSF]), in collaboration with Max-Planck Institute researchers **Eugene Kotomin** and **Joachim Maier**, have used large scale computer modeling to demonstrate that the vacancy formation energy in (Ba,Sr)(Co, Fe)O<sub>3</sub> complex perovskites is much smaller than in other perovskites, which translates into orders of magnitude larger defect concentrations and fast oxygen transport in mixed electronic-ionic conductors for numerous applications. The group published its results in *Energy & Environmental Science*. The work is supported in part by the NSF.

Solid oxide fuel cells (SOFC) are promising devices for generating energy in an environmentally friendly way by a direct conversion of fossil and renewable fuels into electricity and high-quality heat. A major challenge to improving the functionality and implementation of SOFCs is the need to reduce their operating temperatures down to 500–600°C.

In the article, “First-principles modeling of complex perovskite (Ba<sub>1-x</sub>Sr<sub>x</sub>)(Co<sub>1-y</sub>Fe<sub>y</sub>)O<sub>3-δ</sub> for solid oxide fuel cell and gas separation membrane applications,” the authors describe their search of complex perovskites combining high oxygen vacancy concentration (non-stoichiometry) and high vacancy mobility at moderate temperatures, as well as long-term cubic structure stability against transformation and degradation in polluted atmosphere.

The team has demonstrated that the optimal strategy for developing a new and improved SOFC cathode should be based on the combination of key experimental data on oxygen incorporation into material, and first-principles thermodynamics/kinetics of oxygen reduction and related processes. They have been able to identify the atomistic mechanisms of key reactions for (La,Sr)MnO<sub>3</sub> (LSM) with the emphasis on the rate-determining steps. Based on the study, the researchers plan to perform a similar analysis for BSCF and related complex perovskites.

## alumniNEWS

**Olugbenga Famodu** (B.S. '95, chemical engineering; M.S. '04 and Ph.D. '05, materials science and engineering) was featured in a story called "ChEs & EnvEs find work in many fields" in the August/September 2010 issue of *Diversity/Careers in Engineering & Information Technology*, about the variety of career options open to chemical and environmental engineers. Famodu, who is currently a senior process engineer at Intel in Hillsboro, Or., discussed some of the major influences on his educational and career paths, including membership in the Black Engineers Society (a chartered chapter of the National Society of Black Engineers) and the Clark School's Center for Minorities in Science and Engineering. While at Maryland he was the recipient of two National Science Foundation scholarships, the Louis Stokes Alliances for Minority Participation and the Sloan.

**José Reyes Jr.** (M.S. '84 and Ph.D. '86, nuclear engineering) is the head of the nuclear engineering program at Oregon State University and CTO of NuScale Power. OregonLive.com profiled his current efforts to design the next generation of nuclear power plants.

## recent GRADUATES

### 2010 B.S. GRADUATES

#### DECEMBER

**Paul Lambert**

### 2010 PH.D. GRADUATES

#### DECEMBER

**Enrique Cobas:** "High-Frequency Electrical Transport Properties of Carbon Nanotubes." Advisor: Michael Fuhrer (Physics)

**Chaitanya Mudivarthi:** "Magnetic and Structural Characterization of Fe-Ga Using Kerr Microscopy and Neutron Scattering." Co-Advisors: Alison B. Flatau (Aerospace) and Manfred Wuttig

### SHIH WINS NIST-ARRA FELLOWSHIP

MSE graduate student **Jennifer Shih**, advised by Professor and Chair **Robert M. Briber**, has been awarded a National Institute of Standards and Technology—American Recovery and Reinvestment Act (NIST-ARRA) Measurement Science and Engineering Fellowship. Shih will conduct her fellowship research at NIST's Center for Neutron Research (NCNR) under the direction of Dr. **Julie Borchers**.

Shih studies the structural and magnetic characterization of magnetic nanoparticles in a silk elastin-like block copolymer (SELP) system. The material, which has potential applications in cancer treatment and biomedical imaging, consists of therapeutic nanoparticles suspended in a polymer that gels near body temperature. The silk units in the polymer give it its structure, while the elastin, a protein found in connective tissue, gives it flexibility. Shih and her colleagues believe these components create a fibrous, web-like network ideal for lining with nanoparticles.

"One of the applications for my research is hyperthermia cancer treatment," she explains. "SELP containing nanoparticles would be injected near a tumor site, and then an external magnetic field would be applied to further direct the nanoparticles or to cause them to generate enough heat to kill localized cancer cells while leaving surrounding healthy tissue unharmed." Shih adds that the SELP system could also be used as a contrast agent in magnetic resonance imaging (MRI) or as a vehicle for drug delivery.

At the NCNR, Shih plans to conduct neutron scattering experiments to investigate both the structural and magnetic properties of the nanoparticles

and SELPs, determine how these properties correlate with one another, and characterize the system as a whole.

"I'm excited about the winning the fellowship," Shih adds. "It gives me the ability to work with leading research scientists at a national research center and world class facility, and it will provide me with extensive experience in neutron scattering. This will greatly complement the research that I have completed so far in Professor Briber's lab and with the Magnetic Materials Group at NIST this past summer."

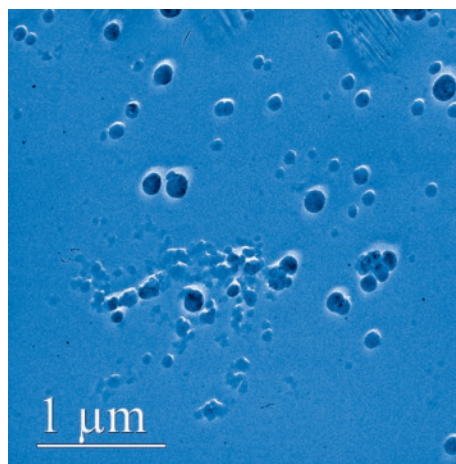
The NIST-ARRA program, which is made possible by a \$15 million grant, will bring some 50 fellows per year over three years to work at NIST laboratories in Gaithersburg, Md., and Charleston, S.C., providing new research collaborations among students, faculty and NIST scientists. The program's goal is to further develop a future scientific talent pool with extensive training in measurement science and engineering.

### CORNETT WINS MRS STUDENT PRESENTATION AWARD

"Simplified Thermoelectric Figure of Merit Calculations for Semiconducting Nanowires," a presentation given by MSE graduate student **Jane Cornett** at the Materials Research Society's (MRS) Fall 2010 meeting,

was selected as one of the five Best Oral Student Presentations in the symposium on Thermoelectric Materials for Solid-State Power Generation and Refrigeration.

Cornett, advised by MSE assistant professor **Oded Rabin**, studies thermoelectric materials, which can convert a temperature gradient into electricity, and vice versa. Thermoelectric



**FROM JENNIFER SHIH'S RESEARCH:** CRYOPLUNGE TRANSMISSION ELECTRON MICROSCOPY (CRYO-TEM) IMAGE OF IRON OXIDE NANOPARTICLES. CRYO-TEM IS USED TO PREVENT NANOPARTICLE AGGREGATION AND IMPROVE DISPERSITY OF PARTICLES FOR ENHANCED IMAGING.



devices can be used as generators that produce power from waste heat, and as refrigerators.

“Waste heat recovery is obviously very exciting as the search for alternative and recycled energy becomes increasingly important,” Cornett explains. “Thermoelectric refrigerators are also particularly appealing because they are quieter and more lightweight than traditional refrigerators, and they don’t contain moving parts. The current struggle in the field of thermoelectrics is that the efficiency of these materials is [still] too low to compete with traditional devices.”

In her presentation, Cornett explained how her research group at the Materials and Interface Nanotechnology Laboratory examined and calculated the thermoelectric properties of semiconducting nanowires in relation to their radii. According to Cornett, despite the widely accepted theory that the smaller the critical dimension of a material (in this case, the diameter of the nanowires) the higher its thermoelectric efficiency, the team discovered that isn’t always true.

“We improved upon the prevailing model so that we can now more accurately predict when, for a given material, smaller is better,” she says.

The revised model should be important to the field of thermoelectrics, she believes, because it can provide guidance to researchers trying to determine the ideal size at which a given material must be used in order to produce the most effective devices.

“The MRS Fall meeting was a great way for me to review all of the current work, both experimental and theoretical, in thermoelectrics and in other fields relevant to Dr. Rabin’s research and my specific interests,” says Cornett. “I had the chance to go to talks and poster sessions by other [MSE] graduate students [including] **Paris Alexander, Khim Karki, Kamal Baloch, and Luz Sanchez.** I think my favorite part of the conference was getting to meet Professor **Mildred Dresselhaus**, a pioneer in the field of nano-scale thermoelectrics, and getting good feedback from her on my work. She also gave an exciting pep-talk on the future of thermoelectrics that included some of my results.”

Bioengineering Laboratory, where he is part of a team that uses high-resolution imaging to track nanoparticles as they travel along neuronal pathways, looking for the signs of impaired transport that could indicate the early stages of disease. Godo is responsible for the fabrication and characterization of the biocompatible iron nanoparticles used in the research. Prior to his work with Shah, Godo was a member of Professor **Gottlieb Oehrlein’s** Laboratory for Plasma Processing of Materials, where he analyzed X-ray photoelectron spectroscopy data to investigate the changes in the surface chemistry of selected materials.

Outside the lab and classroom, Godo is an enthusiastic educator who mentors precollege students in a variety of science and engineering topics, including leading a team participating in SeaPerch, a national underwater robotics program for high school students, hosting nanotechnology workshops for middle school students, and tutoring fellow university students in calculus and chemistry.

Graduate student **Keith Gregorczyk**, advised by Professor **Gary Rubloff**, has been selected to receive an L-3 Graduate Research Fellowship. The award includes a \$25,000 stipend, \$1000 to fund travel to conferences, and a five-credit tuition waiver. An additional \$4000 in discretionary funds and \$5000 to support an undergraduate researcher to work with Gregorczyk will be provided to Rubloff.

Gregorczyk’s research focuses on using atomic layer deposition for the fabrication of heterostructured nanomaterials. His goal is to show that this technique, and the materials that can be made using it, will offer significant improvements in the way batteries store and distribute energy.

Epstein, Godo and Gregorczyk have all been invited to participate in L-3 @ Maryland research events, where they will have the opportunity to discuss their work with L-3 Communications experts working in their fields.



#### KEEP IN TOUCH!



Did you land a great new job? Get married? Have a baby? Win an award? Patent a new process or product? Have you used your engineering skills and experience to make a difference? Let us know! Find us on Facebook or e-mail [mse@umd.edu](mailto:mse@umd.edu).







**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 RED IMAGE USED ON THE COVERS, FROM THE MATERIALS AND INTERFACE NANOTECHNOLOGY LABORATORY DIRECTED BY ASSISTANT PROFESSOR ODED RABIN, IS A SCANNING ELECTRON MICROGRAPH OF 80NM SILVER NANOCUBES SYNTHESIZED BY GRADUATE STUDENT SEUNG YONG LEE. BY CONTROLLING CRYSTAL NUCLEATION AND GROWTH RATES, SELECTIVE FABRICATION OF NANOPARTICLES WITH UNIFORM SHAPE AND SIZE IS ACHIEVED. TO LEARN MORE ABOUT THE LAB'S USE OF SILVER NANOCUBES TO IMPROVE SURFACE ENHANCED RAMAN SPECTROSCOPY AND SENSOR DESIGN, SEE THE RELATED STORY ON P. 8.

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](mailto:mse@umd.edu)

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

## scholarSHIPS

### 3 STUDENTS WIN L-3 SCHOLARSHIPS

Three Department of Materials Science and Engineering students are among the first to receive the A. James Clark School of Engineering's newest scholarships and fellowships.

In July 2010, **L-3 Communications** gave a gift of \$1 million to the Clark School to benefit students through merit-based scholarships, fellowships and student programs. The funds support students who conduct research in cybersecurity, robotics, energy, systems engineering, or reliability engineering.

MSE senior **Eric Epstein** has been awarded a \$4150 L-3 Undergraduate Scholarship. Epstein, who minors in nanotechnology, is a member of MSE professor **John Cummings'** research group, where he has worked on the fabrication of lithium-ion battery electrodes using silicon nanowires. During the first phase of the project, he was responsible for analyzing the performance of the nanowires using transmission and scanning electron microscopy, as well as characterizing any structural changes they had undergone after testing. He is currently investigating their mechanical properties.

Epstein is a self-described "avid member" of Engineers Without Borders (EWB). EWB sends teams of volunteers

to developing countries around the world to complete projects that enable people to obtain safe drinking water, better sanitation, reliable electricity, education, and more. Epstein is part of a team that has designed a water pump, storage, and filtration system for a medical center in Burkina Faso, Africa. This summer, he will intern at the Naval Research Lab. After completing his bachelor's degree, he plans to pursue a Ph.D. in materials science and engineering.

MSE senior **Olatunji Godo** has been awarded an L-3 Undergraduate Research Scholarship. Godo is a member of Fischell Department of Bioengineering professor **Sameer Shah's** Neuromuscular

*continues page 11*