



FALL 2013

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.

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Leite, Mo Join MSE Faculty

PROFESSORS SPECIALIZE IN PHYSICAL AND COMPUTATIONAL MATERIALS SCIENCE FOR SUSTAINABLE ENERGY APPLICATIONS

The A. James Clark School of Engineering's Department of Materials Science and Engineering (MSE) is pleased to welcome its two newest faculty members, **Marina Leite** and **Yifei Mo**.

Leite, who received her Ph.D. from the Physics Institute at the Universidade Estadual de Campinas, Brazil in 2007, will hold a joint appointment with the Institute for Research in Electronics and Applied Physics (IREAP).

At Maryland, her group will focus on sustainable energy solutions, with an emphasis on high efficiency photovoltaic solar cells and long lasting, lightweight rechargeable batteries. The research will include fundamental studies of solid state matter, materials development, device design, and materials performance enhancement through the modification optoelectronic characteristics at the nanoscale.

Leite is excited about her work's potential. "I adore research!" she says, adding that her studies of energy harvesting and storage allow her to be involved in everything from discovery to application. "We need to find ways of substituting our current need for fossil fuels while keeping our [quality of] life...and preserving the environment for future generations. At MSE and IREAP I found an exceptionally collaborative work environment, with a team of outstanding researchers striving to solve scientific problems relevant to our society. I am thrilled to join UMD's effort for sustainability!"

Leite's previous experience includes postdoctoral positions in the Applied Physics & Materials Science Department at Caltech and the Center for Nanoscale Science and Technology at the National Institute of Standards and Technology (NIST).

Mo, who received his Ph.D. from the University of Wisconsin-Madison in 2010, is a computational materials scientist. Using advanced modeling and simulation techniques, he designs new materials without physical trial-and-error, and identifies problems



MARINA LEITE



YIFEI MO

continues pg. 2





ROBERT M. BRIBER

OUR FACULTY HAS GROWN!

This issue, we are pleased to introduce you to the two newest members of our faculty, **Marina Leite** and **Yifei Mo**.

Professors Leite and Mo will help to expand the research and educational efforts of the Department, bringing new expertise in pho-

tovoltaics and computational materials science, respectively.

Since our last issue, our research has received a lot of attention from the media, including coverage by *Science*, *C&EN*, the Department of Energy, and National Public Radio. Look for the related stories and links on the back cover and pages 3-4 and 6-7. As we were preparing to go to press,

Washington, D.C. ABC affiliate WUSA 9 broadcast a story about the faculty and students engaged in fuel cell and battery research at the University of Maryland Energy Center, directed by MSE professor **Eric Wachsman**. You can watch the segment online at ter.ps/usa9energy13

Congratulations are in order for Professors **Manfred Wuttig** and **Alex Roytburd**, both of whom celebrated their 80th birthdays this year. A special symposium was held in honor of Professor Wuttig at the Spring MRS meeting in San Francisco (see p. 6). Congratulations are also due to **Oded Rabin**, who was promoted to Associate Professor with tenure this year. And finally, MSE graduate students won both of the Clark School's 2013 Dean's Student Research Awards (see p. 10).

Our external research partnerships are strong and expanding, including our ongoing collaboration with the Walters Art Museum (see below and p. 3), a new partnership with Agilent Technologies (see p. 4) and Associate Professor **Luz Martínez-Miranda's** ongoing role as a Fulbright

Specialist matched with Professor **Eduardo Soto-Bustamante** of the University of Chile at Santiago. Professor **Ichiro Takeuchi's** expertise in combinatorial materials discovery is helping guide a new multidisciplinary university research initiative (MURI) lead by Duke University and funded by the Office of Naval Research. Professors Wachsman and Takeuchi will also have new ARPA-E programs starting this fall on critical technologies for energy storage and production.

Don't forget—if you're an alumnus or alumna, you can keep us informed of the great news in your life and career by joining the "MSE UMD" Facebook group or e-mailing us at mse@umd.edu. You can get the latest MSE news at any time by visiting mse.umd.edu/news.

Until next time,

Robert M. Briber
Professor and Chair, MSE

in materials that are difficult to study experimentally. His research has appeared in high-impact journals including *Nature* and *Nature Materials*.

"Designing materials in the computer avoids the time-consuming and expensive experiments in the lab, and can significantly reduce the development cycle of new materials," he explains.

At the University of Maryland, Mo plans to apply his techniques to the development of new high-performance materials for batteries and energy applications, study their nanoscale mechanics, and identify how their interactions at interfaces and surfaces affect their properties. He hopes his work will overcome some of the challenges to the development and distribution of renewable energy technology, and believes the Clark School is an ideal place for him to pursue his goals.

"MSE at UMD is one of the finest programs in the world," he says. "It boasts

the state-of-the-art facilities and the leading experts in a variety of areas of materials science...[I] will be able to work with the best experimentalists. I look forward to the exciting synergy between the computational [and] experimental research on campus."

Prior to joining the MSE faculty, Mo was a postdoctoral research associate at Massachusetts Institute of Technology (MIT).

ATOMS-THICK COATING READY FOR FIRST TEST ON SILVER ARTIFACT

The team behind the development of a new technique designed to protect silver artwork has announced it is preparing to apply a removable, clear coating mere atoms thick to its first artifact, a late 15th century Spanish processional cross from the collection of the Walters Art Museum in Baltimore, Md.

The important milestone in the ongoing collaboration between the Department of

Materials Science and Engineering (MSE), the Walters, and E-squared Art Conservation Science was recently reported by *Science*, both online at *ScienceNOW* and in its March 29, 2013 print edition, following a press briefing at the national meeting of the American Physical Society (APS).

Since 2010, the research group, one of the first to be funded by the National Science Foundation's SCIART grant program, has sought a more effective solution to a problem faced by many museums: the threat of tarnish. Currently, silver objects are most often either painstakingly hand-coated or sprayed with nitrocellulose lacquers that begin to discolor or break down after about 20 years (at which point they must be cleaned and coated again), or kept in special exhibition cases. MSE professor **Ray Phaneuf** and his collaborators have been using a technique called atomic layer deposition (ALD) to

apply coatings of aluminum oxide onto silver in layers measuring only atoms thick. The coatings are transparent, optimized to reduce the rate of corrosion, durable but easily removable, harmless to the artifact, and estimated to last at least 80 years.

Phaneuf describes ALD as providing “an exquisite level of control” that allows them to consistently apply coatings to the finest and deepest nooks and crannies in a way a conservator’s brushes cannot.

The team first tested their coatings on small samples of fine and sterling silver, tooled in ways designed to mimic the complex surfaces of sculptures, utensils and jewelry. They simulated the passage of time on the coatings using accelerated testing techniques that exposed the treated samples to tarnish-inducing conditions: environments containing 100,000 times the natural concentration of hydrogen sulfide found in the atmosphere, or temperatures of 150 degrees centigrade. Using kinetics models, the results were translated into how long an equivalent amount of tarnish would take to build up at the concentrations and temperatures found in a museum.

Finally, they tested the removal of the coatings. “Copper depletion at the surface of our test subjects was the main

concern,” says project team member **Eric Breitung** of E-squared Art Conservation Science. “Through multiple tests, we found that only a few nanometers’ worth might be removed during removal of the ALD coating, whereas polishing removes hundreds of nanometers of both copper and silver from the surface of an object.”

After extensive experimentation, Walters Director of Conservation & Technical Research **Terry Drayman-Weisser** approved the application of the ALD treatment to one of the silver plates covering the wooden core of a late 15th century Spanish processional cross. The small piece of metal will be the first object from the museum’s world-class silver collection to receive the new protective coating.

The Walters’ role in the project, she says, has been to bring professional conservation concerns to the table.

“Our focus is long-term preservation of the objects in our care,” she explains. “Tarnishing of silver is problematic since polishing, even with mild abrasives, removes metal leading to loss of surface detail, and protective

lacquer coatings can encourage severe corrosion if areas are missed during the application process. This is what has made the investigation of the ALD process appealing. Recent work has demonstrated that an ALD coating protects silver significantly longer than nitrocellulose, and that it coats the surface thoroughly with a layer of material that can be removed with negligible effects on

the underlying silver. Although the process will not be appropriate for all silver objects and evaluation continues, we now feel confident in testing ALD on a piece from our cross.”

Walters Art Museum conservation scientist **Glenn Gates** explains the cross was chosen because the plate can be easily removed for coating and is small enough to fit in the university’s ALD chamber. Because the cross is adorned with many strips of sculpted silver, the condition of the newly treated piece can be compared to others of the same age, origin and quality.

“The adjacent strips have the traditional nitrocellulose coating, so conservators and curators will be able to determine the visual suitability of our coating in a ‘real-life’ situation,” says Gates, adding that after treatment, the cross will be on display in the Walters’ Northern Realism gallery.

MSE Graduate student **Amy Marquardt**, who has worked on the project for the past three years, says the observation phase will be a crucial step in determining whether appearance of the ALD film on an object is aesthetically pleasing enough to be widely adopted. Ideally, the coating will not reflect light in a way that affects the apparent color of the piece, or that makes it too shiny or too dull.

Professor **Gary Rubloff** (MSE and Director, Maryland NanoCenter) also contributes to this research.

Science’s coverage of this work, “Atomic Science Keeps Silver shining Bright,” can be found at ter.ps/scisilver

Our original press release about the project can be found at: ter.ps/msesilver

For More Information:

Amy Marquardt, Eric Breitung, Glenn Gates, Terry Weisser, Gary Rubloff and Ray Phaneuf: “Effective Lifetimes of Atomic Layer Deposited Diffusion Barrier Films for Silver Artifacts.” Bulletin of the American Physical Society 58(1). APS March Meeting, Baltimore, Maryland, March 2013.



THIS ELABORATE PROCESSIONAL CROSS FROM ZARAGOZA, SPAIN, IS MADE OF SILVER AND ENAMEL OVER A WALNUT WOOD CORE, RADIOCARBON DATED TO THE LATE 15TH CENTURY. IT WILL BE THE FIRST ARTIFACT FROM THE WALTERS’ WORLD-CLASS COLLECTION TO RECEIVE A COATING VIA ATOMIC LAYER DEPOSITION TO PROTECT IT FROM TARNISH. OVERALL: 63 1/2 x 23 1/2 x 7 9/16 IN. (161.3 x 59.7 x 19.2 CM). PURCHASED BY HENRY WALTERS CIRCA 1909. CREDIT: WALTERS ART MUSEUM.

“CLOSING THE FIELD”: SURPRISING DISCOVERY MEANS RESEARCHERS NEED TO RE-THINK PURSUIT OF MATERIALS FOR FUEL CELL CATHODES

Research doesn't always have a “happy ending,” but that does not necessarily diminish the importance of a dead end.

MSE adjunct professor **Maija Kukla** (National Science Foundation) is a leader in the field of computational materials research. Her group, which is currently focused on improving the performance of solid oxide fuel cells (SOFCs), uses advanced simulation and modeling techniques to obtain information about the behavior of materials that is difficult or impossible to acquire through physical experimentation alone.

For years, Kukla, like many other scientists, has been studying barium strontium cobalt iron complex perovskites (BSCF), a class of oxide materials considered frontrunners for use in SOFC cathodes, where a complex series of chemical reactions converts chemical to electrical energy. Perovskites have been an attractive option because their crystal lattices are flexible, allowing them to be customized by the incorporation of practically any chemical elements, and suggesting they would hold up under repeated cycles of charging and discharging. The hope was that the BSCF perovskites' flexibility, derived from four metal sub-lattices within their cubic arrangement and coupled with the fastest oxygen chemistry known to oxides, would enhance the SOFC cathode performance under specific operating conditions.

“BSCF is very complex,” says Kukla, “but its flexibility gives you a lot of opportunities to design a material the way you want it. You can make your lattice a specific size, for example, which is an important factor in energy conversion, but you have to pay a price. Everything is about a tradeoff.”

What Kukla and her colleagues discovered in the molecular “fine print” of the deal turned out to be more serious than anyone had imagined.

“The tradeoff for this material,” she explains, “which was predicted to be the best material, a panacea for energy conversion—[was that] we discovered that it's unstable.” This was not the sort of revelation researchers dream of announcing, and at first, the news was not well received.

“We closed the field,” Kukla says. “There was shock in the [SOFC] community, not only because nobody expected it, but because people were very excited about this material and a lot of research money was invested in it. So now, imagine one of us standing up at a conference and saying, ‘Look guys, this material is actually never going to work.’”

Following an initial flurry of disbelief and disappointment, the results were accepted. People became “respectfully excited” again, Kukla explains, because while BSCF perovskites had been declared a dead end, her research explained why, which provided insight on how a good fuel cell cathode material should work, and how it should be designed. Her group also proposed another perovskite material, LSCF, as a better option. LSCF is now being actively studied around the world.

And what about the fate of BSCF complex perovskites, the former fuel cell materials star? It's not all bad news, Kukla says. They can be used in other, less demanding energy applications, such as gas separation membranes that reduce CO₂ emissions, in which it is easier to mitigate their instability.

Kukla and her colleagues were invited to share their game-changing results in a recent issue of *Physical Chemistry and Chemical Physics*, one of the premiere publications of Europe's Royal Society of Chemistry.

For More Information:

M. M. Kuklja, E. A. Kotomin, R. Merkle, Yu. A. Mastrikov and J. Maier, “Combined theoretical and experimental analysis of processes determining cathode performance in solid oxide fuel cells,” *Phys. Chem. Chem. Phys.* 2013 Apr 21;15(15):5443-71.

FLEXIBLE NANOPAPER FEATURED IN CHEMICAL & ENGINEERING NEWS

In our last issue, we reported on MSE assistant professor **Liangbing Hu's** production of “nanopaper,” a smooth, flexible material made of nanometer-length paper fibers that reduce its ability to scatter light, resulting in 90-95% transparency. The application of a thin coating of carbon nanotubes makes the paper strong and highly conductive—ideal for use in printed electronics.

The work caught the attention of *C&EN*, which interviewed Hu for a story. You can find it online at:

ter.ps/hucanden2013



AGILENT GIFT FUNDS EXPLORATION OF ENHANCED SENSOR TECHNOLOGY

MSE associate professor **Oded Rabin** has received a \$50,000 research gift from Agilent Technologies' University Relations Program. The gift will support his exploration of engineered nanoparticle arrays used to boost the capabilities of surface-enhanced Raman spectroscopy (SERS), a powerful sensing technique that determines the presence, amount and identity of chemicals in a sample by the way light from a laser scatters when shined on it. Rabin will collaborate with MSE professor and chair **Robert M. Briber** and Agilent scientist Dr. **Miao Zhu** on the project.

The “surface” in “SERS” is an extra component, typically a metal-coated wafer of silicon or glass. This substrate focuses and intensifies the light from the system's laser probe, boosting its ability to detect target materials in trace quantities as small as a few thousand molecules. Rabin's research group has been developing novel, more effective SERS substrates for the past few years. In this case, the substrates consist of billions of gold nanoparticles arranged in a hexagonal pattern over a silicon wafer.

“Our substrates are exceptional in three ways,” Rabin explains. “First, they

are fabricated by self-assembly, providing a significant cost benefit. Second, they produce a strong, consistent signal across their entire area—this is of considerable importance as the lack of reproducibility has stalled the transition of SERS from academic settings to real-world diagnostics for decades. Third, the plasmon modes of our substrates' nanostructures can be adjusted to match any given Raman spectrometer that uses a laser excitation in the visible or the near infrared range. This is achieved by changing a single parameter in the fabrication process, with predictable and repeatable results."

"The gift from Agilent Technologies will support our efforts to improve this technology and demonstrate its adaptability to market needs," says Briber. "Our work will help design high-throughput assays that best utilize the virtues of the SERS substrates and account for their limitations."

Rabin and Briber hope the collaboration will blossom into a partnership in which Agilent, a manufacturer of measurement and analysis systems, will be able to utilize the new substrate technology in the production of spectroscopy devices and substrate kits.

NANO "BEADS ON A STRING" COULD ADVANCE BATTERY TECHNOLOGY

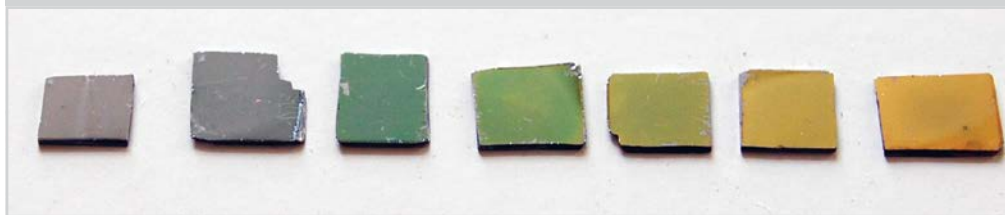
By Martha J. Heil, Maryland NanoCenter

Tiny beads of silicon, about ten thousand times thinner than a piece of paper, could someday make electric vehicles travel farther on a single charge or extend the life of your laptop's battery.

Rechargeable lithium-ion batteries—the kind in your phone, camera, and some hybrid cars—use graphite as an electrode. Silicon can store up to ten times more lithium ions than graphite, but until now, silicon structures tended to crack or break when they were used over and over. Now chemists and materials scientists at the University of Maryland have designed a tiny silicon structure for batteries that can last through more charging cycles than previous designs did.

The scientists—including Department of Materials Science and Engineering

NOVEL GOLD-NANOPARTICLE SERS SUBSTRATES: BY CONTROLLING THE SIZE AND SPACING BETWEEN NANOPARTICLES THAT SELF-ARRANGE INTO PATTERNS ON THE SURFACE OF THE SUBSTRATE, THE COLOR OF THE LIGHT IT ABSORBS OR REFLECTS IS TUNED. THE SUBSTRATES' NANOSCALE ARCHITECTURE IS OPTIMIZED TO ENHANCE THEIR INTERACTION WITH THE PROBING LASER LIGHT AND THE CHEMICALS TO BE DETECTED.



(MSE) professors **Gary Rubloff** and **John Cumings**, and MSE graduate student **Khim Karki**—grew tiny beads of silicon on a carbon nanotube, then used a powerful microscope to watch the electrode charge and discharge.

To make the beads, their colleague, Assistant Professor **YuHuang Wang** (Department of Chemistry and Biochemistry) and his team attached part of a molecule sometimes found in food flavorings along carbon tubes less than fifty nanometers wide. Then they flooded the space with a gas containing silicon. The organic molecule caused beads of silicon to grow on the tube.

Then, they charged the silicon with lithium ions. The team watched the tiny electrode in action under the electron microscopes in the Maryland NanoCenter's Nanoscale Imaging Spectroscopy and Properties (NISP) Laboratory.

The researchers think the structure is more resilient because unlike flat silicon coatings, silicon beads grow like flexible balloons. The organic molecule that initially attracted the silicon to the tube made the silicon bond to the tube more strongly, preventing the silicon from breaking apart, the researchers found.

As the beads were charged by the lithium, they grew and shrank without cracking or ripping.

The beads expand outward from the nanotube, but not toward each other, so they can be placed close together.

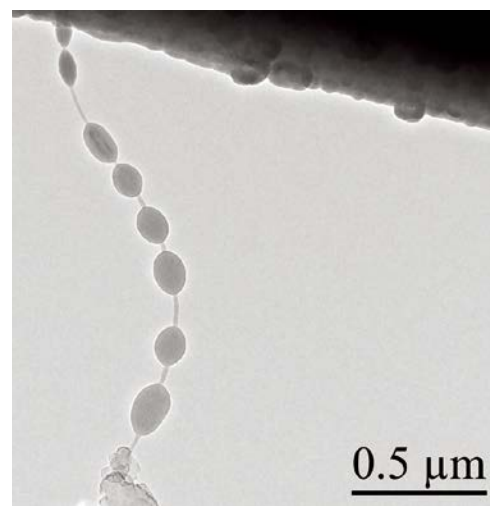
In addition to Cumings, Karki and Rubloff and Wang, the project's team of experimental and theoretical scientists

included research associates **Chuan-Fu Sun** and **Hongwei Liao** (Department of Chemistry and Biochemistry); Associate Professor **Teng Li** and graduate student **Zheng Jia** (Department of Mechanical Engineering); **Yu Qi** (General Motors); and graduate student **Yin Zhang** (Xi'an JiaoTong University).

Funding for the research was provided by the National Science Foundation and by Nanostructures for Electrical Energy Storage (NEES), the Department of Energy's Energy Frontier Research Center based at the University of Maryland.

For More Information:

Sun et. al. "A Beaded-String Silicon Anode," ACS Nano, 7 (3), 2717 (2013).



TINY BEADS OF SILICON, GROWN ON A TUBE A HUNDRED THOUSAND TIMES THINNER THAN A PIECE OF PAPER, COULD STORE UP TO TEN TIMES MORE LITHIUM THAN GRAPHITE, A COMPONENT OF MANY COMMERCIAL BATTERIES. CREDIT: UNIVERSITY OF MARYLAND NANOCENTER.

WUTTIG HONORED AT NATIONAL MEETING OF THE MATERIALS RESEARCH SOCIETY

MSE Professor **Manfred Wuttig** was the guest of honor at a symposium celebrating both his distinguished career and 80th birthday at the national meeting of the Materials Research Society (MRS), held in San Francisco, Ca. in April 2013.

The two-part symposium, “Celebrating Manfred Wuttig’s 80th Birthday I: Exploring Ferroic Materials and Elastocaloric Cooling” and “Celebrating Manfred Wuttig’s 80th Birthday II: Oxides and Adaptive Phases,” featured a full roster of presentations delivered by friends and colleagues from around

CUMINGS’ RESEARCH FEATURED BY DEPARTMENT OF ENERGY

Research by MSE associate professor **John Cumings** was featured in April 2013 by the Department of Energy’s Office of Science as a “Story of Discovery and Innovation.”

Cumings, who works to advance our understanding of the dynamic properties of nanoscale systems, was recently studying how heat behaves in electronic devices, a phenomenon known as resistive or Joule heating. Joule heating occurs as electric currents travel through the wires and conductors of electronic devices, and is a common process in items we use every day, including coffee machines, electric stoves and laptops.

Cumings and his collaborators discovered that a carbon nanotube conducts electricity without heating up—the heat actually appeared a short distance away! The team named this new phenomenon “remote Joule heating.” The research was recently published in *Nature Nanotechnology*.

For the DOE’s story, visit: ter.ps/doeremjoule

or read our original release, “The Weird World of Remote Heating,” at ter.ps/remotejoule

the world. Speakers included MSE professor **Alexander Roytburd**, MSE adjunct professor **Jun Cui** (Pacific Northwest National Lab), former MSE professor **Ramamoorthy Ramesh** (University of California, Berkeley), and MSE alumnus and former Wuttig group member **Shenqiang Ren** (Ph.D. ’09), now a professor at the University of Kansas.

“It just made perfect sense to use the MRS symposium as the venue to celebrate Manfred’s birthday and to honor his legacy in materials science,” says MSE professor **Ichiro Takeuchi**, who co-chaired the symposium. “We invited a number of speakers who worked with Manfred as close colleagues, mentees, and advisees, and their talks were all great tributes to his lifelong achievements.”

“Manfred Wuttig has always been an outstanding scientist with truly innovative ideas, contributing [to] excellent research on smart materials and multiferroics for the last 20 years,” says longtime colleague Professor **Eckhard Quandt**, head of Inorganic Functional Materials at Christian Albrechts Universität, Kiel, Germany. “My collaboration with Manfred is truly characterized by team spirit, reliability, and friendship, something for which I am very grateful.”

Wuttig, who earned his Dr. -Ing. in physics and metallurgy from the Technische Hochschule Dresden and Technische Universität in Berlin, Germany in 1958, is an internationally recognized expert in the fields of ferromagnetic, ferroelectric and ferroelastic materials; reversible phase transformations, multiferroics, magnetoelectrics, and nanomagnetism.

Before coming to Maryland, Wuttig was a physics lecturer at Physikalisch-Technische Bundesanstalt, Berlin; a research associate at the Gauss Ingenieur Schule, Berlin; a professor in the Department of Metallurgy at both the University of Illinois and the University of Missouri–Rolla; and director of the National Science Foundation’s metallurgy program. He joined the University of Maryland’s then-Department of Chemical and Nuclear Engineering in 1986, where he was the director of the Graduate Program in

MANFRED WUTTIG CELEBRATING HIS 80TH BIRTHDAY.



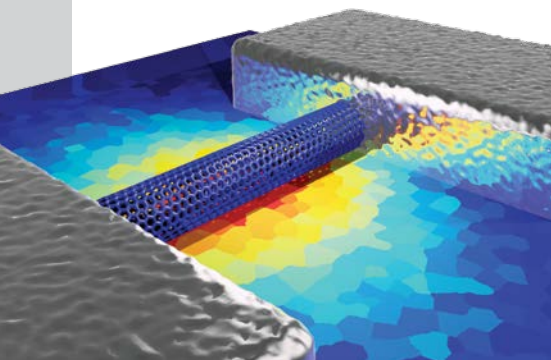
Materials Science, and in 1992 became the first Acting Chair of the then-Department of Materials and Nuclear Engineering. He has served as MSE’s graduate program director since the late 1990s.

Wuttig’s recent and current research projects include the synthesis and characterization of magnetoelectric composites, organic multiferroics for spintronics, and the study of alloys with magnetostrictive properties. He has also been involved in the development of an all solid-state, elastocaloric cooling technology based on latent heat generated by the martensitic transition (change in crystal structure) of shape memory alloys, for which he, Takeuchi and Cui won the University of Maryland’s Physical Sciences Invention of the Year in 2011. The highly-efficient system could potentially replace vapor-compression based air conditioners and refrigerators, which utilize hydrofluorocarbons and hydro chlorofluorocarbons (such as Freon) that are harmful to the environment.

“Manfred is my lifetime advisor and mentor,” says Ren. “I’ve learned a lot from him about how to [explain] profound concepts in a simple, efficient and straightforward way. His scientific passion and mentoring legacy have made a tremendous impact on my life.”

“Manfred was the best researcher that I ever worked with,” adds **Dwight Viehland**, a professor of materials science and engineering at Virginia Tech. “I began working with him nearly 30 years ago, on my senior thesis as an undergraduate [at U.Miss.-Rolla]. He was patient, kind, and nurturing. He taught me most of what I know. I am forever indebted to him.”

“Manfred Wuttig is a great teacher and inspiration for the [materials] community,”



says **Kaushik Bhattacharya**, the Howell N. Tyson, Sr. Professor of Mechanics and Professor of Materials Science at Caltech. “He combines an encyclopedic knowledge with an amazingly open-minded and creative way of thinking.”

Wuttig’s academic and research prowess are not the only things his friends and colleagues appreciate. “Aside [from] learning science from him, Manfred showed me how to appreciate life,” says Cui. “Actually, I didn’t know Pilsner Urquell until he got me one and explained the history of pilsner. Now, Urquell is my all-time favorite.”

RABIN PROMOTED

The Department of Materials Science and Engineering (MSE), the Institute for Research in Electronics and Applied Physics (IREAP), the Maryland NanoCenter and the A. James Clark School of Engineering extend their congratulations to **Oded Rabin**, who was promoted to the rank of Associate Professor with tenure effective July 1.

Rabin’s Materials and Interface Nanotechnology Lab (MINT) has grown at a brisk pace since his arrival in 2007, breaking new ground in thermoelectric materials and spectroscopy research. The group’s goal is to discover how the unique properties and behaviors materials exhibit at the nanoscale can be used to create new products and improve nanomanufacturing techniques, with an emphasis on applied fields including energy, sensors, and bioimaging.

Rabin and his colleagues’ and group members’ notable accomplishments include the publication of a new, more accurate model for predicting the efficiency and performance of thermoelectric materials at the nanoscale; and demonstrating how pairs of silver nanocubes can enhance the effectiveness of surface-enhanced Raman spectroscopy

(SERS), paving the way for improved sensor design. In 2012, Rabin won a NSF CAREER Award for a study that is exploring how pinwheel-like plasmonic (metallic and highly conductive) nanostructures can be used to detect and identify the orientation of chiral molecules—those that exhibit different properties based on whether they twist to the left or to the right.

Most recently, Rabin received a Technologies Research Gift from Agilent Technologies’ University Relations Program (see p. 4) to explore the use of engineered nanoparticle arrays to enhance SERS. Rabin will collaborate with Agilent scientist **Miao Zhu** on the project.

In July 2012 Rabin was invited to author *Nature Nanotechnology*’s News and Views column, in which he commented on the development and impact of novel technologies for guiding the parallel self-assembly of nanoscale objects. That same year, his work also appeared on the cover of *Nanotechnology*.



ODED RABIN

Rabin has also collaborated with fellow members of the Maryland Nanocenter on energy research projects, and in 2010 was one of the co-PIs on a proposal that earned a \$15 million grant from the National Institute of Standards and Technology (NIST) to develop and implement a Postdoctoral Researcher and

Visiting Fellow Measurement Science and Engineering Program.

Rabin received his Ph.D. from the Massachusetts Institute of Technology (MIT) in 2004. Prior to joining the Clark School, he held postdoctoral positions with the Harvard Medical School at Massachusetts General Hospital, and with the University of California, Berkeley. He currently holds a joint appointment with MSE and IREAP.

WOOD BATTERY, continued from back cover.

times, the wood ended up wrinkled but intact. Computer models created by ME graduate student **Zheng Jia** showed that the wrinkles effectively relax the stress in the battery during charging and recharging, enabling it to survive many cycles.

“Pushing sodium ions through tin anodes often weaken the tin’s connection to its base material,” says Li, “but the wood fibers are soft enough to serve as a mechanical buffer, and thus can accommodate the changes in the tin. This is the key to our long-lasting sodium-ion batteries.”

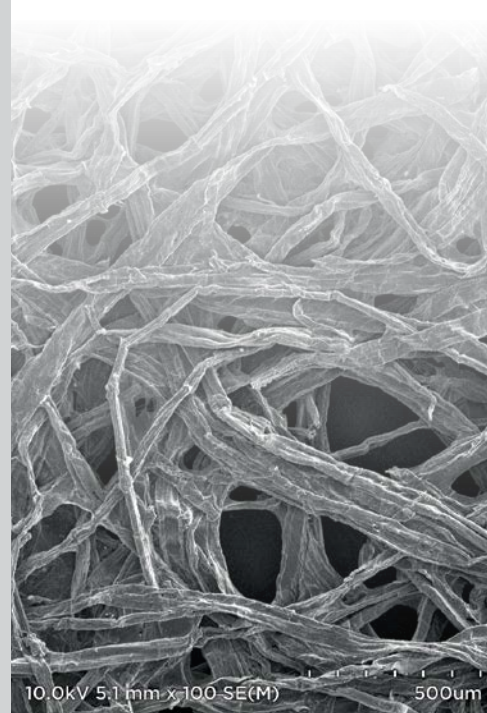
The team’s research was supported by the University of Maryland and the National Science Foundation.

Professor Hu and MSE alumnus **Nick Weadock** (B.S. ’13) were interviewed about the “wood battery” for a segment on NPR’s *Morning Edition*, which you can listen to online at:

ter.ps/nprbattery

For More Information:

Hongli Zhu, Zheng Jia, Yuchen Chen, Nicholas J. Weadock, Jiayu Wan, Oeyvind Vaaland, Xiaogang Han, Teng Li, and Liangbing Hu. Tin Anode for Sodium-Ion Batteries Using Natural Wood Fiber as a Mechanical Buffer and Electrolyte Reservoir. *Nano Letters*, 2013, 13 (7): 3093–3100





JOSHUA TAILLON

TAILLON WINS NSF GRADUATE RESEARCH FELLOWSHIP

Silicon carbide (SiC), MSE graduate student **Joshua Taillon** explains, is a material that has “immense potential” to improve the efficiency and performance of electronic devices for high-power applications, including renewable energy, aerospace equipment, communications systems, and electric vehicles.

“The primary benefit of silicon carbide is that it can be used in many environments where [typical] silicon-based devices simply cannot function,” he explains, “—at high temperatures, high power levels, in high radiation environments, or in space. Silicon carbide-based sensors, for example, can be operated at temperatures up to about 900 degrees Celsius. Ordinary silicon breaks down at about 350 degrees.” SiC also maintains its stability in these extreme environments longer than ordinary silicon, he adds, which could lead to savings in the form of devices that need to be replaced less often.

All microelectronics rely on an interface between a semiconductor (typically silicon) and an oxide layer (typically silicon dioxide). Despite SiC’s advantages as a semiconductor, the commercialization of devices that use it

has been limited due to atomic-scale defects that occur at these interfaces.

Taillon’s search for answers that could lead to overcoming this fundamental flaw now has the support of the National Science Foundation (NSF), which has awarded him a Graduate Research Fellowship. He is honored to have received the award, which he says will assure his financial security and give him the freedom to explore additional areas of research.

Taillon, advised by MSE professor **Lourdes Salamanca-Riba**, uses techniques including transmission electron microscopy and electron energy loss spectroscopy to characterize the interface of SiC-based electronics in order to learn more about the material’s performance-limiting defects. He collaborates with electronic device researchers from Rutgers University, Auburn University, and the U.S. Army Research Laboratory on the work, which has been presented at several conferences and published in the *Journal of Applied Physics*. The team, one of only a few applying these microscopy and spectroscopy techniques to SiC systems, hopes its research will lead to a better understanding of the fundamental physics that control them.

After earning his B.S. in Materials Science and Engineering from Cornell University, Taillon chose to study MSE at the Clark School because of its expert faculty, location near and partnerships with national labs, and its focus on the development of materials for energy applications.

“I have had access to the highest-quality characterization tools—both here and at NIST [the National Institute of Standards

and Technology]—and am surrounded by faculty and students who are driven and passionate about using their research talents to positively affect the world,” he says. “It has been an incredible learning experience to be part of groundbreaking research that has such immediate real-world applications.”

After earning his Ph.D., he would like to continue his research in either an industry or government setting. He has also developed an interest in federal science policy, and is thinking about how he could contribute to the government’s decision-making process. “[I] think that there is a critical need for advanced researchers to have a stronger impact informing policymakers on scientific issues,” he says.

For More Information:

Joshua A. Taillon, Joon Hyuk Yang, Claude A. Ahji, John Rozen, John R. Williams, Leonard C. Feldman, Tsvetanka S. Zheleva, Aivars J. Lelis, and Lourdes G. Salamanca-Riba. Systematic structural and chemical characterization of the transition layer at the interface of NO-annealed 4H-SiC/SiO₂ metal-oxide-semiconductor field-effect transistors. J. Appl. Phys. 113, 044517 (2013)

YOUNG ECS CHAPTER EMPHASIZES OUTREACH, WINS CHAPTER AWARD

Although not quite two years old, the University of Maryland student chapter of the Electrochemical Society (ECS) already has a busy schedule and a reputation for outreach and energy-related advocacy. This summer, their efforts earned them the ECS’s first Outstanding Student Chapter Award.

MSE professor and University of Maryland Research Center director **Eric Wachsman**, who serves as the group’s advisor, is proud of its progress.

“Within one year of formation [it] was already extremely active and growing in membership,” he says. “[Its members] are actively engaged in research, yet find the time to reach out to the D.C. regional community.”

“I’m honored that [we’re] being recognized for initiating an outlet to bring researchers together outside of the laboratory and for vigorously furthering the ECS mis-



MEMBERS OF ECS AT CONGRESSIONAL VISITS DAY. LEFT TO RIGHT: MSE GRADUATE STUDENTS COLIN GORE AND AMY MARQUARDT; SENATOR BARBARA BOXER (D-CALIFORNIA), MSE GRADUATE STUDENT HANNA NILSSON, AND CHEMICAL AND BIOMOLECULAR ENGINEERING GRADUATE STUDENT WILL GIBBONS. PHOTO COURTESY OF THE OFFICE OF SENATOR BARBARA BOXER.

sion through our activities,” says chapter president and MSE graduate student **Colin Gore**.

Here are just a few of the chapter’s notable activities from the past year:

“**Getting Juice from Juice.**” In February 2013, the chapter headed to the National Institute of Standards in Technology, where they hosted a session of the Adventure in Science Program. The program gets scientists and kids aged 8-15 together for presentations and activities designed to inspire and entertain. Graduate students **Will Gibbons** (Department of Chemical and Biomolecular Engineering), **Colin Gore** (MSE), **Amy Marquardt** (MSE), and **Chris Pellegrinelli** (MSE) led the students through a hands-on project in which they were able to use anthocyanin, a pigment molecule found in blackberry juice, and electrically conductive glass slides to fabricate their own dye-sensitized solar cells, which they then tested under different lighting conditions.

Science, Engineering, and Technology Congressional Visits Day. In March 2013, ten chapter members traveled to Capitol Hill, where they discussed the benefits of the “innovation ecosystem” created through a combination of federal and private scientific research programs, and the importance of stable and predictable federal funding in the face of the Sequester. The group met with Senators **Mark Udall** (D-Co.), **Tom Harkin** (D-Ia.), **Chuck Grassley** (R-Ia.), **Elizabeth Warren** (D-Mass.), **Ben Cardin** (D-Md.), **Barbara Mikulski** (D-Md.), and **Pat**

2013 CAPSTONE PROJECTS

In Capstone, a course taken in the senior year, teams of students utilize what they have learned throughout their undergraduate studies to create their own engineering designs from concept to product. This year, MSE expanded its Capstone format to include four groups that delivered oral and poster presentations, and a lunch at which winners of department and college-level awards were recognized and new members of Alpha Sigma Mu, the international professional honor society for materials science and engineering, received their certificates and tassels.

This year’s projects included preventing corrosion in biomedical implants, improving anodes in sodium-ion batteries, the creation of new catalysts for photocatalytic water splitting, and shape memory polymers for prosthetics.

TO LEARN MORE AND SEE TEAM VIDEOS, VISIT ter.ps/msecapstn13

Toomey (R-Pa.), all of whom are members of committees focusing on commerce, science and transportation, energy and natural resources, and related appropriations.

Energy Seminars by Distinguished Guests. The chapter has hosted or co-sponsored prominent speakers such as Massachusetts Institute of Technology professor **Donald R. Sadoway** and U.S. Department of Energy Hydrogen Production Technology Development Manager **Eric Miller**.

Chapter members have also toured local companies and presented their research at national meetings of the ECS.

recent GRADUATES

MAY 2013 B.S. GRADUATES

Elizabeth Ashley	Santiago Miret
Caleb Barrett	Mark Reese
Norena Beaty	Zara Simpson
Emily Dumm	Rachel Stein
Nicholas Faenza	Kerry Toole
Mari Hagemeyer	Hanna Walston
Tanner Hamann	Nicholas Weadock
Benjamin Jones	Joseph White
David Lockman	Erik Wienhold
Owen McGovern	Matthew Zager

MAY 2013 M.S. GRADUATES

Nitinun Varongchayakul

MAY 2013 PH.D. GRADUATES & DISSERTATIONS

Xinyi Chen: “ALD Processes and Application to Nanostructured Electrochemical Energy Storage Devices.” Advisor: **Gary Rubloff**

Keith Gregorczyk: “Atomic Layer Deposition of Ru and RuO₂: New Process Development, Fabrication of Heterostructured Nanoelectrodes, and Applications in Energy Storage.” Advisor: **Gary Rubloff**

Brendan Hanrahan: “Tribology of Microball Bearing MEMS.” Advisor: **Reza Ghodssi** (ECE/ISR)



UNDERGRADUATES GETTING READY FOR THE COMMENCEMENT CEREMONY, MAY 2013.



ZARA SIMPSON (LEFT) AND PROFESSOR AND CHAIR ROBERT M. BRIBER (RIGHT).

DEPARTMENT AWARDS

Chairman's Outstanding Senior Award: **Mark Reese**

Outstanding Materials Student Service Award: **Elizabeth Ashley** and **Nick Faenza**

The Department of Materials Science and Engineering Student Research Award: **Nick Weadock**

CLARK SCHOOL AWARDS

The Center for Minorities in Science and Engineering Service Award: **Norena Beaty**

The Dinah Berman Memorial Award: **Chris Berkey**

The Kim Borsavage and Pamela J. Stone Student Award for Outstanding Service: **Santiago Miret**

TO LEARN MORE ABOUT OUR HONOREES, VISIT ter.ps/mseawards13

NIST SURF FELLOWS

Luis Correa
Nicholas Faenza
Emily Hitz
Benjamin Jones

Kari McPartland
Eshwari Murty
Thomas Oeste
DoRonne Shyu

2013 DEAN'S STUDENT RESEARCH AWARDS

MSE graduate students won both Dean **Darryll Pines'** 2013 Doctoral and Master's Student Research Awards, beating competition from every Clark School department.

Pines created the thesis and dissertation awards to give top student researchers special recognition that will be valuable in launching their careers, and to demonstrate to all students the importance of high quality engineering research. Students submit their work to the Dean's Office after winning competitions at the department level. Members of department advisory boards serve as judges for the final, college-level competition.

Our winners were:

Doctoral

Jane Cornett

Advisor: Associate Professor **Oded Rabin**

"Thermoelectric Transport Phenomena in Semiconducting Nanostructures"

Cornett's research uses theoretical techniques to model the thermoelectric properties of nanostructures, including nanowires and thin films. Thermoelectric materials, which can convert waste heat into usable electrical energy, present a promising approach to tackling the escalating energy crisis. Her research can be used as a guide for future experimental work in the field of nanostructured thermoelectrics.

Master's

Nitinun Varongchayakul

Advisor: Assistant Professor **Joonil Seog**

"Direct Observation of Amyloid Nucleation Under Nanomechanical Stretching"

Varongchayakul studied the nucleation mechanism of silk elastin-like peptide (SELP) nanofibers using time-lapse lateral force microscopy. In this process, the mechanical force stretches the protein chain along the scan direction, which leads to nuclei formation. Varongchayakul used this technique to successfully create a single nanofiber pattern with a directional control.

CANOSA WINS CHAPMAN FELLOWSHIP

MSE alumna **Elyse Canosa** (B.S. '08) has received the University of Arizona's (UA) Thomas G. Chapman Fellowship. Canosa is pursuing her Ph.D. in the UA Department of Materials Science and Engineering's heritage conservation science program.

Canosa, who specializes in photography, wrote her M.S. thesis on carbon isotope analysis of 19th century paper negatives and will study corrosion resistance of photographic materials for her doctorate. She has worked in numerous museums, including the Smithsonian Museum Conservation Institute, the New York University Conservation Center, and the Art Institute of Chicago. The \$10,000 Chapman Fellowship was established in honor of **Tom Peterson**, dean of the UA College of Engineering from 1998 to 2008, and current head of the engineering directorate at the National Science Foundation.

ALUMNA APPOINTED BRANCH CHIEF AT NRC

Clark School alumna **Diane Jackson** has been named the Nuclear Regulatory Commission's (NRC) Branch Chief of Geoscience and Geotechnical Engineering Branch 2.

Jackson, who earned her B.S. in nuclear engineering and mechanical engineering in 1992, joined the NRC in 1993. Prior to her promotion to Branch Chief, she held a variety of positions within the agency, including serving as a technical reviewer in the Balance of Plant and Reactor Systems branches, advisor for the Organizational Effectiveness Branch, and reactor technical assistant to former NRC chairman **Nils Diaz**. From 2009 to 2012, she was the Deputy Head of the Nuclear Safety Division at the Organization for Economic Co-operation and Development (OECD) Nuclear Energy Agency in Paris, France, and most recently she served as the Executive Technical Assistant in the Office of the Executive Director for Operations for coordination of international activities and the Office of Nuclear Regulatory Research. She received the NRC's Meritorious Service Award in 2007.

During her time at the Clark School, Jackson worked for Department of Materials Science and Engineering professor **Mohamad Al-Sheikhly** as a reactor operator and as an undergraduate research assistant in the Laboratory for Radiation and Polymer Science, where she measured free radicals in irradiated polyethylene.

ALUMNUS APPOINTED HEAD OF UCONN MATERIALS SCIENCE AND ENGINEERING

MSE and the A. James Clark School of Engineering extend their congratulations to alumnus Professor **S. Pamir Alpay** (Ph.D. '99), who was appointed head of the University of Connecticut's (UConn) new Department of Materials Science and Engineering (MSE), part of its School of Engineering.

In the fall of 2012, UConn's materials science program, formerly part of the Department of Chemical, Materials, and Biomolecular Engineering, became one of the school's newest departments. Alpay, who had served as the program's director, was nominated by the faculty to become the department head. He says he expects his new role to be demanding, but is looking forward to the challenge thanks to the support he's received from his peers.

"My major goal is to work with my colleagues toward bringing a center of excellence to UConn MSE," he says. His plans include increasing undergraduate enrollment from its current size of approximately 130 to 200, which would put the department in the top five percent of MSE departments nationally, and to strengthen ties with industry.

"Connecticut is the home to several [large] companies, including United Technologies Corp., GE Industry Solutions, Stanley Black & Decker, and Electric Boat," he explains. "All of these companies work on problems related to materials



PAMIR ALPAY

synthesis [and] processing, characterization, and properties measurements. Considering the wide spectrum of expertise covered by UConn MSE faculty, I believe that we can play a significant role in the technical, and thus economic, development

of such companies and the state of Connecticut."

Alpay became interested in metallurgy and materials science and engineering thanks to his aunt and uncle, mechanical engineers who worked in the steel and aluminum industries. He was attracted to a career in academia by his longtime interest in research. His experiences at the Clark School assured him he'd made the right decision.

"Interacting with truly superb professors at UMD clinched it," he says. "I had the pleasure of working with eminent faculty including [former and current MSE] Professors [**Alexander**] Roytburd, [**Ramamoorthy**] Ramesh, [**Manfred**] Wuttig, and [**Richard**] Arsenault...[who are] widely recognized for their contributions to the physics of functional materials nationally and internationally...I am extremely grateful for their guidance and encouragement." He describes Roytburd, his advisor, as his "mentor and biggest supporter," and cites postdoctoral research with Ramesh as an important factor in launching his academic career.

Alpay, who holds a joint appointment with UConn's Department of Physics, is the director of the Functional Materials Group, which specializes in thin films of functional oxides and smart materials, and the relationships between their microstructures, defects, and properties. His early work led to the development of temperature insensitive, dielectrically tunable devices for telecommunications applications. His current work focuses on conducting oxides, polarizable semiconductors, and electrocaloric materials.

Since joining UConn in 2001, Alpay has received numerous honors and awards, including the United Technologies Corp. Professorship in Engineering Innovation,

the Outstanding Junior Faculty Award, and a NSF Early Career Development (CAREER) Award. In 2012, he was elected a member of the Connecticut Academy of Sciences and Engineering.



MSE HOSTS LEAD ACADEMY

This summer, MSE joined forces with the Clark School's Women In Engineering program to host a Leadership Enhancement, Application and Design (LEAD) Academy. LEAD Academies give high school students the opportunity to immerse themselves in an engineering discipline for a day, conducting experiments, learning fundamental concepts, and meeting students, faculty, staff and alumni.

MSE associate professors **John Cumings** and **Oded Rabin**, MSE graduate students **Colin Gore** and **Amy Marquardt**, and associate director of student services Dr. **Kathleen Hart** introduced the field of materials science and lead the students through hands-on experiments to illustrate core concepts. Participants created large models of crystal structures using gumdrops and toothpicks, calculated the hardness of several types of chocolate using an impact test, learned about current materials research, and tested solar cell performance under different kinds of light.



A. JAMES CLARK
SCHOOL OF ENGINEERING

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ABOUT THE COVER IMAGE

A BATTERY MADE OF *WHAT?* ASSISTANT PROFESSOR LIANGBING HU AND HIS GROUP ARE USING WOOD FIBERS COATED WITH TIN TO CREATE A SUPPLE SODIUM-ION NANOBATTERY CAPABLE OF WITHSTANDING REPEATED SWELLING AND SHRINKING AS ELECTRONS MOVE IN AND OUT. FOR MORE INFORMATION, SEE THE STORY BELOW. PHOTO COURTESY OF THE MARYLAND NANOCENTER.

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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A Battery Made of Wood?

WOOD FIBERS HELP NANOSCALE BATTERIES KEEP THEIR STRUCTURE

Courtesy of and based on the original by Martha J. Heil, Maryland NanoCenter

A sliver of wood coated with tin could make a tiny, long-lasting, efficient and environmentally friendly rechargeable battery.

But don't try it at home yet—the components in the battery tested by scientists at the University of Maryland are a thousand times thinner than a piece of paper. The experimental device also uses sodium instead of the lithium commonly found in rechargeable batteries, which makes it environmentally benign. Sodium, however, doesn't store energy as efficiently as lithium, so consumers won't

see this battery in their cell phones—instead, its low cost and common materials make it ideal for storing huge amounts of energy at once, such as solar energy at a power plant.

Existing batteries are often created on stiff bases, which are too brittle to withstand the repeated cycles of swelling and shrinking that occur as electrons are stored and used up. Department of Materials Science and Engineering (MSE) assistant professor **Liangbing Hu** and Department of Mechanical Engineering (ME) associate professor **Teng Li**, members of the University of Maryland Energy Research Center, found

that wood fibers are supple enough to let their sodium-ion battery last more than 400 charging cycles, which puts it among the longest lasting nanobatteries.

"The inspiration behind the idea comes from the trees," says Hu. "Wood fibers that make up a tree once held mineral-rich water, and so are ideal for storing liquid electrolytes, making them not only the base but an active part of the battery."

Lead author Dr. **Hongli Zhu** (MSE) and her colleagues noticed that after charging and discharging the battery hundreds of

continues page 7