SPRING 2009

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.

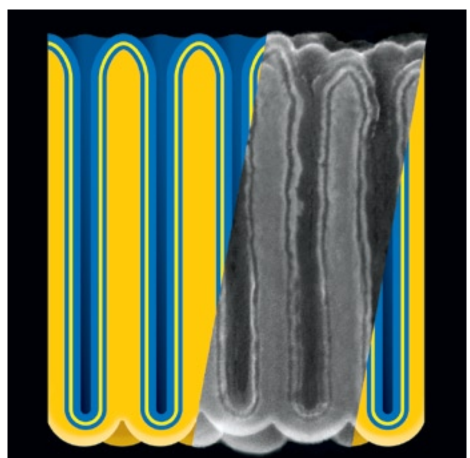
IN THIS ISSUE:

Better Energy Storage Options

NANOCENTER RESEARCHERS CREATE NEW DEVICE TO STORE ELECTRICAL ENERGY DERIVED FROM SUN, WIND

In order to save money and energy, many people are purchasing hybrid electric cars or installing solar panels on the roofs of their homes. But both have a problem—the technology they use to store the electrical energy is inadequate.

Battery systems that fit in cars don't hold enough energy for long driving distances, yet take hours to recharge and don't give much power for acceleration. "Renewable energy sources like solar and wind," says Department of Materials Science and Engineering professor and Maryland NanoCenter director **Gary Rubloff**, "provide time-varying, somewhat unpredictable energy supplies, which must be captured and stored as electrical energy until demanded. But conventional devices to store and deliver electrical energy—batteries and capacitors—cannot achieve the needed combination of high energy density, high power, and fast recharge that are essential for our energy future."



ELECTROSTATIC NANOCAPACITORS FORMED IN NANOPOROUS ANODIC ALUMINUM OXIDE (DARKER YELLOW) FILM BY SEQUENTIAL ATOMIC LAYER DEPOSITION OF METAL (BLUE), INSULATOR (YELLOW), AND METAL. INSERT: CROSS-SECTION OF ACTUAL STRUCTURE, REPRESENTED AS RESCALED SCANNING ELECTRON MICROGRAPH.

Hoping to provide a solution to this pressing problem, Rubloff and his research group, in collaboration with the research group of Department of Chemistry & Biochemistry Associate Professor **Sang Bok Lee**, have developed new systems for storing electrical energy derived from alternative sources that are, in some cases, 10 times more efficient than what is commercially available. The results of their work are available in the April 2009 issue of *Nature Nanotechnology.*

Materials behave according to physical laws of nature. Using new processes central to nanotechnology, the Rubloff and Lee groups exploit unusual combinations of these behaviors (called self-assembly, self-limiting reactions, and self-alignment) to construct millions—and ultimately billions—of tiny, virtually

ENERGY STORAGE continued on p. 2

chair's MESSAGE

ROBERT M. BRIBER

THE DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING HAS HAD A GREAT YEAR with new projects emerging from the research labs, a great undergraduate and graduate recruiting season and both faculty and students receiving honors and awards.

One item that is particularly exciting is outlined in the cover article in this issue of the newsletter. Professor Rubloff and Associate Professor Lee (Chemistry) have developed a new nanoscale capacitor system that can exceed the efficiency in current commercial systems by a factor of 10 times.

Professor Takeuchi is the news with the discovery of a new lead free piezoelectric material, bismuth samarium ferrite (BFSO) with properties similar to that of lead zirconium titanate (PZT). BFSO promises to be an exciting new material for the future. Professor Takeuchi has also been acknowledged for his work in the field of combinatorial materials science by the National Academy of Engineering as one of the top 100 outstanding young engineers in 2008.

Professor Ankem was a finalist for the University of Maryland Invention of the Year for his development of a new process for making nanoporous titanium implant surfaces to enhance growth to build a strong bond between the implant and the bone.

Our students have received a number of honors. Bobby Bruce attended a NSF funded special symposium in Australia. Parag Bannerjee has been named a John and Maureen Hendricks Energy Research Fellow for his work on energy harvesting and storage devices. Sank Hak Shin was invited to attend the National School on X-ray and Neutron Scattering held at Argonne and Oak Ridge National Labs.

The future for materials science and engineering looks even brighter with the Department playing a strong role in campus initiatives in nanotechnology, energy research and biotechnology. If you are in the Washington D.C. area please stop by the Department and the University and learn about all the new things that are happening. If you are an alumna/us keep us informed on the changes in your career.

Robert M. Briber
Professor and Chair, MSE

ENERGY STORAGE, continued from p. 1

identical nanostructures with shapes tailored to transport energy as electrons rapidly to and from the very large surface areas where they are stored.

"These devices exploit unique combinations of materials, processes, and structures to optimize both energy and power density—combinations that, taken together, have real promise for building a viable next-generation technology, and around it, a vital new sector of the tech economy," Rubloff says.

"The goal for electrical energy storage systems is to simultaneously achieve high power and high energy density to enable the devices to hold large amounts of energy, to deliver that energy at high power, and to recharge rapidly (the complement to high power)."

Electrical energy storage devices fall into three categories. Batteries, particularly lithium ion, store large amounts of energy but cannot provide high power or fast recharging. Electrochemical capacitors (ECCs), also relying on electrochemical phenomena, offer higher power at the price of relatively lower energy density. In contrast, electrostatic capacitors (ESCs) operate by purely physical means, storing charge on the surfaces of two conductors. This makes them capable of high power and fast recharge, but at the price of lower energy density.

The team's new devices are electrostatic nanocapacitors which dramatically increase energy storage density of such devices—by a factor of 10 over that of commercially available devices—without sacrificing the high power they traditionally characteristically offer. This advance brings electrostatic devices to a performance level competitive with electrochemical capacitors and introduces a new player into the field of candidates for next-generation electrical energy storage.

Where will these new nanodevices appear? Lee and Rubloff emphasize that they are developing the technology for mass production as layers of devices that could look like thin panels, similar to solar panels or the flat panel displays we see everywhere, manufactured at low cost. Multiple energy storage panels would be stacked together in combination with a car battery system or solar panel. In the long run, they foresee the same nanotechnologies providing new energy capture technology (solar, thermoelectric) that could be fully integrated with storage devices in manufacturing.

This advance follows soon after another accomplishment—the dramatic improvement in performance (energy and power) of electrochemical capacitors ("supercapacitors") by Lee's research group, published recently in the *Journal of the American Chemical Society*. Efforts are under way to achieve comparable advances in energy density of lithium (Li) ion batteries but with much higher power density.

"U-Md.'s successes are built upon the convergence and collaboration of experts from a wide range of nanoscale science and technology areas with researchers already in the center of energy research," Rubloff says.

The Lee and Rubloff groups are part of a larger team at the University of Maryland developing nanotechnology solutions for energy capture, generation, and storage. Their collaborators span multiple departments and colleges, and include Department of Materials Science and Engineering professors **John Cumings** and **Oded Rabin**.

SEOG LAB INSTALLS OPTICAL MINI-TWEEZERS

The Molecular Mechanics Laboratory, directed by Assistant Professor **Joonil Seog** (joint, Fischell Department of Bioengineering), is completing setup of a new optical tweezers unit to be used in studies of protein aggregation, gene delivery and self-assembled biomaterials. The relatively uncommon device has been specially customized to be more compact, reduce acoustic noise and other vibratory interference, and eliminate labor-intensive calibration steps, resulting in a more user-friendly experience for researchers.

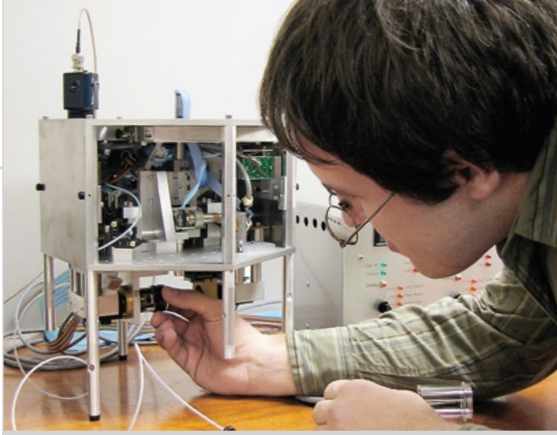
Optical tweezers use the optical forces generated by a laser to capture, or "tweeze", a micron-sized dielectric particle, such as a polystyrene bead. A second particle is attached to a pipette tip. A molecule to be studied—such as a protein or peptide—is suspended between them by tethering each end to a bead using DNA "handles". The pipette is then moved back and forth to exert force on the molecule.

The end result is a device capable of applying tiny amounts of force to delicate single-molecule samples, gently stretching and relaxing them or holding them still to observe their dynamics in real time. For example, the self-assembly of specific peptide molecules to form well-defined nanostructures can be followed. Seog points out that his lab's optical tweezers have two advantages over most other units: instead of calculating force based on spring constants and displacements, his directly measures force without labor-intensive calibration steps. Also, its small size—not much larger than two gallons of milk, compared to more common units that require 3'x6' optical tables on which to sit—allows it to be more stable and accurate due to the reduction of the optical path length, minimizing the chances of any interference.

Seog, who previously used optical tweezers to explore the mechanical behavior of cell adhesion molecules, plans to apply the technique to further research in nanomedicine and nanobiotechnology.

One project will focus on the protein aggregates (buildups) that are known to cause neurodegenerative diseases such as Alzheimer's, Parkinson's, and Mad Cow. Although these diseases have been widely studied, what happens in their earliest stages of development is largely unknown. The optical tweezers will allow Seog and his team to study the earliest interactions between individual proteins that lead to the formation of small complexes called oligomers, and eventually aggregation. What the group learns may lead to improved treatments that could prevent the progression of a disease in its earliest stages.

Seog is also working in collaboration with Dr. **Jason Kahn** (Department of Chemistry & Biochemistry) and Dr. **A. James Mixson** (Department of Pathology, UMB School of Medicine) to develop a more effective carrier for use in gene therapy. One of the challenges in designing an artificial carrier to deliver and introduce genetic material into a cell—a process called transfection—is a lack of knowledge about the fundamental mechanisms of gene delivery. "The optical tweezers will allow us to directly observe, in real time, the process of gene carrier/DNA complex formation and DNA release at the single molecule level," Seog explains. "It will provide new insight on molecular structures for improved transfection efficiency."



DEPT. OF MATERIALS SCIENCE & ENGINEERING GRADUATE STUDENT **ADAM KARCZ**, ADVISED BY PROFESSOR **JOONIL SEOG**, ASSEMBLING THE OPTICAL MINI-TWEEZERS. THE DESIGN IS BASED ON A DEVICE LOCATED IN THE **BUSTAMANTE LAB** AT THE UNIVERSITY OF CALIFORNIA, BERKELEY. KARCZ SPENT TIME AT THE LAB WITH RESEARCH SCIENTIST **STEVEN SMITH** TO LEARN HOW TO BUILD THE TWEEZERS FOR SEOG'S MOLECULAR MECHANICS LABORATORY, AS WELL AS CREATE DOCUMENTATION AND SCHEMATICS FOR IT.

PHANEUF GROUP RESEARCH SELECTED FOR *VJBO*

A paper produced by the research group of Associate Professor **Raymond Phaneuf** has been selected for inclusion in the *Virtual Journal for Biomedical Optics (VJBO)*. The journal, published by the Optical Society of America (OSA), is a compilation of articles recently published in OSA's various peer-reviewed journals, plus content published in the Society for Applied Spectroscopy's *Applied Spectroscopy* journal. The selected articles are considered to represent cutting-edge and state-of-the-art research in optics.

The paper, "Enhanced fluorescence and near-field intensity for Ag nanowire/nanocolumn arrays: evidence for the role of surface plasmon standing waves," originally published in *Optics Express* (Vol. 16, Issue 22, pp.18417-18425 [2008]), presents new insight into the mechanism for nanoparticle enhancement of fluorescence. Phaneuf's group found that for nanowires or columns of the right dimensions it is possible to set up standing waves consisting of counter-propagating surface plasmons. The resulting fields at nearby fluorescent molecules are greatly enhanced over that for the incident light, creating a much larger fluorescent intensity. This knowledge should help in the design of highly efficient biomolecular sensors, with applications in medical screening and anti-bioterrorism technology.

Phaneuf's co-authors are his former advisee, **Sherman Guo** (Ph.D. '08); postdoctoral research associate **Julia J. Heetderks**; and former postdoctoral research associate **Hung-Chih Kan**, who is currently an associate professor at the National Chung Cheng University, Taiwan.

REDUCING OUR LEAD FOOTPRINT

A group of researchers led by Associate Professor **Ichiro Takeuchi** have discovered a new lead-free material, bismuth samarium ferrite (BSFO), for use in products ranging from biomedical imaging devices to airbag sensors to inkjet printers. If implemented commercially, it could replace a common lead-based material found in these and other electronic devices, keeping lead out of landfills.

While manufacturers have developed replacements for lead in many products, until now no commercial replacement existed for lead zirconate titanate ($Pb(Zr,Ti)O_3$, or PZT)—the material of choice for transducers, actuators, sensors, and microelectromechanical systems used in common electronic devices.

PZT is more than 40 percent lead, but it also has piezoelectric properties, which means it acts like a switch—it can either create a voltage when mechanical stress is applied to it, or it can deform its shape when voltage is applied. This behavior is used to create actuators, moving components in electronic devices that translate electrical input into motion to accomplish mechanical tasks, such as controlling the inkjet nozzles on a printer.

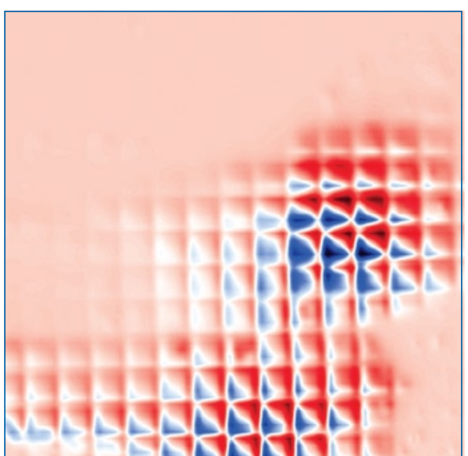
Takeuchi and his collaborators at the University of Maryland's Keck Laboratory for Combinatorial Nanosynthesis and Multiscale Characterization have created a new piezoelectric material, which in addition to enhanced piezoelectric properties can operate at higher temperatures and is easier to make than other proposed lead-free alternatives. These qualities make it a good candidate for a PZT replacement.

The discovery of the new BSFO compound was introduced in a recent issue of *Applied Physics Letters*. A provisional patent has been filed for the material.

Behind the discovery is a relatively new technique called combinatorial materials synthesis, 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.

According to Takeuchi, there are only a handful of laboratories capable of this kind of work in the world. The Keck Lab at the University of Maryland is unique among American universities.

Takeuchi starts with puck-like pieces of each of his ingredients, in this case bismuth ferrite and samarium ferrite. A precisely controlled laser blasts away molecular sized pieces of each puck, which are then deposited as thin films on a substrate. Each film contains varying proportions of the original ingredients. Multiple layers of the films combine to form continuously varying formulae for new materials with new properties, each one just a little different from the next. A collection of these tiny samples housed on a chip is known as a combinatorial library, and it allows researchers to study hundreds of materials in a single experiment.



AN EXAMPLE OF A COMBINATORIAL LIBRARY CHIP, PART OF A MAGNETIC SMART MATERIALS LIBRARY. EACH SQUARE HAS A SAMPLE WITH DIFFERENT PROPORTIONS OF ATOMS AND EXHIBITS DIFFERENT PHYSICAL PROPERTIES. THE PINK AREAS OF THE LIBRARY ARE REGIONS IN WHICH NO MAGNETIC PROPERTIES WERE DETECTED IN THOSE PARTICULAR SAMPLES.

As the samples were analyzed the group found that enhanced piezoelectric properties always occurred in instances where their atomic-scale structures were on the verge of changing from one crystal structure to another—i.e., near a phase boundary.

"A material like this is kind of teetering on the edge," Takeuchi explains. "If you apply just a little force or an electric field to it, the molecular structure rearranges, and the material changes structure. The ability to snap between these two phases based on external stimulus makes it perfect for use as switches or actuators in electronic devices. The fact that our version is as responsive as its lead-based counterpart is a huge bonus."

Takeuchi says products that use the new compound could hit the market in about five years.

The lead-free piezoelectric compound research is currently funded by the Keck Foundation, the National Science Foundation Materials Research Science and Engineering Center, and the Army Research Office.

Takeuchi's collaborators include alumni **Shigehiro Fujino** and **Sung-Hwan Lim** (both Ph.D. '08); former postdoctoral fellow **Makoto Murakami**; Materials Science and Engineering professors **Manfred Wuttig** and **Lourdes Salamanca-Riba**; and University of New South Wales (Australia) faculty **Varatharajan Anbusathaiah** and **Valanoor Nagarajan**.

For more information, see "Combinatorial discovery of a lead-free morphotropic phase boundary in a thin film piezoelectric perovskite." Applied Physics Letters 92, 202904 (2008).

ANKEM BONE IMPLANT INVENTION PROMOTED BY OFFICE OF TECHNOLOGY COMMERCIALIZATION

Professor **Sreermamurthy Ankem** has developed a new, patent-pending implant fabrication technique that promotes a stronger implant/bone interface, resulting in an increase in the life of the implant

KOFINAS' AND JANIAK'S INTELLIGENT PACKAGING POLYMER, WHICH TURNS FROM CLEAR TO COLORED IF BACTERIAL CONTAMINATION IS DETECTED.

and a reduction in costs and patient stress. Licensing opportunities are being offered by the university's Office of Technology Commercialization (OTC).

The surfaces of bone-implant joints are rough, which allows the patient's bone cells to attach to them more easily and create a bond between the bone and the artificial joint. Ankem's new fabrication method involves creating micropores in the rough surface of the implant, producing a much greater surface area in the same space for bone cells to attach to, resulting in a stronger bond and an increased functional lifespan for the joint. The new method adds little cost to the manufacturing process and is extremely economical when measured against the cost of additional surgeries. According to Ankem, his invention also has broader applications, and can be used to join any two surfaces with increased bond strength. To date, a metal implant device surface has been fabricated with micropores with a categorized nano-roughness.

Ankem's proposal for the invention, "Microporous Bone-Implant Joints" was a finalist in the campus OTC's annual Invention of the Year awards.

JANIAK/KOFINAS MIPS TECHNOLOGY WINS AWARDS, INDUSTRY ATTENTION

Two molecularly imprinted polymer (MIP) technologies and a startup company created by graduate student and Fischell Fellow **Dan Janiak** and his advisor, Fischell Department of Bioengineering Professor and MSE affiliate professor **Peter Kofinas**, won two major university awards in 2008. The research and development of the new materials is being conducted in Kofinas' Functional Macromolecular Laboratory.

In April, a MIP developed in collaboration with Associate Professor **James Culver** (University of Maryland Biotechnology Institute) capable of filtering viruses from the blood was named the Outstanding Invention of the Year in the Life Sciences category of the University's Office of Technology and Commercialization's annual awards. The technology, often referred to as the "virus sponge", takes the form of a highly absorbent, water-insoluble polymer hydrogel that resembles firm gelatin. The gel is imprinted with a specific virus' shape. When molecules of that target virus are filtered though the gel, they—and only they—fit snugly into the imprint cavities and are trapped. The polymer is compatible with dialysis, hemodialysis, and blood analysis systems already available in hospitals and clinics, providing an easy and cost-effective means of converting existing equipment into systems capable of the direct removal of viruses from the bloodstream. Different versions of the polymer can be synthesized to address a variety of illnesses. While not a cure, it should aid in treatment and reduce symptoms. Link Plus Corporation, a biotechnology company located in Columbia, Md., has been granted an exclusive license to the technology.

In May, Intelligent Packaging Systems (IPS), a startup created by the pair that utilizes another of their MIPs-based technologies, took first place in the Faculty and Graduate Student Division of the Maryland Technology Enterprise Institute's 2008 $50K Business Plan Competition. The contest promotes the commercialization of innovative ideas and University-created technologies by offering faculty, students, and alumni prizes for the best new venture plans. Kofinas and Janiak received $15,000 in prize money to continue the development of their company.

IPS manufactures flexible polymer coatings that change color upon the detection of foodborne bacteria such as *E. Coli,* Salmonella, or Listeria. IPS's coatings can be incorporated into any existing food packaging, providing both producers and consumers of a wide variety of foods, such as beef, poultry, pork, fruits, vegetables, juices and dairy products, with a reliable method of identifying contaminated products.

COLLABORATION ON COPOLYMERS BETWEEN NIST AND U-MD. IN THE NEWS

A collaborative research project being conducted with the National Institute of Standards and Technology (NIST), IBM and the University of Maryland is being discussed on a variety science-, nanotechnology-, and semiconductor-oriented news web sites, including *Phyorg.com* and *Science Daily.*

The work involves the use of block copolymers to form arrays and patterns that can used as the basis for electronic components and potentially store terabytes of memory in an area roughly the size of today's USB memory sticks. It is believed that novel materials like these will be the basis of the next generation of smaller, faster electronics.

The team has made progress in how to control the block copolymers' self-assembly, so they produce consistent, aligned and well-formed nanostructures with particular qualities; and in creating vertical nanostructures.

Sangcheol Kim, a U.-Md. postdoctoral research associate with MSE Professor and Chair **Robert M. Briber**, works on the project at NIST with co-authors **R. Jones** (NIST), **K. Yager** (NIST), **X. Zhang** (NIST), **A. Karim** (NIST) and **H. Kim** (IBM).

NANOSCALE THERMOMETRY: NEW IMAGING TECHNIQUE

Assistant Professor John Cumings

Knowing temperature at the nanoscale (<100nm resolution) is a major challenge for both science and technology. Our group–including including postdoctoral research associate **Todd Brintlinger** and graduate students **Yi Qi** (Materials Science and Engineering) and **Kamal Baloch** (Chemical Physics)—in work published recently in the *Journal of Nano Letters* and performed in collaboration with Professor **David Goldhaber-Gordon** at Stanford University—has invented a method to do so using a transmission electron microscope (TEM) and melting transitions in nanoscale metal islands. With the islands acting as distributed, local, passive thermometers, the TEM can be used to map absolute temperature over the entire field-of-view. The technique works in both active and passive devices, and is naturally tailored to measurements on nanowires, nanotubes, and other nanoscale materials.

Traditionally, thermal microscopy is performed by detecting infrared radiation with far-field optics, where resolution is limited by wavelength. Using electrons, smaller wavelengths and higher resolution are possible. An additional obstacle in nanoscale thermometry is accounting for the effect of the probe on the system. Probe-system equilibrium, a necessary condition for temperature to be well-defined, is thus a further requirement along with high resolution. Here, small metal islands are ideally suited to meet this requirement because they combine a small probe size (the diameter of the island) with an intrinsically equilibrium phenomenon (liquid/solid transition).

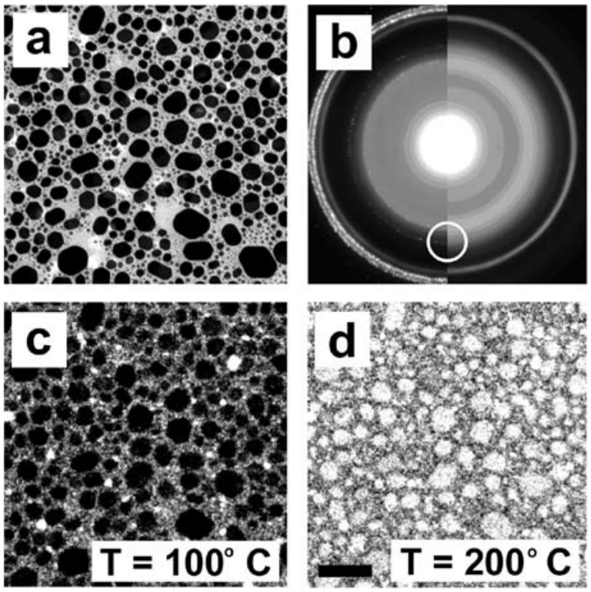


FIG. 1

First, metal islands are deposited on one side of an electron-transparent silicon nitride membrane, loaded into a stage that allows heating inside the microscope, and inserted in the TEM. To image the liquid/solid phase transition, the TEM is used in dark-field mode such that liquid islands appear bright, while solid islands appear dark. This is seen in Figure 1 (scale bar = 1μm), where a) shows the bright field image of indium islands while parts b) and c) show the dark field image for the solid and liquid islands, respectively. This contrast is produced by careful positioning of the objective aperture at the point between the sharp solid ring and the diffuse liquid one, represented by the white circle in Fig. 1b.

To perform electron thermal microscopy, a system with unknown thermal characteristics is placed on the other side of the silicon nitride membrane. The membrane with metal islands on one side and an electrically active device is then inserted into the TEM with a different stage, custom built by our group at the University of Maryland, for *in situ* voltage biasing. By applying power to the active devices, nanoscale thermal gradients can be produced and characterized by the metal islands. To demonstrate and calibrate the technique, the initial system chosen for study is palladium "heater wires", fabricated in the FabLab using standard electron beam lithography. A schematic of the wires and islands is seen in Fig. 2a, in perspective, top and side views. A bright field image of an actual device is seen in Fig. 2b. Again, voltage biasing the wires creates Joule heating which then produces local temperature gradients on the nanoscale (~10K/μm). Using the dark-field imaging outlined in Fig. 1, a map can be assembled in which the voltage required to melt an island is represented by color, seen in part c).

Figure 2d depicts modeling of the device using finite-element analysis with colors taking the same meaning as in Fig. 2c. In our model, temperature is given by:

$$\nabla \cdot (K \nabla T) + \text{Power} = 0 \qquad (1)$$

where K is the local thermal conductivity, T is the temperature, and Power is given by,

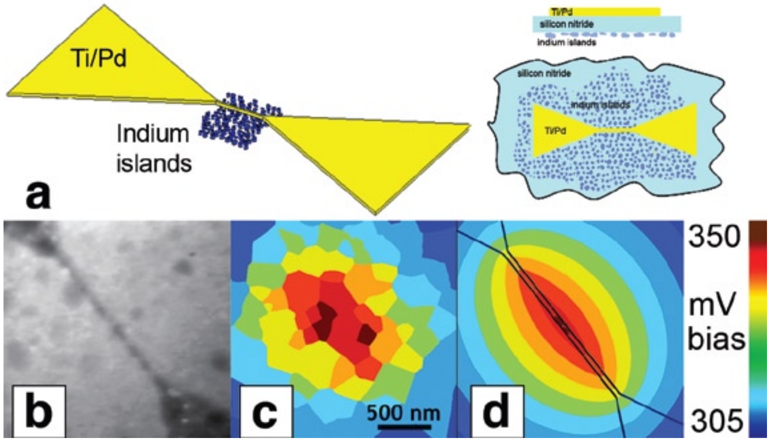


FIG. 2

$$\text{Power} = \sigma \,|\nabla V|^{2}. \qquad (2)$$

Here, V is the electric potential, and σ is the electrical conductivity. The temperature dependence of σ is given by:

$$\sigma = \sigma 0 \,(1 + \alpha \,\Delta T)^{-1}, \qquad (3)$$

where $\sigma 0$ is the room temperature value and α is the temperature coefficient of resistivity. Potential and conductivity are governed by the steady-state equation:

$$\nabla \cdot (\sigma \cdot \nabla V) = 0. \qquad (4)$$

To test the model we leave thermal conductivity of silicon nitride as a free parameter. The lowest voltage needed to initiate melting matches the experimental value when we set the modeled thermal conductivity of silicon nitride to be $3.6^{+0.5}_{-0.1}$ W/m·K. (The asymmetric uncertainty stems from melting point suppression.) This value is then used to produce the thermal map shown in Fig. 2d.

With measurements and modeling for a known system completed, the "heater wire" can be replaced with an unknown material, nanotubes and nanowires being suitable initial candidate materials. These devices can be thermally characterized during electrical operation. This is a natural advantage to the technique as so many nanomaterials are proposed as elements to complement existing electronic device architectures. The heater wire can also be left in position, with passive nanomaterials placed in the vicinity to see how their presence affects the resulting thermal maps.

References:

Todd Brintlinger, Yi Qi, Kamal H. Baloch, D. Goldhaber-Gordon, and John Cumings, Electron Thermal Microscopy, Nano Letters, 8(2), 582 (2008).

invitedLECTURES

A SELECTION OF INVITED LECTURES BY MSE FACULTY IN 2008-09

Mohamad Al-Sheikhly

"Recent and Future Trends in Electron Beam Applications for Nano and Advanced Technologies," The Third Electron Beam Workshop, Taejon, Korea, March 2008.

"Synthesis and Modification of Functional Polymer Nano-hydrogels Using Pulsed Electron Beam," University of Kanazawa, Japan, August 2008.

"Radiation-Synthesized Iron Ionomers based on Copolymers of 2-Ethylhexyl Acrylate and Acrylic Acid," The 2nd Asia-Pacific Symposium on Radiation Chemistry, Tokyo, Japan, 2008.

"Kinetics of Reductive Remediation of Polychlorinated Biphenyls (PCBs) Induced by Electron Beam Irradiation," The International Meeting on Radiation Processing, IMRP–London, September 2008.

Sriramamurthy Ankem

"Recent Advances in Twinning," with P.G. Oberson. International Symposium on Plasticity, Kona, Hawaii, 2008.

Aris Cristou

"Gallium Nitride Semiconductor Heterostructures," University of Crete Physics Colloquium, 2008.

John Cumings

"Artificial Kagome Ice." American Physical Society March Meeting, New Orleans, La., March 2008.

Isabel Lloyd

"Microwave Processing of Dielectrics for High Power Microwave Applications," with Y. Carmel, O.C. Wilson, Jr., and G.-F. Xu. Symposium on Advanced Dielectric Materials and Electronic Devices, Materials Science & Technology (MS&T), Pittsburgh, Pa., October 2008.

Gottlieb Oehrlein

"Studies of Plasma-Polymer Interactions for Nanoscale Patterning of Materials," 6th EU–Japan Joint Symposium on Plasma Processing, Okinawa, Japan, 2008.

"Investigations of Plasma-Polymer Interactions For Nanoscale Patterning of Materials," AVS International Symposium, Boston, Ma., November 2008.

Alexander Roytburd

"Epitaxial Self-Assembly of Multiferroic Nanostructures," International Symposium on Integrated Ferroelectrics, Singapore, June 2008.

"Domain Evolution in Ferroelectric and Ferromagnetic Graded Multilayers and Films," International Congress on Materials Science, Cancun, Mexico, August, 2008.

Joonil Seog

"Understanding Molecular Mechanisms in Biology by Measuring Small Forces," The International Workshop on Emerging Materials & Active Polymer Patterning, Seoul, Korea, November 2008.

Ichiro Takeuchi

"Multiferroic Devices," Winter School on Multiferroics, POSTECH, Pohang, Korea, December 2008.

"Multiferroic Devices," MRS Fall Meeting, Symposium on Smart Materials and Systems, Boston, Ma., November 2008.

"Combinatorial Approach to Functional Materials," Gordon Research Conference on Chemistry at Interfaces, Waterville Valley Resort, N.H., July 2008.

Manfred Wuttig

"Polymer Templated Magnetoelectrics," Albrecht-Christian Universitaet, Kiel, Germany, August 2008.

"Elasticity of Magnetic Shape Memory Alloys," Krumhansl Symposium, University of Osaka, Japan, October 2008.

ICHIRO TAKEUCHI

TAKEUCHI SELECTED FOR SPECIAL NAE SYMPOSIUM

Associate Professor **Ichiro Takeuchi** was among 100 of the nation's most outstanding young engineers invited to attend the National Academy of Engineering's (NAE) U.S. Frontiers of Engineering Symposium in Albuquerque, New Mexico, in September 2008. The annual symposium is a three-day meeting that brings together a select group of young engineers (aged 30-45) from industry, academia, and government to discuss pioneering research in a variety of fields, foster new collaborations, and share new approaches and techniques. Through both formal sessions and informal discussions, the meetings have proven an effective mechanism for the establishment of cross-disciplinary and cross-sector contacts among future engineering leaders. Although the emphasis is on new technology, participants are strongly encouraged to share their experiences in the development and deployment of products in industry.

This year's symposium covered a variety of topics including nanoelectronic devices, cognitive engineering, drug delivery systems, and the counter-proliferation of weapons of mass destruction.

Takeuchi was nominated to participate in the NAE Frontiers Symposium by University of Maryland President **C.D. (Dan) Mote** and Clark School Interim Dean **Herbert Rabin**.

MARTÍNEZ-MIRANDA LEADS U.S. DELEGATION AT ICWIP

Associate Professor **Luz J. Martínez-Miranda** served as co-leader of the United States delegation to the Third International Conference on Women in Physics (ICWIP), held in Seoul, Korea in October 2008. The event is dedicated to celebrating the achievements of women in physics throughout the world, networking to establish new international collaborations, gaining skills for career success, and aiding the formation of active regional working groups to advance women in physics.

According to a study conducted by the American Institute of Physics, fewer than 15% of physicists worldwide are women. "The scarcity of women in physics, especially in leadership positions, is a problem for many countries," Martínez-Miranda explains. "They cannot benefit fully from women's ideas and approaches to improve their economic competitiveness or solve difficult problems in energy, health, and global sustainability. Women, men, institutions, and governments need to work together to encourage, educate, recruit, retain, advance, and promote more girls and women in physics and other science and technology professions." To that end, Martínez-Miranda and the ICWIP participants unanimously approved a resolution, originally presented at the 26th General Assembly International Union of Pure and Applied Physics in Tsukuba, Japan, that addressed these issues.

"Serving as a leader of the U.S. delegation was a great honor," Martínez-Miranda says of the experience. "A lot of physics departments either include a materials science program or are oriented toward materials science, which makes participation in this conference important for the materials scientists. We have a lot to contribute in the fields of interdisciplinary research and education.

"This conference offered me the opportunity to establish or re-establish international collaborations, particularly with colleagues in Latin America, and to attend a session on professional development that gave me many ideas as to where my career may take me."

Martínez-Miranda believes the ICWIP events will ultimately have a positive effect on female leadership in all fields of science and technology. Since the first ICWIP in 2002, most of the countries who sent delegations have made progress in attracting girls to physics, increasing the number of physics degrees awarded to women, and promoting women physicists.

BRIBER RE-APPOINTED MSE CHAIR

The Department of Materials Science and Engineering extends its congratulations to Professor **Robert M. Briber**, who accepted Clark School Interim Dean **Herbert Rabin**'s invitation to continue in his role as Department Chair for a second term, effective July 1, 2008.

In a letter sent to department faculty and staff, Rabin praised Briber's first term as Chair: "[Professor] Briber has done an outstanding job as Department Chair," he wrote. "He has provided strong and effective leadership to address [issues] and to steer the Department on a path toward excellence. The [review] committee noted that under his leadership, the Department has grown in faculty size, staff size, quality of research, quality of services, amount of research funding, quality of space, availability of major laboratory facilities and quality of laboratories."

6 PROFESSORS NAMED 2008 RESEARCH LEADERS

Professors **Robert M. Briber**, **Ray Phaneuf**, **Oded Rabin**, **Gary Rubloff**, **Ichiro Takeuchi**, and **Manfred Wuttig** were among a group university faculty recognized at the 10th Annual Research Leaders Luncheon for their efforts in bringing sponsored research dollars to campus. For the third year in a row, Materials Science and Engineering Research Leaders represent at least one-third of the Department's full-time faculty. Their work covers a variety of fields and interests, including materials design and categorization, microscopy, nanoparticles, bioMEMs, nanopatterning, and thin films.

BANERJEE BRUCE

LONG WINS LUDO FREVEL CRYSTALLOGRAPHY SCHOLARSHIP

Graduate student **Chistian Long**, advised by Associate Professor **Ichiro Takeuchi**, was one of ten students nationwide selected for a 2009 Ludo Frevel Crystallography Scholarship Award. The award, granted by the International Centre for Diffraction Data (ICDD), is designed to support graduate students conducting research in crystallography-related fields. Long won for his proposal titled "Rapid Identification of Structural Phases in Combinatorial Thin-Film Libraries Using X-Ray Diffraction and Non-Negative Matrix Factorization."

This marks the third time Long and the Takeuchi Group have won an award for their work on data mining of combinatorial x-ray data. In 2005 and 2006 Long won Bruker AXS Excellence in X-ray Diffraction scholarships.

This work has been supported by NSF International Materials Institute on COSMIC, NSF MRSEC at U.-Md, ONR MURI on magnetostrictive materials, and NIST.

BANERJEE NAMED JOHN AND MAUREEN HENDRICKS ENERGY RESEARCH FELLOW, SELECTED FOR WINTER SCHOOL

Graduate student **Parag Banerjee**, advised by Maryland NanoCenter director and MSE professor **Gary Rubloff** has been named a John and Maureen Hendricks Energy Research Fellow. Banerjee works in the Laboratory for Advanced Materials Processing, where he focuses on energy harvesting and energy storage devices, including batteries, solar cells, supercapacitors, and nano-fabrication. His fellowship will support a new energy-related research direction he has proposed.

The fellowship program was established by the John and Maureen Hendricks Charitable Foundation to support the efforts of the University of Maryland Energy Research Center (UMERC), a multidisciplinary initiative that focuses on advancing the frontiers of energy science and technology, particularly forward-looking approaches to alternative energy generation and storage.

Benerjee's research efforts in 2008 were also given a boost when he was selected to attend the 2008 International Center for Materials Research (ICMR) Winter School at the Jawaharlal Nehru Center for Advanced Scientific Research in Bangalore, India in December. The competitive fellowship included a full travel grant and expenses for the week long program.

The 2008 Winter School connected young researchers with leading scientists working in the fields of complex organic and inorganic materials. Particular emphasis was given to new carbon based materials and functional oxides used in energy generation and storage, including the latest solar cells and batteries.

BRUCE ATTENDS US-AUSTRALIAN PROGRAM IN SYDNEY

Graduate student **Bobby Bruce**, advised by Professor **Gottlieb Oehrlein**, attended the "Fostering U.S.-Australian Research Collaborations in Materials Program" held in Sydney, Australia in July 2008. The program was part of the 2008 International Conference on Electronic Materials (IUMRS-ICEM). The goals of the program were to connect U.S. and Australian graduate students and their advisors in order to establish collaborations on materials-based research, and to provide students with project leadership training. The program was organized by the Materials Research Institute at Northwestern University and the Australian Research Network for Advanced Materials (ARNAM), and sponsored by the NSF (National Science Foundation) and ARNAM. Bruce was one of only 12 American students nationwide selected to attend.

Before traveling to Australia, Bruce corresponded via e-mail with his Australian collaborator, **Amanda Rider**, advised by Professor **Ken Ostrikov** at the University of Sydney. Rider's research focuses on a numerical simulation approach to modeling nanoassembly of quantum dots on plasma-exposed surfaces.

After arriving in Australia, Bruce spent a week attending talks at the IUMRS-ICEM, while preparing a proposal with Rider and another U.S-Australian team in the program. He also had the opportunity to present the research he conducts at U.-Md. in Oehrlein's Laboratory for Plasma Processing of Materials in an IUMRS-ICEM poster session. His poster was titled "Investigation of Plasma-Polymer Interactions for Patterning Nanostructures."

At the end of the conference Bruce and his collaborators presented their final proposal, which outlined the development of a novel polymer scaffold-on-quantum dot array biosensor. Bruce and Rider thought of an approach to fabricate an array of quantum dot squares with different properties by lithographic patterning and surface modification and subsequent quantum dot growth by plasma. Their fellow collaborators contributed a proposal to use aligned polymer fibers deposited by electrospinning to provide a scaffold for cell growth on top of the quantum dot array. Absorption and reemission of light from colloidal quantum dots within cells would provide a signal that

ALSO IN STUDENT NEWS:

SENIOR MAELING TAPP WON THE A. JAMES CLARK SCHOOL OF ENGINEERING HONORS PROGRAM'S MOST OUTSTANDING RESEARCH AWARD FOR HER PROJECT TITLED "CHARACTERIZATION OF MAGNETIC THIN FILMS FOR THE MEASUREMENT OF MAGNETIC PHASE CONTRAST." TAPP IS NOW A GRADUATE STUDENT AT GEORGIA TECH.

alumniNEWS

Walter Chappas (M.S. '77 and Ph.D. '79, nuclear engineering) has been promoted to Chief Technology Officer at PetroBeam, Inc., a developer of high energy electron beam processing techniques used to upgrade heavy oil and bitumen. A leader in the fields of radiation chemistry and radiation processing, he has been a consultant to the United Nation's International Atomic Energy Agency and a technical advisor to the governments of Saudi Arabia, Mexico, Sri Lanka, and Ecuador. Before his career in industry, Chappas worked at U.-Md. in the 1980s, serving as the Director of the Electron Linear Accelerator Facility, the Associate Director of the Laboratory for Radiation and Polymer Science, and the Director for Radiation Facilities.

Sebastian Engelmann (Ph.D. '08) is working in the Reactive Ion Etching (RIE) group in the department Advanced Materials and Process Science in the IBM Research Division at the T.J. Watson Research Center in Yorktown Heights, N.Y. Sebastian will work on developing plasma etching processes to support current and future research projects for exploratory device research beyond 15nm technology node and/or beyond CMOS era. He can be reached at suengelm@us.ibm.com. "Guess I am continuing to follow in Professor Oehrlein's footsteps!" he told us.

Kevin Greenaugh (Ph.D. '98, nuclear engineering), Director of the Office of Military Application and Stockpile Operations of the National Nuclear Security Administration, and part-time Howard University professor, was the subject of an article titled "The World's Nuclear Guardian" featured in *U.S. Black Engineer and Information Technology,* Vol. 32 No. 3. He discussed the importance of deterrence as well as the benefits to society that have come from the development of nuclear weapons, including supercomuters capable of analyzing energy needs and tracking natural disasters, and the design of peaceful applications of nuclear technology.

Mailing Tapp (B.S. '08) has received a National Science Foundation Graduate Research Fellowship, the oldest and one of the most competitive of its kind. The award includes a three-year annual stipend of $30,000, a $10,500 cost of education allowance for tuition and fees at an accredited U.S. or foreign university, and a one-time $1,000 travel allowance. Tapp is currently pursuing her Ph.D. at the Georgia Institute of Technology, where she is working on the design of an implantable biomaterial to be used in reconstructive surgeries for ligaments and tendons. Her proposed shape memory hydrogel polymer network could improve soft-tissue reattachment procedures by providing more effective mechanical and biological fixation.

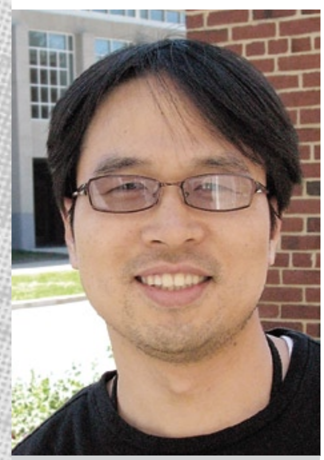
Nagarajan "Nagy" Valanoor (Ph.D. '01) is tenured academic faculty at the University of New South Wales in Sydney, Australia, where he holds an Australian Research Fellowship, awarded by the Australian Research Council. He continues to work in ferroelectrics and electronic oxides, areas of interest he picked up while earning his doctorate. He also still collaborates with researchers at Maryland, especially Professor Takeuchi's research group. At UNSW he has established advanced SPM and thin film capabilities, and his research has focused on two key issues: size scaling ferroelectric thin films, and the synthesis of Pb-free, environmentally sustainable piezoceramics. These programs are funded by Australian Research Council's Discovery Project. Nagy invites fellow Materials Terps to Sydney, "where weekends are best spent having barbecues on white sandy beaches in the company of fantastic Aussie wines."

studentNEWS *continued*

would be picked up by the quantum dot array, providing a dynamic map of cell activity in the polymer scaffold. The resulting novel biosensor has potential use for cancer cell detection and as a monitor for tissue cell growth. The development of a quantum dot array using their techniques would also have potential applications in sensor devices, solar cells, and display technologies.

In addition to the conference, Bruce visited a variety of Australian research institutions, including the University of Sydney, University of New South Wales, and the Australian Nuclear Science Technology Organization (ANSTO), a facility that uses nuclear reactors for materials characterization purposes.

Bruce also made sure to take advantage of opportunities to sightsee in Australia. He dined on a gourmet dinner that included kangaroo fillet and emu carpaccio on the IUMRS-ICEM conference dinner cruise, saw the Sydney Opera House up close, and visited the kangaroos and koalas at the zoo.



SANG HAK SHIN

"I am grateful to U.-Md. for sponsoring me and NSF for enabling my trip to Australia," he said. "I am happy to have met and worked with such great people and hope a potential collaboration will develop so I can continue working with them."

SHIN SELECTED FOR SCHOOL ON NEUTRON, X-RAY SCATTERING

Graduate student **Sang Hak Shin**, advised by MSE Professor and Chair **Robert M. Briber**, was selected to attend the National School on Neutron and X-ray Scattering. The competitive, all-expenses-paid, two-week program was held at Argonne National Laboratory and Oak Ridge National Laboratory in Fall 2008.

The program's goal was to educate graduate students on the use of major neutron and x-ray

facilities in their research. It included lectures presented by scientists from academia, industry, and the government on scattering principles and the characteristics of sources, and seminars on the use of various scattering techniques. Students also conducted four hands-on experiments at Argonne's Advanced Photon Source in Illinois, and at Oak Ridge's Spallation Neutron Source and High Flux Isotope Reactor facilities in Tennessee.

GERASOPOULOS PAPER NAMED JOURNAL "HIGHLIGHT"

A paper first-authored by graduate student **Konstantinos Gerasopoulos** was selected by the *Journal of Micromechanics and Microengineering (JMM)* to be featured in its "Highlights of 2008," a showcase of articles chosen by the *JMM*'s editorial board and publishing team that best represent the top contributions published in the journal in the past year. The special collection is widely promoted and will available for free downloading through 2009.

The paper, "Nanostructured nickel electrodes using the Tobacco mosaic virus for microbattery applications," explains how nanostructured nickel–zinc microbatteries can be developed using the tobacco mosaic virus (TMV). The TMV is a high aspect ratio cylindrical plant virus which has been used to increase the active electrode area in MEMS-fabricated batteries. Genetically modifying the virus to display multiple metal binding sites allows for electroless nickel deposition and self-assembly of these nanostructures onto gold surfaces. The paper presents the integration of this biotemplating approach into standard MEMS micromachining for the development of microfabricated batteries. The TMV-modified devices exhibited a six-fold increase in battery capacities compared to devices with planar electrode geometries.

Gerasopoulos' co-authors were postdoctoral fellow **Matthew McCarthy**, **Elizabeth Royston** (U.S. Patent and Trademark Office), Associate Professor **James N. Culver** (University of Maryland Biotechnology Institute) and Associate Professor **Reza Ghodssi** (Electrical and Computer Engineering/Institute for Systems Research).

recentGRADUATES

2008-2009 B.S. GRADUATES

Grant Hatcher
Pavel Kotlyarskiy
Ryan Douglas Mulholland
Alvin Wilson

2008-2009 M.S. GRADUATES

Janelle Critchfield
Michael Kasser
Adam McClure
Daniel Pines
Bryan Jason West
Sheng-Yu Young

2008–2009 PH.D. GRADUATES

Sebastian Engelmann: Plasma-Surface Interactions of Modified Polymers for advanced PR systems. Advisor: Oehrlein

Shigehiro Fujino: Combintorial Discovery of a Morphotropic Phase Boundary in a Lead-Free Piezoelectric Material. Advisor: Takeuchi

Dan Janiak: Molecular Imprinted Polymers for the Selective Recognition of Proteins. Advisor: Kofinas (Bioengineering)

Sung Hwan Lim: Synthesis and Characterization of Multi-ferroic Thin Films. Advisor: Salamanca-Riba.

Hiroyuki Oguchi: Combinatorial Investigation of Intermetallics Using Electron-beam Deposition. Advisor: Takeuchi.

Yi Qi: Aritifical Spin Ice As a Geometrically Frustrated System: Design, Visualization and Application. Advisor: Cumings.

Mey Saied: Effect of Glass Joins on Performance and Lifetime of Layered Ceramic Systems. Advisor: Lloyd.

Zhuopeng Tan: Self-Assembled Multiferroic nanostructures of PbTiO3-CoFe2O4. Advisor: Roytburd.

Xin Zhang: Synthesis and Characterization of low Flammability Polymer/Layered Silicate Nanocomposities. Advisor: Briber.

studentAWARDS

UNDERGRADUATE AWARDS FOR 2008-2009

Chairman's Outstanding Senior Award: **Ryan Mulholland**

Outstanding Materials Student Service Award: **Hilary Lane**

The Department of Materials Science and Engineering Student Research Award: **Christine Lau**

ALPHA SIGMA MU INDUCTEES:

Abbigale Boyle
Steven Crist
Michael Grapes
Karam Hijji
Alexander Kao
Stephen Kitt
Pavel Kotlyarskiy
Hilary Lane
Christine Lau
Ashley Lidie
Ryan Mulholland
Marshall Schroeder

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 IS AN ELECTRON MICROGRAPH OF CONCENTRIC SUPER PARAMAGNETIC (DARK) AND PARAELECTRIC (LIGHT) NANO-RINGS, PRODUCED BY PROFESSOR MANFRED WUTTIG AND HIS RESEARCH GROUP. THIS NANOCOMPOSITE IS FORMED BY MIXING PARAMAGNETIC AND PARAELECTRIC PRECURSOR MATERIALS WITH A DIBLOCK COPOLYMER AND THEN SPIN CAST AS A FILM. WITH APPROPRIATE ANNEALING THE FILM SELF-ASSEMBLES TO FORM THIS MULTI-FERROIC "NANO-ONION" THAT COULD PROVIDE THE BASIS FOR NEW TYPES SENSORS THAT ARE MORE SENSITIVE AND EASIER TO MANUFACTURE. YOU CAN LEARN MORE ABOUT CURRENT FACULTY RESEARCH INSIDE THIS ISSUE.

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

openHOUSE!

SPECIAL EVENTS FOR STUDENTS WHO WANT TO LEARN MORE ABOUT MATERIALS SCIENCE!

We are now hosting a fall open house for undecided freshman engineering majors and other students thinking of changing majors; and one or more spring open houses for prospective students and their families. Attendees learn about the discipline of materials science and engineering, career paths, our department and curriculum; meet faculty, staff and students; try hands-on demonstrations of materials in action; take lab tours; and apply for a special $2000 MSE Top Terp Department Scholarship or a $1000 First Year Scholarship!!

FOR MORE INFORMATION:

VISIT:
www.mse.umd umd.edu/openhouse

CONTACT DR. KATHLEEN HART:
hart@umd.edu

SEE IF WE'RE ONLINE! AOL IM:
mseatumd