FALL 2011

TECHTRACKS

MATERIALS SCIENCE AND ENGINEERING

A. JAMES CLARK SCHOOL *of* ENGINEERING

UNIVERSITY OF MARYLAND 1856

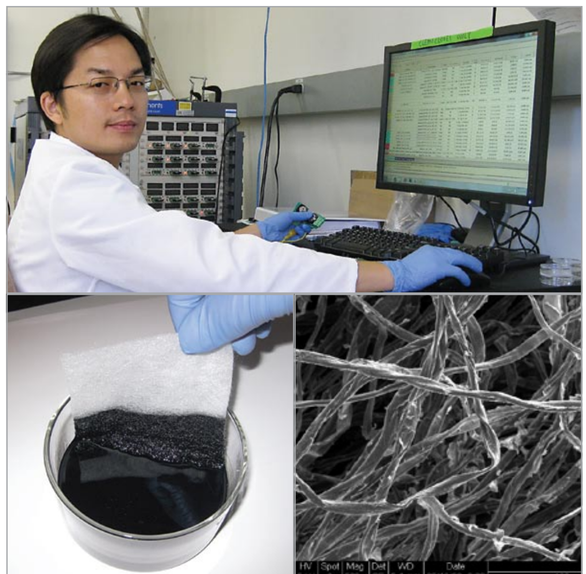
www.mse.umd.edu

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:

Liangbing Hu Joins MSE, UMD Energy Research Center

The A. James Clark School of Engineering and the Department of Materials Science and Engineering (MSE) are pleased to welcome their newest faculty member, Assistant Professor **Liangbing Hu**. Hu will also be a member of the University of Maryland Energy Research Center (UMERC).



TOP: ASSISTANT PROFESSOR **LIANGBING HU**. BOTTOM: COTTON COATED WITH NANOMATERIALS USING NANO-INK PROCESSING, WHICH CAN BE USED FOR TEXTILE BATTERIES AND SUPER-CAPACITORS: DEMONSTRATION OF A SCALABLE INK-BASED PROCESS (LEFT), AND A SCANNING ELECTRON MICROGRAPH (SEM) SHOWING THE MORPHOLOGY OF THE COATED COTTON (RIGHT).

Hu, who earned his Ph.D. in physics from the University of California, Los Angeles (UCLA) in 2007, recently completed a postdoctoral fellowship in the Department of Materials Science at Stanford University. He arrived on campus in August 2011.

The University of Maryland's "outstanding" shared research facilities and centers were part of the reason Hu chose to come to the Clark School, and its people were the other. "The MSE program at UMD is strong and putting a lot of emphasis on energy research," he explains. "I will have the ability to work with the best students and colleagues here."

Hu's research group will focus on nanoscale devices for applications in energy and electronics, with an emphasis on materials design and fabrication. "I have many projects in mind," he tells us. "One goal is to [create] low-cost, high-efficiency and high-energy solar cells through roll-to-roll printed nanostructures. Another goal is to come up with high-performance energy storage systems for electric vehicles through nanoengineering. I am extremely excited about energy research and flexible

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chair's MESSAGE

ROBERT M. BRIBER

CLEARLY THE MATERIALS SCIENCE AND ENGINEERING DEPARTMENT AT THE UNIVERSITY OF MARYLAND IS ON A ROLL!

Our undergraduate enrollment has tripled in the past three years as students have realized that the field of materials science and engineering is at the frontier of many of the most exciting new technologies.

The sponsored research expenditures for the Department were more than $10 million for the fiscal year that ended in June. Exciting new research areas are being developed—see our articles "Liquid Crystal/Nanoparticle Mix Lays Groundwork for New Photovoltaics" (p. 2); "Pocket Change Spectroscopy," about a cheap and novel way to improve SERS (p.4); "Smaller Is Not Always Better," about advances in modeling thermoelectric materials (p. 5); and "Bad Virus Put to Good Use," about virally-templated, performance-boosting electrodes (p. 6). Our faculty and students are winning awards for scholarship, research and entrepreneurship, which is a testament to the innovate work occurring in the Department.

The Department is particularly excited by the arrival of our newest faculty member, Professor **Liangbing "Bing" Hu**, coming from a postdoctoral research position at Stanford University. (See our cover story and back cover.) Hu has lead groundbreaking research projects on conductive films made from carbon nanotubes, paper-based energy storage systems (batteries and supercapacitors), and new nanostructured materials for lithium ion batteries. In addition to publishing his work in peer-reviewed technical journals, Professor Hu's research has been highlighted in the *New York Times, BBC News* and *Scientific American.*

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

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

Robert M. Briber
Professor and Chair, MSE

NEW FACULTY MEMBER, continued from page 1

electronic devices based on nanoscale materials and printing methods."

Hu says his ideas and projects are focused on solving what he describes as society's "practical energy problems" through the development of new electronic technologies and solving fundamental problems in nanoscale energy research. He believes his work will ultimately set the stage for advancements in many consumer products and services, from better touch screens and batteries to more affordable electric vehicles and cheaper electricity.

Hu is currently recruiting members for his research group. Undergraduates, graduate students, postdocs and visiting scholars from a variety of disciplines are invited to learn more by visiting his homepage at **www.mse.umd.edu/facstaff/hu.html**.

LIQUID CRYSTAL/NANOPARTICLE MIX LAYS GROUNDWORK FOR NEW PHOTOVOLTAICS

Nanoparticles mixed with organic liquid crystals could be the cost-effective future of photovoltaic (solar powered) devices, according to a recent study published by MSE professors **Luz J. Martínez-Miranda** and **Lourdes G. Salamanca-Riba**. The work is the first to demonstrate a hybrid photovoltaic system made from nanoparticles and liquid crystals, and the first to prove that a specific ordering of the liquid crystals with the nanoparticles results in higher electrical currents.

The photovoltaic materials used in today's solar cells are solid state and expensive, two factors which have prevented their widespread adoption. The development of an effective liquid crystal-based photovoltaic would not only result in more affordable products, but also more design options, since the liquid crystal could be housed in flexible or custom-shaped containers, or possibly applied as a coating.

In their study, Martínez-Miranda and Salamanca-Riba show that adding nanoparticles made of zinc oxide (ZnO), a semiconductor, to an organic liquid crystal increases the flow of current.

"We found that as we increased the concentration of the nanoparticles, the mutual ordering of the liquid crystals and the nanoparticles would also increase," says Martínez-Miranda. "The liquid crystals align parallel to the electrode surface, with the nanoparticles in between them, creating more direct passages for electrical current in the system. The higher the electron flow, the greater the efficiency and the more current generated. At the optimum level of concentration we've discovered, the system we've created produces three times more current than an ordered liquid crystal could on its own."

Martínez-Miranda and Salamanca-Riba's solution does have some drawbacks, at least for now. "Solid state photovoltaics are currently about 45% more efficient," says Salamanca-Riba, "but a liquid crystal-based system would be a lot cheaper."

One of the reasons for the difference in efficiency is that ZnO, the semiconductor the pair used for their nanoparticles, conducts when exposed to blue and near ultra-violet light, which comprises only a small portion of the visible spectrum produced by the sun. The liquid crystals used absorb in the green.

"In actual production," Salamanca-Riba explains, "an effective liquid crystal photovoltaic system would require the development of nanoparticles from materials that absorb a greater range of visible light, or a combination of materials that cover the entire spectrum. We chose zinc oxide for our study because its properties are well known and we can precisely control its nanoparticle size, which is important in maintaining the ordering of the liquid crystal and the consistency of the current generated. It lets us create a reliable system that can help us understand the mechanics of a hybrid liquid crystal/nanoparticle photovoltaic, and act as a platform for future development."

The liquid crystal was chosen for similar reasons, Martínez-Miranda adds, even though it too would not be ideal in a production environment. "The properties of the liquid crystal we used are very well known, and how to control its alignment in a film is well established."

In the current phase of their research, the pair is replacing their vertical stacks of ZnO nanoparticles with nanowires also made of ZnO or other materials, in the hope that their long, thin shapes and ability to be fastened to a substrate will make ordering the system even more effective. Preliminary results using nanorods or nanowires of ZnO show an increase in the flow of current.

For more information, see "Liquid crystal-ZnO nanoparticle photovoltaics: Role of nanoparticles in ordering the liquid crystal." L. J. Martínez-Miranda, Kaitlin M. Traister, Iriselies Meléndez-Rodríguez, and Lourdes Salamanca-Riba. Applied Physics Letters 97(1), 2010.

RUBLOFF PART OF RESEARCH PARTNERSHIP WITH TRENTO, ITALY

MSE professor and Maryland NanoCenter director **Gary Rubloff** and MSE affiliate faculty member **Reza Ghodssi** (Electrical and Computer Engineering and director, Institute for Systems Research [ISR]) are part of group of Clark School faculty specializing in systems research that will strengthen ongoing collaborations and engage in new ones with their counterparts in the Autonomous Province of Trento, Italy. ISR and the University of Maryland's long-standing and successful relationship with researchers from Trento led to a formal cementing of the partnership in May 2011.

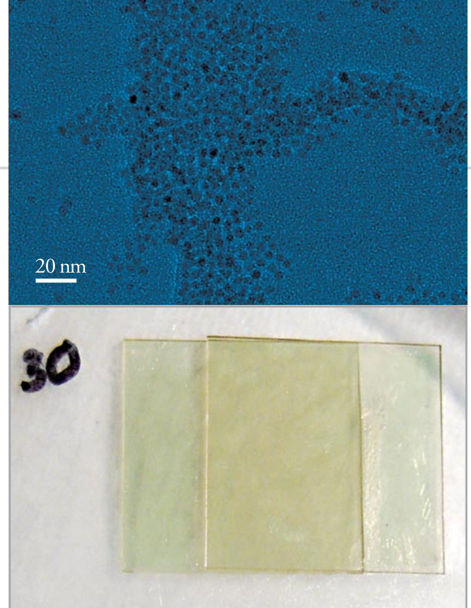
A series of overseas exchange visits fostered the development of two key agreements. Most recently, Ghodssi was part of a delegation of Maryland researchers and staff that attended a technical workshop and extensive laboratory tours in Trento.

The research and education role of the University of Trento is particularly significant, and a memorandum of understanding between the University of Maryland and the University of Trento is being signed. A second memorandum of understanding between the State of Maryland and the Autonomous Province of Trento is in the works. The partnership is beginning with research, and an education component will be added in the near future.

Specific, strategic research topic areas are being defined to build significant collaborations, while work in three existing topic areas will continue. New projects will be added as the partnership develops.

Rubloff, Ghodssi and their colleague **Salvatore Iannotta** (Consiglio Nazionale delle Ricerche) will lead ongoing efforts in the renewable energy, renewable energy storage, and nanomaterials group.

Participants are committed to future four- to six-month bi-directional student exchanges, two- to three-month researcher and professor exchanges, and seed-funded collaborations with matching funds from the Autonomous Province of Trento, the European Union, the State of Maryland, and the United States federal government.



HYBRID PHOTOVOLTAICS: TOP: ZnO NANOPARTICLES DESIGNED BY PROFESSORS **LUZ MARTÍNEZ-MIRANDA** AND **LOURDES SALAMANCA-RIBA**. BOTTOM: SAMPLE ELECTRODE MADE OUT OF ZnO NANOPARTICLES SUSPENDED IN LIQUID CRYSTAL BETWEEN TWO SLIDES. CURRENT WAS RUN THROUGH SAMPLES CONTAINING DIFFERENT CONCENTRATIONS OF NANOPARTICLES TO DETERMINE THE MIXTURE THAT GENERATES THE GREATEST FLOW OF CURRENT.

ISR is leading the U.S. effort on behalf of the University of Maryland and the University System of Maryland, while the Autonomous Province of Trento coordinates efforts overseas. The leading research and education collaborators in Trento are the University of Trento, the Consiglio Nazionale delle Ricerche, and Fondazione Bruno Kessler.

OEHRLEIN, PHANEUF PAPER AMONG AVS' MOST DOWNLOADED

A paper by MSE professors **Gottlieb Oehrlein** and **Ray Phaneuf** and colleague **David Graves** (University of California, Berkeley) is among the most downloaded from the American Vacuum Society's digital library.

"Plasma-polymer interactions: A review of progress in understanding polymer resist mask durability during plasma etching for nanoscale fabrication," originally published in the *Journal of Vacuum Science and Technology B,* 29, 010801 (2011), focuses on plasma-polymer interaction mechanisms during pattern transfer by plasma etching, in particular the challenges faced when manufacturing devices below 30 nanometers in size.

"POCKET CHANGE SPECTROSCOPY" IMPROVES DETECTION OF TOXINS, EXPLOSIVES

New research from the Clark School showing how surface-enhanced Raman spectroscopy (SERS), a highly-sensitive technique used to detect the merest traces of targeted materials, can be made more affordable and more portable by replacing one of its components with a chemical reaction applied to pocket change, was highlighted in *Chemical & Engineering News*.

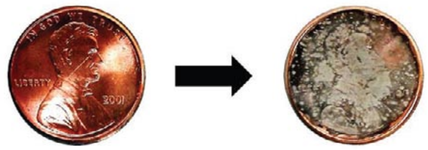
The article covered a contributed talk given at the 241st National Meeting of the ACS by BioE graduate student **Jordan Betz**, titled "SERS on a dime: Galvanic displacement as a rapid, robust, and simple method for SERS substrate fabrication." Working with Betz on the project is his advisor, MSE professor **Gary Rubloff (**Director, Maryland NanoCenter).

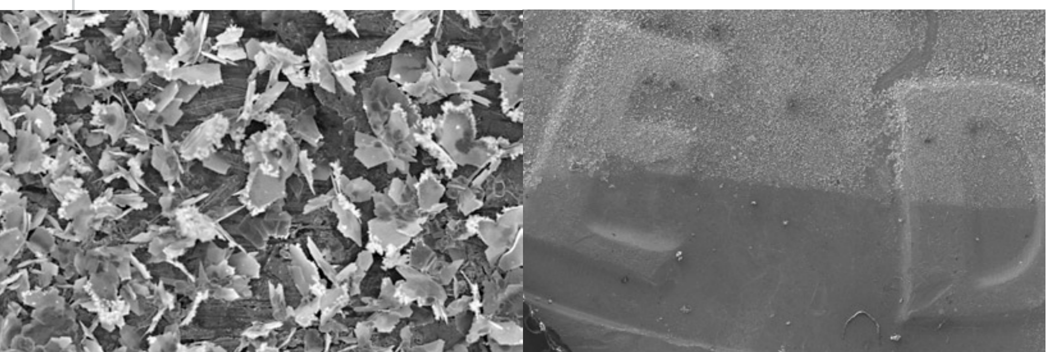
Raman spectroscopy is used to detect and identify substances which may only be present in minute quantities measured in molecules. When light from a laser floods a sample in a sensor, it scatters when it hits the molecules present. Since every kind of molecule scatters the light in its own unique way, scientists can tell what is present, and in what quantity, by analyzing the resulting spectrum. Surface-enhanced Raman spectroscopy takes the process a step further by placing the samples on specially-designed substrates (metal surfaces) capable of greatly intensifying the scattered light, allowing the detection of even tinier traces of a target substance.

While this makes SERS a powerful sensor, its use has been limited by the difficulty of making the substrates, and the cost and short shelf-life of prefabricated ones. Designing an affordable, easy-to-use system for use in the field has been a challenge. Betz and Rubloff think they've found one way around the problem by developing a technique that can use ordinary metal objects like coins as substrates.

In his presentation, Betz described how ordinary coins interact with a solution of silver nitrate in a spontaneous electrochemical process called galvanic displacement. The silver ions in the solution diffuse into the surface of a coin, where they steal electrons from the atoms of copper or nickel. This causes the silver ions to lose their charge and become solid silver atoms, creating a starting point from which micro- and nanoscale crystal structures begin to blossom. The properties of the crystals can be controlled by changing the reaction conditions. The copper and nickel atoms, which convert to ions as they lose their electrons to the silver, diffuse outward into the solution.

Betz, Rubloff and their colleagues found that when exposed to the Raman spectrometer's laser, the combination of silver crystals and the roughness of the coins' surfaces created a very high, localized electromagnetic field that intensified the scattering signal returned by a factor of 109, allowing them to detect lower amounts of a target molecule than they could with normal Raman spectroscopy alone. The coins even outperformed high-tech substrates made with state-of-art equipment in the lab.





"BUDDY, CAN YOU SPARE MY RAMAN SPECTROMETER A DIME?" LEFT: MICRO- AND NANOSCALE SILVER PLATES GROW OUTWARD FROM THE SURFACE OF A DIME. MANY OF THE EDGES OF THESE PLATES TERMINATE IN SMALLER, SHARP FEATURES THAT GREATLY ENHANCE THE RAMAN SCATTERING SIGNAL FROM MOLECULES THAT ADSORB TO THEIR SURFACES. RIGHT: THE EDGE OF A DROPLET OF SILVER NITRATE ON A DIME. THE LIGHTER AREA IS WHERE A GALVANIC DISPLACEMENT HAS OCCURRED AND SILVER CRYSTALS HAVE GROWN.

"Interestingly, the low-tech approach worked best," says Betz. "We hypothesized that the roughness and oxidation on the surface of circulated coins might create more sites at which the silver crystals could grow. To test this, we evaporated very thin films of smooth, unoxidized copper and nickel onto glass slides, then subjected them to the galvanic displacement reaction. In every case, the coins and their crystals were more effective at increasing the scattering."

The process does not deface the currency. "The silver crystals that grow on the coins are so weakly attached you can use scotch tape, a tissue, or even water to remove them," Betz explains. "After cleaning up the coins, they don't look or behave any differently. The amount of copper or nickel displaced by the silver is miniscule. Kicking a coin down the street would probably have more of an effect on its mass and cosmetic appearance."

Using substrates made on common metal objects, he says, will provide new opportunities to develop remote and portable SERS-based sensors that could be used to detect toxins, explosives, and contaminants in groundwater and food, as well as identify specific viruses and bacteria.

"The portability of the coins coupled with the simplicity of the reaction make the possibility of remote, field use of SERS a distinct possibility," says Betz. "For example, other researchers have shown that SERS can be performed using a laser pointer as the excitation source. Hand-held Raman spectrometers are available on the market, and we believe it's only a matter of time before someone develops a Raman spectrometer attachment for a smartphone. Using our method of substrate fabrication, you could have your spectrometer in one pocket, and your SERS substrate in the other."

SMALLER IS NOT ALWAYS BETTER: A NEW MODEL FOR THERMOELECTRIC MATERIALS

No one is happy about rising gas prices, and to make matters worse, up to 60 percent of each gallon is wasted, lost as heat that pours out of the exhaust pipe. But what if some of that heat could be collected and converted back into electricity that can recharge the battery that powers the lights, wipers, power steering, or even the electric motor in a hybrid vehicle?

The technology to do just that exists, but it's still a work in progress. The solution lies in thermoelectric devices, and MSE graduate student **Jane Cornett** and her advisor, Assistant Professor **Oded Rabin** (joint; Institute for Research in Electronics and Applied Physics), are challenging previous assumptions about the behavior of the nanoscale materials used to build them. Create better materials, they say, and cars will get more out of that expensive fossil fuel. But contrary to the common assumption in nanotechnology, "better" in this case may not always mean "smaller." That realization may change the way engineers develop future thermoelectric devices.

A material whose response to a change in temperature generates electric potential, or vice versa, exhibits what is known as the thermoelectric effect. Thermoelectric devices can generate electricity when heated by an external source, or quickly cool or heat their environment when powered with electricity.

So why doesn't every car have a thermoelectric power generator?

"The reason thermoelectric devices have so far been limited to niche markets is that their efficiency is still too low," Cornett explains. "The goal of our work is to design thermoelectric materials that convert energy from one form to another more efficiently so we can promote the widespread use of products that recycle waste heat and effectively reduce our consumption of fossil fuels."

For example, cars manufactured or retrofitted with a thermoelectric device placed around the exhaust pipe can use waste heat to generate electricity, improving their overall miles per gallon, especially when a power-draining system like the air conditioning is in use. If the device is too bulky and inefficient, however, it will consume more energy than it contributes.

To tackle the problem, Cornett and Rabin had to challenge some popular theories.

"Previous models told us that the use of nanomaterials at small dimensions would lead to an improvement in power generation efficiency," says Cornett. "The models also predicted that the smaller the nanostructure, the more significant the improvement would be. In practice, people weren't seeing the gains they thought they should when they designed thermoelectric devices with nanoscale components, which indicated to us that there might be an issue with the interpretation of the original models."

Cornett and Rabin have presented a revised thermoelectric performance model that confirms that smaller is not always better. Using advanced computer modeling to investigate the potential of thermoelectric nanowires only 100 to 1000 atoms thick (about 1000 times smaller than a human hair), they demonstrate that in the set of the tiniest nanowires, measuring 17 nanometers or less in radius, decreasing their radii does result in the increased thermoelectric performance previous models predict. In nanowires above 17 nanometers in radius, however, an improvement is seen as the radius increases.

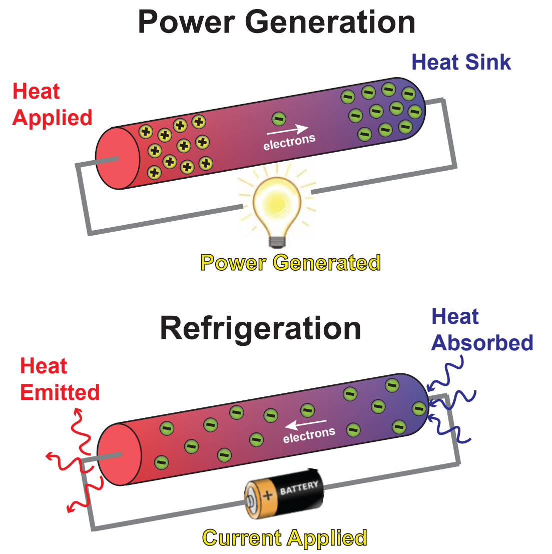
"The surprising behavior in the larger size range demonstrates that a different physical mechanism, which was overlooked in previous models, is dominant," says Cornett.

"People were looking for solutions in the wrong places," says Rabin. "We've created a better understanding of how to search for the best new materials."

Thermoelectric devices are currently used in a few consumer products, including refrigerators and CPU coolers in computers. They could eliminate the need for fluorocarbon refrigerants, giving rise to fluid- and compressor-free cooling systems that pose fewer health and environmental hazards.

Cornett and Rabin's research is supported in part by the Minta Martin Foundation and the ARCS Foundation. The work was recently published in *Applied Physics Letters.*

For more information, see "Thermoelectric figure of merit calculations for semiconducting nanowires." Jane E. Cornett and Oded Rabin. Applied Physics Letters 98(1), 182104 (2011).



THE TWO TYPES OF THERMOELECTRIC EFFECTS: THE SEEBECK EFFECT (TOP) AND THE PELTIER EFFECT (BOTTOM).

WHEN A TEMPERATURE GRADIENT IS APPLIED TO AN N-TYPE THERMOELECTRIC MATERIAL, ELECTRONS MOVE FROM THE HOT SIDE TO THE COLD SIDE, CREATING A POTENTIAL DROP. WITH THIS ARRANGEMENT, THERMOELECTRIC MATERIALS CAN BE USED TO GENERATE POWER FROM WASTE HEAT.

IF ON THE OTHER HAND A CURRENT IS APPLIED TO THE MATERIAL, EXCESS HEAT WILL BE EMITTED AT ONE CIRCUIT JUNCTION (THE HOT SIDE) AND ABSORBED AT THE OTHER JUNCTION (THE COLD SIDE), CREATING A TEMPERATURE GRADIENT. IF CURRENT IS APPLIED IN THE OPPOSITE DIRECTION, THE HOT AND COLD SIDES WILL BE REVERSED. WITH THIS SET-UP, THERMOELECTRIC MATERIALS CAN BE USED AS HEATERS AND COOLERS.

UMD, NIST EXPAND ALLIANCE

A longstanding partnership between the University of Maryland (UMD) and a federal agency known for advancing industrial competitiveness and cutting-edge science is set to grow even stronger.

Patrick Gallagher, under-secretary of commerce and director of the National Institute of Standards and Technology (NIST), visited the university in April 2011 to meet with faculty researchers and administrators, previewing his vision for expanding their robust research and educational collaborations.

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NIST, continued from page 5

"We have a rich alliance, aided greatly by our close proximity, and also by our common goal of providing scientific leadership, innovation and economic prosperity to the region and the nation," Gallagher told the audience.

Gallagher spoke at length about the need for the nation's research community to be the driving force behind innovation. NIST and UMD are already involved with science and outreach efforts designed to help U.S. manufacturers create and retain jobs, increase profits and save time and money through the Maryland Technology Enterprise Institute's Manufacturing Assistance Program (UMMAP). UMMAP, part of NIST's Manufacturing Extension Partnership, is one of more than 70 not-for-profit centers nationwide that provide consulting services to small and medium-sized companies.

Gallhager also highlighted the established collaborative programs already in place with the university—including research in neutron scattering, quantum physics and nanotechnology—and previewed new research thrusts at NIST that match well with the university's strengths, including work in biophysics, cybersecurity, cloud computing and health information technology.

"Our scientific community is well-positioned to align ourselves with any new priorities at NIST," says **Norma Allewell**, UMD's interim vice president for research. "We really couldn't ask for a better opportunity, both for our faculty researchers and for our graduate students."

One successful partnership is a NIST-funded fellowship program that sends 50 fellows per year to work at NIST laboratories in Gaithersburg, Md., and Charleston, S.C., where they can use the latest technologies to study weight and measurement. Funded last year with $15 million in federal stimulus funds, the fellowship program, which is open to all qualified applicants, is administered by the university's Institute for Research in Electronics and Applied Physics.

In another collaborative effort, ongoing for almost two decades, faculty, postdocs and students in the A. James Clark School of Engineering's Department of Materials Science and Engineering (MSE) have worked with the NIST Center for Neutron Research. There, groundbreaking research in neutron scattering—a powerful method for characterizing the nanoscale structure of solids, liquids and macromolecules—is advancing science and technology projects crucial for maintaining U.S. leadership in the world economy.

"The opportunity for Maryland scientists and students to use the world-class research facilities at NIST is unparalleled," says MSE professor and chair **Robert M. Briber**, the principal investigator of several NIST-funded projects involving neutron scattering research.

At the Institute for Bioscience and Biotechnology Research in Shady Grove, Md., the university partners with NIST and others on research involving nanobiotechnology, drug and vaccine discovery, and disease processes.

A key component of the alliance between NIST and UMD is the Joint Quantum Institute, or JQI, focused on advancing a basic understanding of the universe, as well as developing technologies for cryptography, advanced computing and the design and use of sensors.

A NIST-funded Laboratory for Advanced Quantum Science, part of the JQI, is set for completion in 2013, part of the university's new $128 million Physical Sciences Complex now under construction.

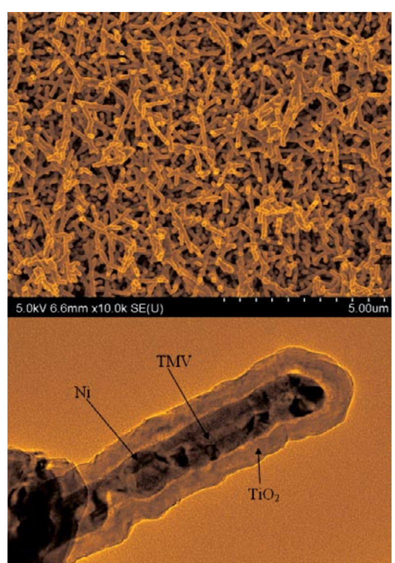
Story courtesy of Thomas R. Ventsias, University Communications.

BAD VIRUS PUT TO GOOD USE: BREAKTHROUGH BATTERIES

Viruses get a bad rap—and rightly so. The ability of a virus to quickly and precisely replicate itself makes it a destructive scourge to animals and plants alike. Now an interdisciplinary team of researchers in the A. James Clark School of Engineering and the College of Agriculture and Natural Resources at the University of Maryland—including MSE graduate student **Konstantinos Gerasopoulos** *(see related story, p. 7)*—is turning the tables, harnessing and exploiting the "self-renewing" and "self-assembling" properties of viruses for a higher purpose: to build a new generation of small, powerful and highly efficient batteries and fuel cells.

The rigid, rod-shaped tobacco mosaic virus (TMV), which under an electron microscope looks like uncooked spaghetti, is a well-known and widespread plant virus that devastates tobacco, tomatoes, peppers, and other vegetation. But in the lab, engineers have discovered that they can harness the characteristics of TMV to build tiny components for the lithium ion batteries of the future.

TMV's nanostructure is the ideal size and shape to use as a template for building battery electrodes. Its self-replicating and self-assembling biological properties produce structures that are both intricate and orderly. The Maryland research team has found that they can modify the TMV rods to bind perpendicularly to the metallic surface of a battery electrode and arrange them in specific patterns. The rods are coated with a conductive thin film that acts as a current collector, and then another layer of material that participates in the battery's electrochemical reactions. The tiny, dense forest of coated rods creates an 80-fold increase in the electrode's surface area and up to a 10-fold increase in its energy storage capacity over standard lithium ion batteries, enabling fast charge/discharge times and a longer life. Because the TMV can be programmed to bind directly to metal, no other binding agents are required, making the electrodes lighter, stronger and less expensive than conventional parts. There is no risk of them transmitting the TMV virus, which is rendered inert by the manufacturing process.



VIRUS-BASED ELECTRODES: ABOVE: SEM IMAGE OF Ni/TiO_2 NANOCOMPOSITE ELECTRODE. BELOW: TEM IMAGE OF A CROSS-SECTION OF AN INDIVIDUAL NANOROD SHOWING THE CORE/SHELL NANOSTRUCTURE.

LEFT TO RIGHT: PROFESSOR **REZA GHODSSI**, **KONSTANTINOS GERASOPOULOS**, AND MSE PROFESSOR AND CHAIR **ROBERT M. BRIBER**.

"The resulting batteries are a leap forward and will be ideal for use not only in consumer electronic devices, but also in other technologies that have been limited so far by the size of their power source," says project leader and Gerasopoulos' advisor, **Reza Ghodssi**, MSE affiliate professor and director of the Institute for Systems Research. "For example, we can produce millimeter- or sub-millimeter-sized energy storage devices for use in large networks of tiny, wireless sensors that can be deployed to monitor security, agriculture, or the environment in remote locations."

Three distinct steps are involved in the team's patent-pending process to produce a TMV-based battery: modifying, propagating and preparing the TMV; processing the TMV to grow nanorods on a metal plate; and incorporating the nanorod-coated plates into finished batteries. The interdisciplinary team of Maryland scientists and their students, specializing in fields ranging from plant science and materials science to electrical and chemical engineering, is what makes each step possible.

First, genetically modified samples of the TMV that can be chemically coated with conductive metals are extracted from tobacco plants grown in the lab. It takes only a few plants to produce enough material from which to synthesize hundreds of battery electrodes. A solution containing the TMV is applied to a metal electrode plate. The genetic modifications program one end of the virus to attach to the plate, producing the forest of vertically aligned virus rods, which are then chemically coated with a conductive metal, mainly nickel. In the final step, nanocomposites of silicon and titanium dioxide are electrochemically deposited onto the metal-encased TMV.

The result is a new and unique electrode architecture in which each nanorod contains a conductive metal core and an active material shell. This architecture both stabilizes the fragile silicon coating and provides it with a direct connection to the battery electrode.

After the electrodes are complete, the team assembles them into experimental high-capacity lithium-ion batteries for testing.

"Our method is unique in that it involves direct fabrication of the electrode onto the current collector," explains one of the project's co-PIs, Assistant Professor **Chunsheng Wang** (Department of Chemical and Biomolecular Engineering [ChBE]). "This makes the battery's power higher, and its cycle life longer."

The use of the TMV virus in fabricating batteries can be scaled up to meet industrial production needs. The manufacturing process is simple, inexpensive, and renewable.

While the team's focus has been on batteries and energy storage, Ghodssi points out that the versatility of the TMV template will allow it to be used in the development of a variety of new technologies, including sensors for detecting explosives such as TNT, water-repellent surfaces, and micro- and nanoscale heat pipes.

In addition to Wang, Gerasopoulos and Ghodssi's collaborators include Ph.D. student **Xilin Chen** (ChBE); Associate Professor **James Culver** and research associate Dr. **Adam Brown** (Department of Plant Science and Landscape Architecture/Institute for Bioscience and Biotechnology); and Professor **Michael Harris** (Chemical Engineering, Purdue University). Funding for the research comes from the National Science Foundation, the Department of Energy Office of Basic Energy Sciences, the Maryland Technology Development Corporation, and the Laboratory for Physical Sciences at the University of Maryland.

The group's work on the TMV battery project has been covered by *Discovery News* and *Nanowerk,* the most popular nanotechnology industry news web site.

For more information, see:

Chen et. al. "Virus-Enabled Silicon Anode for Lithium-Ion Batteries, ACS Nano, 2010, 4 (9), 5366–5372.

Chen et. al. "A Patterned Silicon Anode Fabricated by Electrodeposition of Si on a Virus Enabled 3-Dimensional Current Collector," Advanced Functional Materials, 2010, 21 (2), 380-387.

GERASOPOULOS WINS DEAN'S DOCTORAL RESEARCH AWARD FOR WORK ON VIRALLY STRUCTURED NANO-ELECTRODES

MSE graduate student **Konstantinos Gerasopoulos** was awarded first place and a prize of $1500 in the 2011 Dean's Doctoral Research Award Competition for his dissertation, "Integration and Characterization of Tobacco Mosaic Virus-Based Nanostructured Materials in Three-Dimensional Microbattery Architectures."

Clark School dean **Darryll Pines** created the Dean's Doctoral Research Award Competition in 2009 to give top student researchers special recognition that will be valuable in launching their careers, and to show all students the importance of high quality engineering research. Students submit their work through competitions at the unit level. Gerasopoulos was selected to represent MSE in the competition after winning the MSE Graduate Research Award in April 2011.

Gerasopoulos, advised by Institute for Systems Research director, MSE affiliate professor, and Herbert Rabin Distinguished Professor **Reza Ghodssi** (Electrical and Computer Engineering), works on a project that seeks to turn the normally harmful tobacco mosaic virus (TMV) into a template used to build millimeter- or sub-millimeter-sized energy storage devices. The technology has applications in battery electrodes, sensors, and other micro- and nanoscale devices. *(See related story, p. 6.)*

The research has garnered Gerasopoulos awards, recognition in the academic community, speaking engagements, and media coverage. His previous honors include a paper being named a "Highlight of 2008" by the *Journal of Micromechanics and Microengineering,* an invitation to present in the Massachusetts Institute of Technology's 2010 Micro/Nano Seminar Series, and a Best Poster Award at the 2010 Mid Atlantic Micro/Nano Alliance Symposium.

researchNEWS

RABIN, RUBLOFF, TAKEUCHI, AND WACHSMAN PRESENT AT SUSTAINABILITY WORKSHOP

MSE professors **Oded Rabin**, **Gary Rubloff**, **Ichiro Takeuchi**, and **Eric Wachsman** presented their work on fuel cells, energy storage, reclaimed waste heat, and thermoelastic cooling at the 2011 Clark School Engineering Sustainability Workshop, held in honor of Earth Day. The workshop invites 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, and to minimize its negative impact.

In "Electrons Feel the Heat: Materials for Thermal Energy Scavenging," Rabin described how his group is exploring how to capture waste heat, which accounts for about 60% of the energy produced by the fuels we burn, and convert it into electricity or other useful forms of energy. *(See related story, p. 5.)* The group is investigating the fundamental science of the thermoelectric effect, which defines how electron transport and heat transport couple in materials. This has led to the development of devices that are used to increase the efficiency of energy usage. Thermoelectric devices can utilize heat normally lost to the environment to generate more electricity. As a result, there is an interest in placing thermoelectric devices in cars and power plants to produce more "work," or in the case of cars, miles per gallon. In particular, Rabin is studying how nanostructures express thermoelectric effects and in which conditions they perform better than normal materials.

In his presentation, "The Currency of the Energy Economy," Rubloff, the director of the Maryland NanoCenter, explained that the generation of clean and sustainable energy is only half of the equation: how we store and deliver that energy is just as important. Currently, there is no way to charge an electric car in the five minutes it would take to fill a gas tank. Sunlight and wind are intermittent.

"Electrical energy storage is to the energy world what currency—dollars, Euros, and yen—are to the economic world," he said, "a means to capture and hold value until needed at some other time."

Rubloff also discussed how the university's Nanostructures for Electrical Energy Storage (NEES) program, an Energy Frontier Research Center sponsored by the U.S. Department of Energy, is pursuing the science which will enable the next generation of electrical energy storage technology, directly based on nanotechnology. The NEES team is developing massive "forests" of nanowires composed of multiple materials that store and transport energy and maintain their stability while electrical charges are moved back and forth.

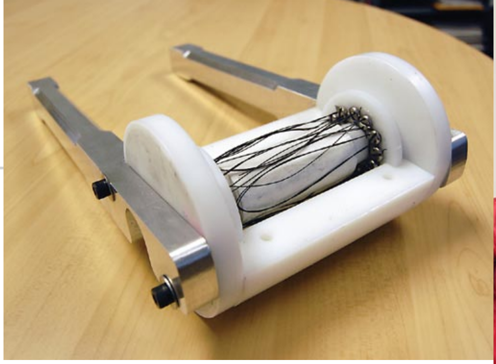
In his talk, "Thermoelastic Cooling: Shape Memory Alloys as a Novel Solid State Refrigerant," Takeuchi presented the latest developments in his group's efforts to design materials that can be used in more efficient cooling systems.

Takeuchi and his colleagues–including MSE professor **Manfred Wuttig**, MSE adjunct professor **Jun Cui**, and MSE research associate **Yiming Wu**–previously developed a two-state solid coolant that can take the place of fluids used in conventional refrigeration and air conditioning compressors. The alloy alternately absorbs or creates heat in much the same way as a compressor-based system, but uses far less energy, has a smaller operational footprint, and avoids the use of fluids with high global warming potential. A novel cooling system based on the technology was named the University of Maryland's Office of Technology and Commercialization's Physical Sciences Invention of the Year. The system was one of four chosen for top honors out of a field of over 130 cutting-edge new products invented and patented at the university in 2010.

The team is currently working on a cooling system design that employs commercially available thermoelastic wires. Using a simple hand-held device, Takeuchi demonstrated how one of these wires gave off heat when put under mechanical stress, and became cool when released. He also presented a 30W, hand-cranked water cooler based on the same technology.

In "Low Temperature Solid Oxide Fuel Cells: A Transformational Energy Conversion Technology," Wachsman (joint; Department of Chemical and Biomolecular Engineering), the director of the University of Maryland Energy Research Center, discussed his group's recent advances in the development of solid oxide fuel cells. These cells have the flexibility of operating on hydrogen or diesel fuel, which could make them feasible for use in vehicles before a hydrogen fuel infrastructure is in place, and allow them to remain functional after. His team is working on reducing the cells' operating temperature to 600°C or lower in order to make them safe for automobiles.

Wachsman also described his work on other types of fuel cells that could be used to power a home. Advances in cathode technology could provide ten times the power density—about 10W per cm^3—at half the operating temperature than the commercially available cells currently sold by Bloom Energy.



PHYSICAL SCIENCES INVENTION OF THE YEAR

ABOVE LEFT: THE FIRST DEMONSTRATION UNIT OF A 30W HAND-CRANKED THERMOELASTIC WATER COOLER, OPENED TO EXPOSE ITS THERMOELASTIC WIRES.

ABOVE RIGHT: AT THE INVENTION OF THE YEAR AWARDS, LEFT TO RIGHT: **NORMA ALLEWELL**, VICE PRESIDENT FOR RESEARCH AT THE UNIVERSITY OF MARYLAND; **JUN CUI**; **ICHIRO TAKEUCHI**; AND **AYATRI VARMA**, EXECUTIVE DIRECTOR OF THE OFFICE OF TECHNOLOGY COMMERCIALIZATION. (PHOTO BY MIKE MORGAN)

Video of all of the event's presentations can be accessed from the Clark School Engineering Sustainability Workshop web site at **eng.umd.edu/events/sustainability-workshop2011**.

SPACE HELPS NANOFILLER KEEP FLAMES AT BAY

If materials scientists accompanied their research with theme songs, a team from the National Institute of Standards and Technology (NIST) and the A. James Clark School of Engineering at the University of Maryland (UMD) might be tempted to choose the garage punk song "Don't Crowd Me"* as the anthem for the promising, but still experimental nanocomposite fire retardants they are studying.

That's because the collaborators, including Department of Materials Science and Engineering postdoctoral research associate **Xin Zhang**, have demonstrated that the more widely and uniformly dispersed nanoscale plates of clay are in a polymer, the more fire protection the nanocomposite material provides.

Writing in the journal *Polymer,* the team reports that in tests of five specimens—each with the same amount of the nanoscale filler (5 percent by weight)—the sample with the most widely dispersed clay plates was far more resistant to igniting and burning than the specimen in which the plates mostly clustered in crowds. In fact, when the two were exposed to the same amount of heat for the same length of time, the sample with the best clay dispersion degraded far more slowly. Additionally, its reduction in mass was about a third less.

In the NIST/UMD experiments, the material of interest was a polymer—a type of polystyrene, used in packaging, insulation, plastic cutlery and many other products—imbued with nanometer scale plates of montmorillonite, a type of clay with a sandwich-like molecular structure. The combination can create a material with unique properties or properties superior to those achievable by each component—clay or polymer—on its own.

Over the past decade, polymer-montmorillonite nanocomposites have attracted significant research and commercial interest. Studies have suggested that how the clay plates disperse, stack or clump in polymers dictates the properties of the resultant material. However, the evidence—especially when it comes to the flammability properties of the nanocomposites—has been somewhat muddy.

Led by NIST guest researcher and Department of Fire Protection Engineering research professor **Takashi Kashiwagi**, the NIST-UMD team subjected their clay-dispersion-varying samples to an exhaustive battery of characterization methods and flammability tests. Affording views from the nanoscopic to the microscopic, the array of measurements and flammability tests yielded a complete picture of how the nanoscale clay plates dispersed in the polymer and how the resultant material responded when exposed to an influx of heat.

The researchers found that with better dispersion, clay plates entangle more easily when exposed to heat, thereby forming a network structure that is less likely to crack and leading to fewer gaps in the material. The result, they say, is a heat shield that slows the rate of degradation and reduces flammability. The NIST team, led by **Rick Davis**, is now exploring other approaches to reduce flammability, including the use of advanced materials and novel coating techniques.

For more information, see: M. Liu, X. Zhang, M. Zammarano, J.W. Gilman, R.D. Davis and T. Kashiwagi. "Effect of Montmorillonite dispersion on flammability properties of poly(styrene-co-acrylonitrile) nanocomposites." Polymer. Vol. 52, Issue 14, June 22, 2011.

* *Keith Kessler, "Don't Crowd Me."*

Story courtesy of and adapted from the original by Mark Bello, National Institute of Standards and Technology.

ASHLEY LIDIE

studentNEWS

LIDIE WINS SMART SCHOLARSHIP

MSE graduate student and alumna **Ashley Lidie** (B.S. '10) has been awarded a Science, Mathematics And Research for Transformation (SMART) Scholarship by the Department of Defense (DOD).

The highly selective SMART program was established to support the education of the nation's future scientists and engineers, and to increase the number of civilian scientists and engineers employed by the DOD. Undergraduate and graduate students in Science, Technology, Engineering and Mathematics (STEM) majors who are accepted into the program receive a full scholarship, a cash award of $25,000–$41,000, health insurance and textbook allowances, and mentoring. While earning their degrees, SMART Scholars are assigned to a DOD laboratory, in which they serve paid summer internships. After graduation, they continue to work for the DOD as civilian employees engaged in theoretical or applied research for a period of at least one year.

Lidie, advised by MSE professor and University of Maryland Energy Research Center director **Eric Wachsman**, will begin her first internship at the U.S. Army Communications-Electronics Research Development Center at the Aberdeen Proving Ground in the summer of 2012. On campus, her work will focus on the processing of ceramic materials for solid oxide fuel cells.

Lidie became involved in research as an undergraduate, starting when MSE helped place her in what would become a three-year internship at the Army Research Laboratory after her freshman year. There, she worked on ceramic processing of transparent armor and other transparent materials, published her results, and developed a "hunger for more knowledge."

The experience, combined with a love for the environment, inspired her to

continues next page

SMART, continued from page 9

become involved in energy research as a graduate student, where she could apply her knowledge of ceramics to the design and fabrication of solid oxide fuel cells (SOFCs). And that, she says, brings her full circle, back to the Army and the SMART Scholarship.

"Fuel cells and batteries can be designed in a way that they can power a soldier's equipment without weighing him or her down," she explains. "This can allow for the implementation of new or enhanced technologies that are currently limited by their weight.

"Professionally, I want to have a career in which I can use materials science to increase the chances of bringing more soldiers home safely," she adds. "[The SMART] program has opened the door for me to do what I've always dreamed of—marry my love for materials science and the opportunity to help the American Warfighter. It will also allow me to focus on my work, knowing my future beyond my degree is already determined."

While her SMART scholarship will prepare her for her future, Lidie says her past experiences as a MSE undergraduate, including academic performance and her involvement in numerous student activities and societies, prepared her to win it. "The University of Maryland has set me up for success from the very beginning," she says. "If I had any advice to give, it would be to strive for more, do not be afraid to take on a new challenge, and embrace all this campus has to offer. The hard work will pay off!"

CORNETT NAMED ARCS SCHOLAR

MSE graduate student **Jane Cornett**, advised by Assistant Professor **Oded Rabin**, has received an Achievement Rewards for College Scientists (ARCS) Foundation graduate scholarship.

Cornett, who conducts her research in Rabin's Materials and Interface Nanotechnology Laboratory, studies thermoelectric materials, which can convert a temperature gradient into electricity, and vice versa. Thermoelectric devices can be used as generators that produce power from recovered waste heat, and as refrigerators. Her work to improve a model used to calculate the thermoelectric properties of semiconducting nanowires in relation to their radii recently earned her a Best Student Presentation Award from the Materials Research Society.

THE 2011 SENIOR CAPSTONE TEAM. FRONT ROW, LEFT TO RIGHT: PROFESSOR **RAY PHANEUF**, **NICHOLAS STRNAD**, **TRICIA ALWARD**, **ROBERT THOMPSON**, **COIT HENDLEY**, **IAIN KIERZEWSKI**, AND **WILLIAM SCHOENFELDER**. BACK ROW, LEFT TO RIGHT: **MICHAEL MEADOWS**, **TUNJI GODO**, AND **NINOSKA MORATIN**.

The ARCS Foundation provides science, medicine and engineering scholarships to outstanding students who are U.S. citizens contributing to the advancement of science and technology. Fellows are selected by representatives of the 52 U.S. academic institutions that the foundation supports, based on strict criteria and recommendations from departmental advisers and faculty, and receive a renewable award of $15K per year.

See p. 6 for a related story about a significant breakthrough in Jane's thermoelectric research.

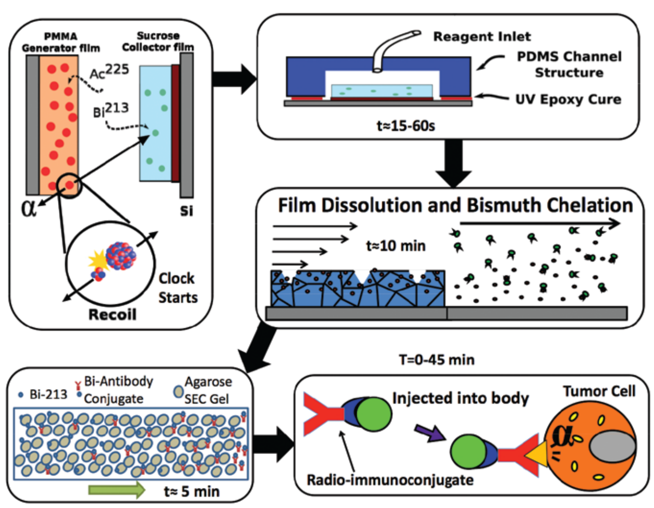
JONES WINS TMS SCHOLARSHIP

The Minerals, Metals & Materials Society (TMS) has awarded MSE junior **Ben Jones** its Materials Processing & Manufacturing Division Scholarship.

Each year, TMS offers two of the $2500 scholarships to sophomores or juniors majoring in metallurgical or materials science and engineering who focus on manufacturing, including product design, process control, production, and applied research. The recipients, known as MPMD Scholars, are invited to the society's annual meeting to accept their awards, and receive up to $500 for their travel expenses.

"Attending the TMS conference will help me to further understand what a career in MSE entails, and I'm very excited to have the opportunity to do so," says Jones.

From 2010-2011, Jones conducted undergraduate research in MSE professor and chair **Robert M. Briber**'s group, where he worked under MSE research associate Dr. **Xin Zhang** on a project studying the pattern formation and alignment of a block copolymer.



THE 2011 CAPSTONE TEAM'S LAB-ON-A-CHIP DEVICE FOR TARGETED ALPHA THERAPY, WHICH GENERATES BISMUTH^{213} FROM ACTINIUM^{225}, ATTACHES THE Bi^{213} TO ANTIBODIES IN A SPECIAL MIXING CHAMBER, AND EMBEDS THE RESULTING THERAPEUTIC IN AN AGAROSE SEC GEL THAT IS INJECTED INTO THE PATIENT.

"This technology could have applications in the nanopatterning of microelectronics, making their manufacture more efficient and faster," Jones explains. A paper he co-authored with Zhang and other group members on the work, "Poly(2-vinylnaphthalene)-block-poly(acrylic acid) Block Copolymer: Self-Assembled Pattern Formation, Alignment, and Transfer into Silicon via Plasma Etching," was recently published in *Macromolecular Chemistry and Physics.*

Over the past summer, Jones studied semiconductors at the National Institute of Standards and Technology (NIST).

"[I'm] trying to branch out," he says, "and experience the various fields of materials science in preparation for starting my own research as a graduate student."

MSE CAPSTONE 2011

MSE seniors gathered for the presentation that represented the culmination of their undergraduate experience at the Capstone finale in May 2011. Capstone, a course taken in the senior year, is one of the most important parts of the Clark School's engineering program. In it, teams of students utilize what they have learned throughout their undergraduate studies to create their own engineering designs from concept to product.

The team of nine students—**Tricia Alward**, **Tunji Godo**, **Coit Hendley**, **Iain Kierzewski**, **Michael Meadows**, **Ninoska Moratin**, **William Schoenfelder**, **Nicholas Strnad**, and **Robert Thompson**—created a microfluidic device that would allow healthcare providers to quickly and efficiently administer radiation therapy while lowering hospital and patient costs.

The seniors focused on targeted alpha therapy, a new way to deliver individual radioisotopes to specific tumor cells in the body. The technique, currently in clinical trials, has the potential to treat a variety of cancers but is extremely expensive, in part because bismuth^{213} (Bi^{213}), the radioisotope it uses, must first be generated from another radioactive chemical element, actinium^{225} (Ac^{225}). Due to the short half-lives of these elements, those who administer the treatment have only two hours and fifteen minutes to produce the Bi^{213}, attach it to cancer cell-targeting antibodies, and deliver it to the patient. Most hospitals are not equipped to handle the procedure.

To make targeted alpha therapy easier to prepare in existing hospital labs, the team designed a lab-on-a-chip device that stimulates the production of Bi^{213} from Ac^{225} and collects it on a sucrose film. The film is then dissolved in another of the device's chambers, where it undergoes a microfluidic mixing process that attaches special antibodies to the Bi^{213}. Once the resulting solution is injected into the patient, the antibodies seek out specific cancerous cells, taking the radioactive bismuth along with them.

"It is an especially selective technique as it only kills cells within about 70 micrometers of the emitting radioactive isotope atom," explains Professor **Ray Phaneuf**, who advised the Capstone team. "The antibody-radioisotope pairing effectively kills cancer cells without affecting the healthy cells around them."

Using the lab-on-a-chip device would largely automate the complex, time-sensitive process, and avoid the need for a hospital to purchase and maintain equipment capable of generating Bi^{213} from Ac^{225}. Hospitals would only need to acquire the Ac^{225}, place it in the device, and administer the resulting therapeutics. The single-use chips can be disposed of safely. The cost of treatment, the Capstone team estimates, could be reduced from $10,000-$40,000 a dose to less than $10 per chip, plus the costs of the required actinium and administration of the treatment.

PROFESSOR **RAYMOND PHANEUF** WITH HIS ADVISEE, DR. **SHU-JU PHEOBE TSAI**.

recent GRADUATES

MAY 2011 B.S. GRADUATES

Iain Kierzewski
Michael Meadows
Ninoska Moratin
Nicholas Strnad
Robert Thompson

MAY 2011 M.S. GRADUATES

Michael Carrier
Linmaris Santiago

MAY 2011 PH.D. GRADUATES AND DISSERTATIONS

Ping-Yen Hsieh: "Syntheses, Structures and Properties of Nanoporous Metal-Organic Framework Materials." Advisor: Robert M. Briber

Mark Kujawski: "Polymer Composites for Sensing and Actuation." Advisor: Elizabeth Smela (Mechanical Engineering)

Shu-Ju Tsai: "Spectroscopic Enhancement from Noble Metallic Nanoparticles." Advisor: Raymond Phaneuf

Brian Watson: "Processing of Cellulose for the Advancement of Biofuels." Advisors: Isabel Lloyd and Steven Hutcheson (Cell Biology & Molecular Genetics)

student AWARDS

Congratulations to the following students, who have all demonstrated outstanding performance and have made contributions to the Department and field. Complete award citations are available on our web site at: **www.mse.umd.edu/news/news_story.php?id=5652**

Chairman's Outstanding Senior Award: **Paul Lambert**

Outstanding Materials Student Service Award: **Michael Meadows**

The Department of Materials Science and Engineering Student Research Award: **Douglas Trigg**

A. James Clark School of Engineering Keystone Design Challenge Award: **Emily Dumm** was a member of Team Legend, which won the Spring 2010 hovercraft competition.

KEEP IN TOUCH!

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

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ABOUT THE COVER IMAGE

THE RED IMAGE USED ON THE COVERS, CREATED BY THE DEPARTMENT'S NEWEST FACULTY MEMBER, ASSISTANT PROFESSOR **LIANGBING HU**, IS A SCANNING ELECTRON MICROGRAPH (SEM) SHOWING COTTON THAT HAS BEEN COATED WITH CARBON NANOTUBES USING NANO-INK PROCESSING. THE MATERIAL IS USED FOR TEXTILE BATTERIES AND SUPERCAPACITORS. HU ALSO DEVELOPS ROLL-TO-ROLL PRINTED ELECTRONICS THAT CAN BE USED TO CREATE THIN FILM TRANSISTORS, DISPLAYS, BATTERIES, SUPERCAPACITORS AND SOLAR CELLS ON FLEXIBLE SUBSTRATES SUCH AS PLASTIC, PAPER, AND TEXTILES. FOR MORE INFORMATION, SEE OUR COVER STORY.

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. Attendees can also apply for a $2000 Top Terp Scholarship! *(See **mse.umd.edu/openhouse** for eligibility requirements and more information.)*

UPCOMING DATES:

Friday, October 7, 3:00pm–5:00pm
Saturday, October 22, 9:00am–12:00pm

FOR MORE INFORMATION:

Visit:
www.mse.umd.edu/openhouse

Contact Dr. Kathleen Hart:
hart@umd.edu

See if we're online! AOL IM: mseatumd