FALL 2009

TECHTRACKS

MATERIALS SCIENCE AND ENGINEERING

A. JAMES CLARK SCHOOL *of* ENGINEERING

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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:

Wachsman Appointed Director of Energy Center, Joins MSE Faculty

Eric Wachsman, an expert on solid oxide fuel cells, has been named the University of Maryland Energy Research Center's (UMERC) first director. Professor Wachsman holds the William L. Crentz Chair in Energy Research, and has a joint appointment between the Department of Materials Science and Engineering and the Department of Chemical and Biomolecular Engineering. Most recently, he was a professor of Materials Science and Engineering at the University of Florida in Gainesville, where he spearheaded the creation of the Florida Institute for Sustainable Energy.

ERIC WACHSMAN

Wachsman is set to take the helm of one of the university's newest and most exciting centers, which is attracting faculty and students from throughout campus whose research addresses current and future energy needs and issues, including biofuels, batteries, fuel cells, policy, photovoltaics, nuclear technology, and energy storage.

Wachsman is passionate about energy research. "Energy may be the defining issue of this century," he says. "Our quality of life, standard of living, and security depend on it. The limited supply of fossil energy, its accelerated consumption, impact on global warming, and the dependence on supply from unstable countries are major U.S. economic and security issues."

These issues, he believes, can be addressed at UMERC. "I decided to come to the University of Maryland because I believe it has the expertise in not just energy technology, but also policy and climate change, which are necessary to create viable solutions," he says.

He envisions UMERC coordinating energy-related activities, research and collaborations throughout campus while developing a reputation beyond it. "UMERC has the potential to be the leading comprehensive energy research center in the nation, and my goal is that UMERC is recognized internationally for that expertise...that [it] is the first place that our government officials look to for help in driving the national energy policy agenda."

Wachsman has focused his career on developing advanced and efficient energy conversion devices and technologies, and is also interested in energy policy. His research,

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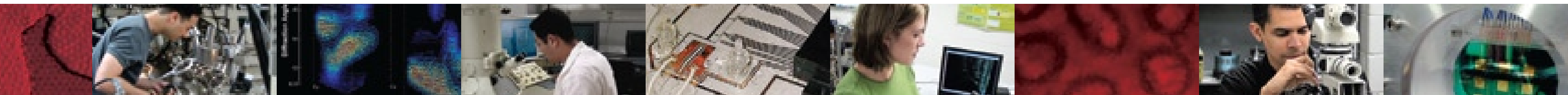


chair's MESSAGE

ROBERT M. BRIBER

A CRITICAL ISSUE THAT IS ON EVERYONE'S MIND THESE DAYS IS ENERGY. From buying gas at the pump to the halls of Congress, the topic of energy is being discussed everywhere. At the heart of some of the most exciting trends in energy research is the field of materials science and engineering. Many of the key enabling technologies that will lead to energy independence and sustainability are currently limited by the underlying materials. The efficiency and cost of solar cells, the energy storage capacity of batteries and supercapacitors, the reliability of fuel cells, and our ability to build nuclear fusion reactors are all constrained by the materials we currently have available. Exciting new breakthroughs are needed and at the core of many of these will be new materials.

In this issue we welcome to campus Professor **Eric Wachsman** from the University of Florida as the new director of the University of Maryland Energy Research Center (UMERC). He will be a faculty member in the Department of Materials Science and Engineering (MSE) with a joint appointment in the Department of Chemical and Biomolecular Engineering. Professor Wachsman's expertise is in solid oxide fuel cells, which builds on an area of existing strength in the A. James Clark School of Engineering. With his arrival, MSE will be right in the middle of some of the most exciting energy research in the country. And with the recently announced DOE Energy Frontier Research Center lead by Professors **Gary Rubloff** (MSE) and **Sang Bok Lee** (Chemistry & Biochemistry) (see pp. 3 and 7), nanostructures being developed by Professors **John Cumings** and **Ray Phaneuf** (see p. 4), the search for new superconductors with Professor **Ichiro Taekuchi** (see p. 5), and novel thermoelectric materials from Professor **Oded Rabin**, we're pushing the boundaries of science and technology.

Take a moment to visit the Department website and read through the news. Our students are winning awards and presenting their work at conferences across the country and around the world. Talented students like these need your support. Now more than ever, even a few hundred dollars can make the difference between a student obtaining a Terp education or not. We can help you find creative ways to give—for example, creating a unique scholarship in honor of a family member or friend. Please visit **www.mse.umd.edu/alumni/givetomse.html** to learn more.

The future of engineering depends on the underlying materials that form the building blocks of our modern society. Whether it's energy, microelectronics, nanotechnology or biotechnology, new advances are often set by the discovery of new materials and materials systems that allow these fields to move forward. Please encourage the potential future scientists and engineers you meet to think about materials science and engineering as a career—if they do they will be at the center of some of the most exciting developments that we will see in the next decade. The Department looks forward to hearing from you on these topics. Please be sure to stay in touch.

Robert M. Briber
Professor and Chair, MSE

WACHSMAN, continued from page 1

which he plans to continue at Maryland, includes the development of solid oxide fuel cells, gas separation membranes, solid-state gas sensors, the electrocatalytic conversion of CH_4, and the post-combustion reduction of NO_x using advanced ion conducting materials. He also has plans to teach courses on ionic transport in solids.

Wachsman holds a Ph.D. in materials science and engineering from Stanford University, and a B.S. in chemical engineering from the University of California at Berkeley. Prior to pursuing an academic career, he rose through the ranks from post-doctorate to senior scientist at SRI International, an independent, nonprofit research institute.

Wachsman is a Fellow of The Electrochemical Society and the past chair of its High Temperature Materials Division. In addition, he is editor-in-chief of *Ionics,* formerly an associate editor of the *Journal of the American Ceramic Society,* councilor of the Florida Section of the American Ceramic Society, and a member of the American Chemical Society, the International Society for Solid State Ionics and the Materials Research Society. He has more than 140 publications and eight patents on ionic and electronic transport in ceramics, their catalytic properties, and device performance.

Wachsman is also frequently invited to serve as a panelist on fuel cell and hydrogen energy research, ranging from the U.S. Department of Energy's "Fuel Cell Report to Congress" and "Basic Research Needs Related to High Temperature Electrochemical Devices for Hydrogen Production, Storage and Use," to the National Science Foundation's "Workshop on Fundamental Research Needs in Ceramics," NATO's "Mixed Ionic-Electronic Conducting (MIEC) Perovskites for Advanced Energy Systems," and the National Academies' "Global Dialogues on Emerging Science and Technologies."



researchNEWS

UMERC/NANOCENTER TEAM NAMED "ENERGY FRONTIER" CENTER

The U.S. Department of Energy (DOE) has awarded the University of Maryland an Energy Frontier Research Center (EFRC) as part of a major new program. The Center will be funded by a $14 million grant.

EFRCs are a means to enlist the talents and skills of the very best American scientists and engineers to address current fundamental scientific roadblocks to U.S. energy security. The centers will address these "grand challenges" in a broad range of research areas defined by the DOE Office of Science.

Led by A. James Clark School of Engineering Professor **Gary Rubloff** (joint, Department of Materials Science and Engineering and Institute for Systems Research) as director and Associate Professor **Sang Bok Lee** (Department of Chemistry & Biochemistry) as associate director, the University of Maryland EFRC enlists faculty from three colleges—the Clark School, Chemical & Life Sciences, and Computer, Math & Physical Sciences—who are also part of the University of Maryland Energy Research Center *(see related stories, p. 1 and at right)* and the Maryland NanoCenter.

The EFRC also includes planned collaborations with scientists from the University of Florida, Yale University, the University of California–Irvine, Sandia National Laboratories, and Los Alamos National Laboratory, including the Center for Integrated Nanotechnologies.

The Center will address a central goal of using nanotechnology to create new electrical storage technologies that store and deliver more power, charge faster, and will enable us to manufacture smaller, lighter batteries. The scientific objective of the project, titled "Science of Precision Multifunctional Nanostructures for Electrical Energy Storage," is to understand how nanostructures formed from multiple

continues next page

ABOUTumerc

Several of our stories this issue mention faculty members affiliated with the **University of Maryland Energy Research Center (UMERC)**. We'd like to take this opportunity to introduce you to this young, rapidly growing center with participating faculty from departments campus-wide—including Materials Science and Engineering.

Established in 2006, UMERC is a multidisciplinary initiative that focuses on the critical needs required to achieve energy sustainability and independence, as well as the need for more efficient small-scale portable power systems. The center is supported by approximately $10 million a year in Federal and private funding.

UMERC's approximately 50 faculty members are actively pursuing research in areas including biofuels, advanced solar energy conversion, fuel cells, electrochemical energy storage, next generation nuclear reactors, fusion, small-scale portable power for electronics and propulsion, energy efficiency, and energy policy and economics. UMERC faculty collaborate not only with each other but also with other universities (including Caltech, the University of Wisconsin, Yale, the Norwegian University of Science and Technology, and the Colorado School of Mines), Federal labs (including Los Alamos, Oak Ridge, NIST, and the Army Research Laboratory), industrial partners (including Ballard and Exxon-Mobil), and international institutions (including the Petroleum Institute). A complete list of the center's current projects can be found at **www.umerc.umd.edu/research**.

Professor **Greg Jackson** (Department of Mechanical Engineering) has served as UMERC's Steering Committee Chair and Interim Director since its founding, but will soon be handing the reins to UMERC's first director, Professor **Eric Wachsman** (see related story, p. 1). Jackson says he is excited about Wachsman's arrival.

"Dr. Wachsman builds on our growing strengths in electrochemical energy conversion," he says. "His international recognition for high-temperature electrochemistry and materials development really complements a lot of our efforts here at U-Md., including our Energy Frontier Research Center on electrical energy storage.He also brings great experience from his leadership at the Florida Institute for Sustainable Energy and this will no doubt help him in mobilizing the diverse and large group of energy researchers here at College Park."

Currently, a three-phase project is underway to create a new, centralized space and shared facilities for UMERC. The first phase, funded by a grant from the Department of Energy, The A. James Clark School of Engineering, the Office of the Provost, and Operations & Maintenance, will invest $2.3 million into the renovation of the exterior and 5000 ft^2 of lab space in the Engineering Lab Building, located behind Glenn L. Martin Hall. The second and third phases will renovate an additional 11,000–12,000 ft^2 in the building over two floors. Phase one is expected to be complete by September of 2010, and the entire project completed by September 2011. Plans are in place to equip the new facility's roof with solar panels and possibly wind turbines as well.

Wachsman says the new facilities should be "a locus of activity" for faculty and students engaged in energy research, not only in technology but also policy and societal issues. He expects the new center to feature shared user labs, the ability to showcase demonstrations of energy technologies developed at the university, conference rooms, and offices for faculty and students.

UMERC is administered by the A. James Clark School of Engineering. It includes faculty from all Clark School departments, as well as from the College of Agriculture and Natural Resources, the College of Chemical and Life Sciences, the College of Computer, Mathematical and Physical Sciences, the School of Public Policy, and the College of Behavioral and Social Sciences.

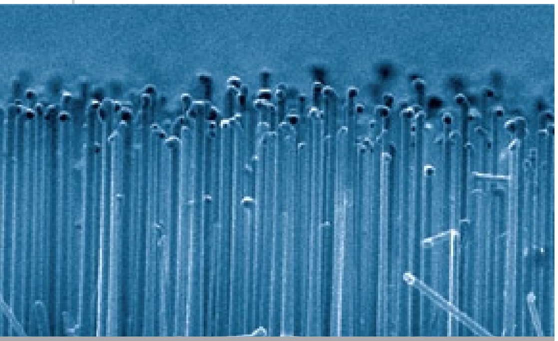
EFRC, continued from page 3

materials behave and explore their potential for a new generation of electrical energy storage technology.

In a recent statement issued by the DOE, Rubloff explained the Maryland EFRC's research path:

"Nano-structured electrodes offer vastly greater surface area and smaller path lengths for motion of electrons and ions, increasing the rate at which charges can be moved and stored, leading to much increased power and energy density and faster charging. By using materials in precisely built nanostructures, energy storage devices will hold more energy, will charge or deliver electricity faster, and remain stable for longer lifetimes, while reducing space and weight."

For more information about Energy Research Centers, see: www.sc.doe.gov/bes/EFRC.html.



A PHALANX OF SEMICONDUCTOR NANOWIRES SYNTHESIZED BY EFRC COLLABORATOR TOM PICRAUX USING A NEW TEMPLATED NANOFABRICATION TECHNIQUE. NANOWIRES LIKE THESE MAY EVENTUALLY SERVE AS IDEAL LITHIUM STORAGE MATERIALS FOR THE NEXT GENERATION OF BATTERY TECHNOLOGY.

CUMINGS LEADS EFRC NANOWIRE TEAM

Assistant Professor **John Cumings** will serve as the group leader of one of the University of Maryland Energy Frontier Research Center's (EFRC) four research thrusts that seek to substantially improve the storage capacity of lithium ion batteries *(see related story, p. 3)*. Together with co-leader **Tom Picraux** of Los Alamos National Laboratory, Cumings will lead Thrust B, "Self-Healing Nanostructures for Electrodes," which will explore the use of silicon nanowires in the batteries' anodes.

JOHN CUMINGS

Currently, lithium-based batteries do not see widespread use in cars and other machinery for several reasons, including their low discharge (power output) rates, that they are not considered safe enough for highway use, and that some of the materials used to make them have a relatively low level of sustainability. The Maryland EFRC hopes to address these problems.

Cumings and his collaborators will focus on the anode (the energy storage portion) of the battery. The most common storage material used in lithium battery anodes is carbon. One lithium atom can be stored for every five or six carbon atoms. If silicon is used in the anode, however, the ratio changes drastically: four lithium atoms for each silicon atom. Unfortunately, simply switching materials isn't enough to create a solution.

"The problem is that when you try to store that much lithium, the silicon expands, and when the lithium is removed, the silicon collapses and crumbles after only a couple of charging cycles," Cumings explains. That's what happens at the micro- and macro-scales, but it may not be the case if the team thinks small. This is because materials' behavior changes at the nanoscale, sometimes so dramatically that the usual rules no longer apply.

"If we can nanostructure the silicon to expand in some dimensions while not in others, it could keep its structure during the cycling of the battery," says Cumings. "Using silicon nanowires is one possible way to realize that—they will be stronger and more flexible."

Scientists have known about the high lithium-capacity of silicon for over thirty years, but it's only now that nanotechnology has caught up enough to make silicon battery electrodes a possibility. Cumings' knowledge of the mechanics and properties of nanoscale structures, combined with his expertise in testing materials in realtime and *in situ* in transmission electron microscopes will help give his group the ability to directly observe the nanowires and record how their properties change before and after lithium insertion.

In addition to Cumings, the EFRC Thrust B team includes Assistant Professor **Chunsheng Wang** (Department of Chemical and Biomolecular Engineering); Assistant Professor **Yuhuang Wang** (Department of Chemistry & Biochemistry), Dr. **Thomas Picraux** (CINT Chief Scientist, Los Alamos National Laboratory), and Professor **Mark A. Reed** (Departments of Electrical Engineering and Applied Physics, Yale University).

PROFESSORS PRESENT AT SUSTAINABILITY WORKSHOP

Professors **Gary Rubloff** and **Ichiro Takeuchi** presented research aimed at improving electronics and energy storage at the first A. James Clark School of Engineering Sustainability Workshop, held in honor of Earth Day. The workshop invited faculty, students and guests from industry and government to present and propose ways to maximize technology's positive impact on the long-term availability of natural resources, while minimizing its negative impact.

Rubloff introduced the audience to one of his group's current projects on energy storage devices. While wind and solar are attractive alternatives to fossil fuels, the technology to store the electrical energy they generate is inadequate. Rubloff and his collaborators have created collections of millions of identical nanostructures with shapes tailored to transport energy as electrons rapidly to and from the very large surface areas where they are stored. The resulting device is not only more efficient than those currently on the market, but can also be much smaller and inexpensive to produce.

Takeuchi addressed the issue of the need to find replacement manufacturing materials for those that have been shown to have a negative effect on the environment or human health. He explained how combinatorial materials synthesis has allowed his research group to pursue that goal faster and more efficiently in the quest to completely remove lead from electronics. Most recently, he explained, they discovered a lead-free alternative to lead zirconate titanate ($Pb[Zr,T]O_3$, or PZT) a widely used piezoelectric material.

For more information on Rubloff and Takeuchi's research, see "Better Energy Storage Options" and "Reducing Our Lead Footprint" in the Spring 2009 issue of Techtracks, *available online at www.mse.umd.edu/newsletters.*

$2M DARPA GRANT FOR NEW MAGNETOMETER TECHNOLOGY

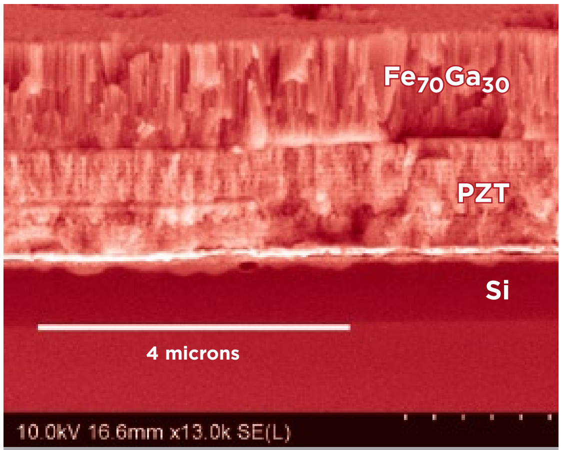
Professor **Ichiro Takeuchi** has received a three-year, $2 million grant from the U.S. Defense Advanced Research Projects Agency (DARPA) for a proposal titled "MEMS/NEMS Based Multiferroic Magnetic Sensors for Sub-Femto Tesla Detection." The project proposes a new way to construct magnetometers, devices used to detect small magnetic fields and analyze materials and other phenomena, using multiferroic thin film structures. DARPA is interested in developing the technology to expand our ability to detect threats including concealed weapons and explosives.

Takeuchi's collaborators on the project are Professor **Hong Tang** (Departments of Electrical Engineering and Mechanical Engineering, Yale University), an expert in the field of nanoelectromechanical devices; and **Star Cryoelectronics**, a leading manufacturer of highly sensitive magnetometers used in biomedical devices, materials evaluation, and geophysical exploration.

Existing magnetometers able to achieve high levels of sensitivity, known as superconducting quantum interference devices (SQUIDs), must operate at cryogenic temperatures, which requires a large and costly setup. As a result, many applications that would benefit from high-sensitivity magnetometry, such as weapons detection and certain kinds of biomedical imaging, are not possible outside of a well-equipped lab.

The Takeuchi team's design is based on multiferroic thin films, composite materials consisting of two layers, one piezoelectric and one magnetic. Because they can be produced at the micro- or nanoscale, they can be used to create extremely large arrays of microelectromechanical (MEMS) or nanoelectromechanical (NEMS) cantilevers (springboard-like devices) on a chip. "When you make the devices that small," says Takeuchi, "and are able to pack so many of them together, you get high sensitivity, a better signal-to-noise ratio, better signal amplification, and better performance." This project marks the first time anyone has sought to fabricate and demonstrate devices of this kind.

If successful, magnetometers based on the new design would be far less expensive to use and maintain than SQUIDs, and the combination of their size and ability to operate at room temperature would make the technology more portable and versatile in the field.



CROSS SECTIONAL MICROGRAPH OF THE MULTIFERROIC DEVICE. IT CONSISTS OF A MAGNETIC MATERIAL CALLED FeGa AND A PIEZOELECTRIC MATERIAL CALLED PZT ON A SILICON BASE.

Results so far indicate that the new devices could also be very sensitive. SQUIDs measure magnetic fields, described in units called Teslas, in the pico to femto range—1000 to 1 million times smaller than the nanoscale range. Like SQUIDs, Takeuchi's sensors should also be able to detect magnetic fields in the pico-Tesla range, but he's ultimately aiming for the femto-Tesla range. "It would be equivalent to detecting the field from a refrigerator magnet from about 30 feet away," he says.

New, easier-to-use devices capable of picking up magnetic fields that small could also be used to detect other threats to human health. The human heartbeat, for example, generates a magnetic field in the pico-Tesla range, and magneto cardiograms (MCGs), an alternative to electrocardiograms (EKGs), are one example of a technology that could benefit from a switch to a more portable, room-temperature platform. "MCGs are much more precise than traditional EKGs in detecting and ruling out cardiac abnormalities," Takeuchi explains, "but if you ask for an MCG at a hospital, most don't have the equipment because it's just too expensive and sometimes too big."

The Takeuchi Group recently published a paper demonstrating a proof-of-concept of their device. Their next steps are to reduce the design to the micro- and nanoscales, address methods of mass-production, and increase sensitivity.

"By combining the expertise of the collaborative team, we have the chance to do something truly unique and make devices which have never been made before," says Takeuchi. "It's also very exciting that potentially, applications which previously were not very practical may become possible."

For more information, see "Fabrication and characterization of all-thin-film magnetoelectric sensors," Applied Physics Letters, 94, 243507 (2009).

faculty PROMOTIONS

PHANEUF, TAKEUCHI PROMOTED TO FULL PROFESSORSHIP

The Department of Materials Science and Engineering extends its congratulations to faculty members **Ray Phaneuf** and **Ichiro Takeuchi**, who were promoted to the rank of full professor effective July 1, 2009.

RAY PHANEUF

Phaneuf's interests include nanotechnology, surface physics, low electron microscopy, photoemission electron microscopy, scanned probe microscopy, and templating for directed self-assembly. Takeuchi works with combinatorial synthesis and the characterization of novel electronic and smart materials, fabrication and characterization of novel thin-film multilayer devices, and microscopy.

Within the past year and a half, both professors' research has attracted the attention of both the academic community and the media.

A press release about Phaneuf's work on templating for directed, atomic-level self-assembly—which could be used to "grow" new kinds of computers and sensors—was picked up by online and print news outlets around the world *(see "Templating for Directed Self-Assembly,"* Techtracks, *Spring 2008.)*. The research was presented at the Nanosteps workshop in France and selected for the *Virtual Journal,* published online weekly by the American Institute of Physics and the American Physical Society. *Virtual Journal* editors hand-select recently-published papers with which they feel researchers should be familiar in order to keep up with developments in the field.

ICHIRO TAKEUCHI

Takeuchi was recognized for his group's recent discovery of a new, lead-free piezoelectric material that could replace PZT, a lead-based compound widely used in electronics. *(see "Reducing Our Lead Footprint,"* Techtracks, *Spring 2009.)* After the research was published in *Applied Physics Letters,* a corresponding press release received wide distribution. Takeuchi was also selected as one the nation's 100 most outstanding young engineers invited to attend the National Academy of Engineering's 2008 U.S. Frontiers of Engineering Symposium, a special forum for young engineers (aged 30-45) from industry, academia, and government to discuss their pioneering research.

Both professors have also been recognized by the Clark School as "Research Leaders" for their efforts in bringing sponsored research dollars to campus.

You can learn more about Professor Takeuchi's research on p. 5.

student NEWS

BANERJEE WINS MSA PRESIDENTIAL STUDENT AWARD

Graduate student **Parag Banerjee**, advised by Professor **Gary Rubloff**, won the Microscopy Society of America's (MSA) Presidential Student Award for a paper titled "Crystallization Behavior of HfO_2 Nanotubes in Different Environments," which he presented at the MSA's 2009 Microscopy & Microanalysis Meeting this July in Richmond, Va. The award recognizes papers first-authored by students that reflect excellence in research.

Banerjee's paper describes how nanotubes of amorphous hafnium oxide crystallize when heated under various conditions of mechanical stress and temperature. Samples were generated in the Laboratory for Advanced Materials Processing and the Maryland NanoCenter's Nanoscale Imaging Spectroscopy and Properties Laboratory transmission electron microscopy facilities. By studying the formation of tiny crystals in these nanotubes, Banerjee hopes to shed light on fundamental atomic rearrangements that occur in nanostructures during crystallization.

Banerjee's overall research concentrates on creating energy harvesting devices (including solar cells) and energy storage devices (including supercapacitors and batteries) using conventional semiconductor processes as well as self-assembled techniques for nano-fabrication.

"If these devices are going to be commercialized," he explains, "they need to be integrated with the [manufacturing] processes currently available. At the same time the devices need to be cheap. These varied process requirements mean that one has to be creative in one's approach and yet

BANERJEE

come up with devices that possess improved performance characteristics."

REN WINS THESIS AWARDS

Graduate student (now alumnus) **Shenqiang Ren** (Ph.D. '09), advised by Professor **Manfred Wuttig**, was awarded first place and a prize of $1500 in the 2009 Dean's Doctoral Research Award Competition. His project, "Bottom-up Multiferroic Nanostructures," earned top honors from a panel of judges including members of the Clark School's Board of Visitors.

To give top Clark School doctoral student researchers special recognition that will be valuable in launching their careers, and to show all students the importance of high quality research, Dean **Darryll Pines** created the Dean's Doctoral Research Award Competition this year. Students submitted their work through competitions at the department level. Ren was selected to represent the Department of Materials Science and Engineering in the competition after winning the inaugural MSE Doctoral Thesis Award. MSE Professor and Chair **Robert M. Briber** describes Ren's work as "exciting and promising."

Ren was recognized for the high level of creativity and intellectual insight he has demonstrated in his development of new, self assembled multiferroic nanocomposite materials that could be used to create electronic nanodevices for use in future generations of computers and storage devices. His efforts have led to four first author papers published between 2007-2009 in *Applied Physics Letters,* three of which were also selected for the *Virtual Journal of Nanoscience and Technology.* Ren has filed for four patents based on his work.

"He is uniquely qualified for this award because of his outstanding intellectual contribution to materials science and his high productivity," Wuttig wrote of Ren in his nomination letter. "He created a new field of materials science, diblock copolymer templated nano-oxide composites, and he used his unique synthetic skills to create novel nano-magnetoelectrics with very high magnetoelectric coupling coefficients. In my opinion, Shenqiang embodies the ideal of [the] most successful graduate student: highly intelligent, dynamic, hard driving but even tempered, forward looking and not intimidated by seemingly insurmountable obstacles."

"The Clark School gave me the freedom to pursue my research interests, to do what I believe in," says Ren of his Ph.D. experience. He credits Wuttig's support for his success.

This fall, Ren began postdoctoral research at the Massachusetts Institute of Technology.

STUDENT ENERGY RESEARCH: ISRAEL PEREZ

Graduate student (now alumnus) **Israel Perez** (Ph.D. '09), advised by Professor **Gary Rubloff**, conducted research into how nanoporous anodic aluminum oxide (AAO) can be used as a platform for energy storage.

Perez has created tiny energy-storing devices called metal-insulator-metal (MIM) nanocapacitors *(see p. 8 for an example).*

The innovation involves the use of AAO to boost energy density. This has resulted in a tenfold gain in the amount of energy that can be stored, which allows these nanocapacitors to compete with electrochemical supercapacitors as viable energy storage devices. Near-term applications include working in parallel with conventional energy storage devices in cell phones and laptops, and perhaps eventually becoming the sole energy source in such devices.

Nanoporous AAO has vast implications as a tool for nanoscience research and as a structure from which devices can be fabricated because of its regular and ordered nanopores. Nanoporous AAO membranes are formed by anodizing highly pure aluminum in an electrolytic solution. During the anodization process the nanopores naturally self-organize into arrays of hexagonal ordering. This processing leads to a high aspect ratio (1000:1) membrane which contains straight and cylindrical pores with diameters of ~50-80nm and depths of 0.5-30µm aligned normal to their substrate.

Perez's research involved synthesizing nanoporous AAO templates and studying the characteristic shapes and materials composition of the structures to better understand the implications for energy devices built on their surfaces.

The MIM nanocapacitors are an example of an energy device created using these templates. Using atomic layer deposition, a thin-film deposition method able to deposit conformal films in high aspect ratio nanostructures, a three-layer MIM structure (TiN-Al_2O_3-TiN) was deposited into the nanopores of AAO templates. When he tested this structure, Perez found that using nanoporous AAO boosted the energy density of the simple MIM structure, surpassing the capacitance density values previously reported for similar devices by a factor of 10. The high power density characteristic of the electrostatic capacitors, coupled with this large improvement in energy density, makes the MIM nanocapacitors capable of competing with electrochemical supercapacitors as viable energy storage devices.

This fall, Perez began postdoctoral research at the University of California–Irvine.

REN

PEREZ

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ABOUT THE COVER IMAGE

THE RED IMAGE USED ON THE COVERS, FROM THE RESEARCH GROUP OF PROFESSOR GARY RUBLOFF, SHOWS A HFO_2 NANOTUBE FILM CREATED BY THE DEPOSITION OF A HIGHLY CONFORMAL ATOMIC LAYER DEPOSITION FILM INTO A NANOPOROUS ANODIC ALUMINUM OXIDE TEMPLATE. AN ENERGY DEVICE CONSTRUCTED IN THIS WAY BENEFITS FROM A LARGE ENHANCEMENT TO THE SURFACE AREA OF ITS CHARGE STORING INTERFACE, RESULTING IN HIGH ENERGY DENSITY STORAGE. YOU CAN LEARN MORE ABOUT THIS RESEARCH ON PAGES 3 AND 7. PHOTO BY ISRAEL PEREZ.

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:

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

openHOUSE!

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

We are hosting open house events this fall 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; and take lab tours.

FOR MORE INFORMATION:

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

CONTACT DR. KATHLEEN HART:
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