

# MSE News

SPRING 2011

*The Newsletter of  
the Department of  
Materials Science  
and Engineering*

## U-M to Enter New Era of Atomic Imaging with Aberration-Corrected TEM

Thanks to the beginning of a new era of atomic resolution imaging, U-M is poised to leap to the highest level of transmission electron microscopy (TEM) ever achieved. The Electron Microbeam Analysis Laboratory (EMAL) will house an ultra-high-resolution TEM developed by JEOL, Ltd., the world's leading manufacturer of electron optics instruments. This new generation 300 kV TEM incorporates unique technologies in both imaging and probe forming correctors, which are based on a new generation of spherical aberration (Cs)-corrected electron optics developed by the Japan Science and Technology Agency's team-based Core Research of Evolutional Science and Technology (CREST) project. It provides unsurpassed imaging resolution (0.05 nm, which is half the size of an atom) in both TEM and STEM (scanning transmission electron microscope) modes. A cold field emission gun delivers excellent energy resolution (0.35 eV) with large probe currents in a very small aberration-corrected electron probe.

The epicenter of materials research in the automotive heartland, EMAL includes an intensive energy research program for the development of fuel cells, solar cells, lithium-ion batteries, thermoelectrics, sensors, and catalysts. The new TEM instrument will provide EMAL

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Xiaoqing Pan with ultra-high-resolution TEM



## Dear Alums:



Let me begin by wishing you a happy New Year! While news about the performance of our football team could be better, I have good news to report about our department. This year was a very successful one; enrollment in our undergraduate and graduate programs continued to increase, reaching a record high. Additionally, our research expenditures, from resources procured through competitive processes, also reached a record number this year. In recent months, we welcomed two new members to our faculty at the junior and senior levels. Two faculty members were successfully promoted to the ranks of associate professor, with tenure, and one to professor. I will expand on these new developments and provide you with some insight into our current and future activities, particularly in relation to our undergraduate program.

With regard to our educational program, our combined graduate and undergraduate enrollment is now at 260. Additionally, 30 graduate students from the fields of macromolecular science and engineering, physics, applied physics, and mechanical engineering are supervised by MSE

faculty and perform research in MSE; they will earn doctoral degrees in their respective fields. Our undergraduate committee continues to develop programs in collaboration with the College of Engineering; currently, we are working together on a formal co-op program and a study abroad program. To provide our students with study abroad opportunities, we are establishing connections with universities outside of the United States, where students can spend a semester or two without losing time toward completion of their degrees. In addition, sufficient flexibility is being built into the curriculum so that students can participate in a formal co-op program without sacrificing an unreasonable amount of time before graduation. Our current major activity this year is preparing for our upcoming ABET review. Steve Yalisove is leading this effort on behalf of the department (see p. 11 for a related article).

Since my last letter, Emmanuelle Marquis and John Allison joined our faculty at the ranks of assistant professor and professor, respectively.\* Marquis joins us as the Dow Corning Assistant Professor of Materials Science and Engineering; she was employed at the University of Oxford, United Kingdom, where she held a prestigious Royal Society Dorothy Hodgkin Fellowship in the Department of Materials. Her interests revolve around pushing the limits of atomic scale microscopy techniques, such as atom-probe tomography and high-resolution transmission and scanning transmission electron microscopy. While most of her research has focused on the area of metals, she will establish programs on the imaging of different classes of functional organic

and inorganic materials. Her efforts in this area will greatly complement the research being conducted with our new sophisticated, aberration-corrected electron microscope, which is capable of atomic resolution. On page 1, Xiaoqing Pan describes this new instrument's capabilities, which have enabled the discovery of the details of certain defect structures in materials, details that were not previously known, and about which scientists have only previously speculated. Allison came from Ford, where he was a senior technical leader in the research and advanced engineering division; his expertise is in the area of the mechanical behavior and processing of metals. One of Allison's primary goals is to establish a center on integrated computational materials engineering (ICME) here at the University of Michigan. His arrival is timely, as this new program will exploit the world-class expertise that we have developed within the department in the area of computational materials science and engineering. Our expectations for this program are high, particularly with regard to its industrial and economic impact. Further details about the program appear on page 4.

With respect to faculty news, Max Shtein, Katsuyo Thornton, and Joanna Mirecki Millunchick were promoted this past fall; Shtein and Thornton were promoted with tenure to the rank of associate professor and Millunchick, to the rank of professor. Millunchick was the College of Engineering's choice for one of the top educator awards. John Halloran was recognized with the Holt teaching award for sustained excellence in teaching. Anish Tuteja, who was hired in 2009, won the Air Force Young Investigator

Award this year. Shtein, who recently redesigned our senior capstone design course, taught an interdisciplinary course, SmartSurfaces, in collaboration with faculty from other schools. This very popular course earned the highest evaluations of all interdisciplinary courses taught at U-M (see p. 8 for a discussion of course goals).

With regard to research, our research expenditures, based on funds obtained from external competitive sources, have continued to increase. Most of the new research funds are for the areas of energy conversion and storage and the structure/synthesis/properties of nanostructured materials. Our success in procuring funds for

this research is derived largely from the investments in faculty with expertise in the structure and properties of inorganic and organic materials at the nanoscale and from our computational capabilities. It also results from our ability to develop collaborative teams with colleagues in other departments on campus, who view MSE as an integral part of their long-term research strategy. We currently are conducting searches for two faculty members, the first in the area of energy storage and the second in the area of computational materials science (petascale computing).

Our newsletter contains additional details about new technical programs within the department as well as other news items of interest. I hope that you enjoy reading it. Please share any comments about, or suggestions you have for, our newsletter.

Go Blue!

*Peter Green*  
Peter Green

P.S. I hope that next year this time we will be celebrating good news about our football team.

*\*For information on Emmanuelle Marquis's studies and research focus, go to [www.mse.engin.umich.edu/about/news/emmanuelle-marquis-joins-mse-faculty](http://www.mse.engin.umich.edu/about/news/emmanuelle-marquis-joins-mse-faculty). To read about John Allison's background and research, visit [www.mse.engin.umich.edu/about/news/john-allison-joins-mse-faculty](http://www.mse.engin.umich.edu/about/news/john-allison-joins-mse-faculty).*



**Emmanuelle Marquis**



**John Allison**



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## Integrating Materials, Manufacturing and Design—Virtually

Imagine conducting a durability “test” on an automotive or aircraft engine before the engine’s individual components are cast or forged. Then imagine that this “test” could measure how variations in the manufacturing processes affect results. Creating such a capability is a challenge that a few major companies, such as the Ford Motor Company and General Electric, have taken on and accomplished. Of course, the answer is to conduct this “test” virtually, on high-performance computers, long before components are manufactured or assembled into a system. And the companies that have accomplished this have spawned a new “discipline” within the materials field that is now called “integrated computational materials engineering”—or ICME (1).

But developing an effective ICME capability is much easier said than done, according to Professor John Allison, who, prior to joining MSE in September, spent over a decade working on exactly this task at Ford. Allison lead a team of researchers at Ford that developed one of the first ICME tool sets focused on aluminum castings.

According to Allison, “Understanding how a material behaves in a complex structural assembly, like an engine, requires a thorough knowledge of a multitude of individual metallurgical phenomena. Doing this in a computational domain challenged us to be much more quantitative than is typical and required an approach that integrates theory, experimental results, and a wide variety of modeling tools and providing them to a global engineering workforce. The developments at Ford included manufacturing simulation, first-principles computations, calculated

phase diagrams, models for microstructural evolution, and micro-mechanical approaches for improved constitutive modeling for finite-element analysis.”

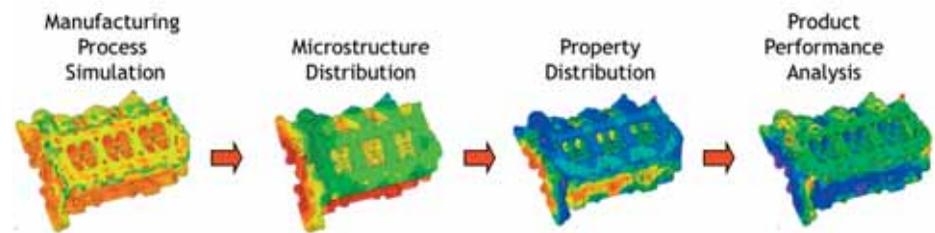
Allison and other faculty members at U-M are working on plans to launch a new ICME Center of Excellence. The center will serve manufacturing industries by developing ICME computational tools and educating practitioners of this new field. The planned center will be a virtual organization composed of researchers from a wide variety of disciplines working collaboratively toward common goals. “Working together in this center we will have the opportunity to attack major problems, produce world-class science, and provide significant value to industry,” Allison says.

A member of the center, Professor Katsuyo Thornton of MSE, is an expert at computational modeling. She is also the inaugural chair of the newly formed ICME committee within

materials tools into their curricula.

The ICME approach has caught the eye of government officials at the highest level. According to a recently released draft report from the White House Office of Science and Technology Policy, “modeling and simulation is a paradigm-changing tool for industrial product and process design, enabling innovation by reducing design cycle time, development costs, certification costs, and re-engineering costs, and improving performance and efficiency while reducing waste” (2).

“The University of Michigan is uniquely positioned to take on an ICME initiative and to excel,” says Allison. “Around campus, we have world-class materials and mechanics research, strong computational capabilities, and exceptional material characterization staff and facilities. All of the right ingredients exist for something really special that will challenge scientists and also provide great value to the



**An illustration of the flow chart for an integrated computational materials engineering (ICME) toolset for an automotive engine cast aluminum cylinder head.**

The Minerals, Metals and Materials Society (TMS). Because of her interest in incorporating computational methods into curricula, she recently secured funding from the National Science Foundation to launch a summer program (see p. 5) for faculty and post-doctoral researchers who wish to incorporate the latest computational

U.S. manufacturing industry. Although the first developments will likely be in the metals area, I believe that the concept is pervasive and I can imagine this extending to development of ICME toolsets for things such as energy conversion and storage devices, electronic components, and polymer composites.”

## MSE Faculty Member Will Launch Summer Program

continued from page 4

### References

1. "Integrated Computational Materials Engineering: A Transformational Discipline for Improved Competitiveness and National Security," T. M. Pollock, J. E. Allison, D. G. Backman, M. C. Boyce, M. Gersb, E. A. Holm, R. LeSar, M. Long, A. C. Powell, J. J. Schirra, D. D. Whitis, and C. Woodward, *The National Academies Press, 500 Fifth Street, N.W. Washington, DC 20001, 2008.*

2. "Simulation-Based Engineering and Science for Discovery and Innovation," *White House Office of Science and Technology Policy, Fast Track Action Committee on Computational Modeling and Simulation, Committee on Technology, National Science and Technology Council, June 2010.*



**Katsuyo Thornton**

While integrated computational materials engineering (ICME) is now recognized as a key discipline within the field of materials engineering, barriers remain to its growth. One barrier is the general dearth of materials scientists who are capable of utilizing the growing number of computational tools. To overcome this challenge, Katsuyo Thornton, an associate professor in MSE, is planning to launch a two-week summer program for ICME education, which will include a "crash course" on computational materials science and engineering (CMSE) and focus sessions on educational modules that can be incorporated into existing core courses. The participating graduate students and faculty can then bring their newly gained knowledge back to their home institutions, teaching computational modules in their thermodynamics and kinetics courses. This will enable the rapid integration of CMSE into undergraduate curricula at a broad range of institutions, including teaching colleges and universities without computational faculty. We gratefully acknowledge the National Science Foundation for providing financial support for this program.

## 2010 ASM Summer Teacher Camp



**Kathy Hayrynen looks on as John Keough, adjunct professor and owner of Joyworks Studio, prepares a pattern for metal castings that students created in his studio.**

For the ninth year in a row, MSE hosted the ASM Teacher Camp. As usual, MSE created an exciting, fun-



**John Keough in a teaching moment.**

filled week of high-energy learning experiences for middle- and high-school teachers from around the country. John Keough once again was gracious in donating his time and studio so the teachers could experience metal casting firsthand.

This year, MSE also held a follow-up review session in November for camp

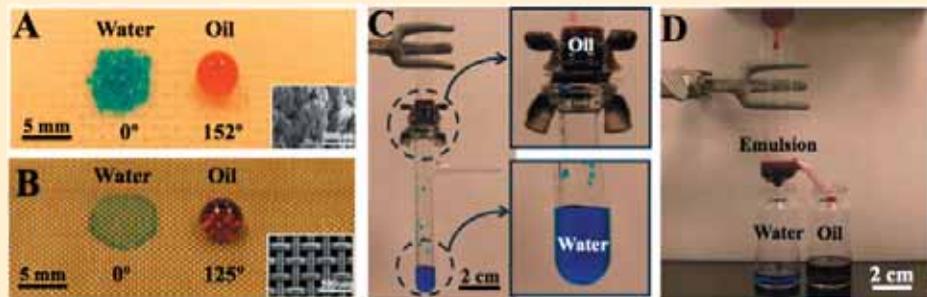
participants. Thanks to our ASM volunteers, several teachers were able to review experiments they had conducted at camp and discuss the successes and challenges they had experienced trying to teach the skills they learned.

Additional changes will be made to the 2011 camp: This year, teachers who have already attended camp will be able to return for a second year in order to gain an even deeper insight into the world of materials science. We look forward to working with the extremely dedicated ASM volunteers and teachers to make this year's camp the best ever.

# Membranes for Gravity-Based, Continuous, Oil–Water Emulsion Separation

With the recent Deepwater Horizon oil-spill disaster in the Gulf of Mexico, the Chinese tanker that ruptured on the Great Barrier Reef, and the Port Arthur oil spill in Texas, the year 2010 highlighted the acute need for developing new solutions to achieve effective oil–water separation. Mixtures of oil and water are classified based on the size of the oil droplet ( $d_{oil}$ ) as— free oil if  $d_{oil} > 150 \mu\text{m}$ , dispersed oil if  $20 \mu\text{m} < d_{oil} < 150 \mu\text{m}$ , and emulsified oil if  $d_{oil} < 20 \mu\text{m}$ . While conventional gravity separators and skimming techniques can separate free oil and dispersed oil from water, they are unable to separate it from emulsified oil, especially if the oil was stabilized using surfactants.

Membrane-based separation technologies are often used for emulsion separation because they are cost-effective, and applicable across a wide range of industrial effluents. To separate oil–water emulsions into pure oil and water, a membrane must allow one phase to permeate through while retaining the other phase. Typically, oil–water separation membranes are classified as either hydrophobic (water-hating) or hydrophilic (water-loving). Hydrophobic membranes can be used to separate water from oil in both oil-in-water emulsions and water-in-oil emulsions. However, as the density of oil is less than that of water, these membranes cannot be used for gravity-based separation. Thus, typically, they have to be used in an energy-intensive, “cross-flow” filtration setup. Further, these surfaces can get easily fouled with oil, leading to a dramatic reduction in the flux of pure



**Figure 1:** A. Droplets of water (dyed blue-green) and rapeseed oil (dyed red) on a commercially available polyester fabric. The inset shows the morphology of the dip-coated fabric. The contact angles of both water and rapeseed oil on the fabric are also shown. B. Droplets of water and rapeseed oil on a dip-coated stainless steel window-screen mesh. C. The gravity-based separation of a multi-phase mixture (pure oil, pure water, oil-in-water emulsion, and water-in-oil emulsion) into > 99% pure oil and pure water using the membranes developed in Professor Tuteja’s group. D. A setup for the continuous separation of oil–water emulsions.

oil or water over time. In contrast, hydrophilic membranes are resistant to fouling, and can be used for gravity-based separation of oil-in-water emulsions. However, they cannot separate water-in-oil emulsions or free oil and water.

Researchers surmise that the ideal membrane for the continuous separation of oil–water mixtures is oleophobic (oil-hating) when submerged under both oil and water. However, such a membrane has not been developed to date. Recently, members from Professor Tuteja’s group, including postdoctoral researcher Arun Kota, Ph.D., and graduate student Gibum Kwon, have developed liquid-responsive membranes that, counterintuitively, are wet by water (hydrophilic), but can easily repel oil (see fig. 1A and fig. 1B). These membranes maintain their oleophobicity when in contact with either air or water, and are based on a polymeric coating that combines a hydrophilic polymer with low-surface energy fluorinated molecules. To

develop membranes for oil–water emulsion separation, this polymeric coating is deposited on cheap, commercially available porous materials such as polyester fabric (fig. 1A) or window-screen mesh (fig. 1B) using a simple dip-coating methodology. It is also possible to spray the coating on these porous materials.

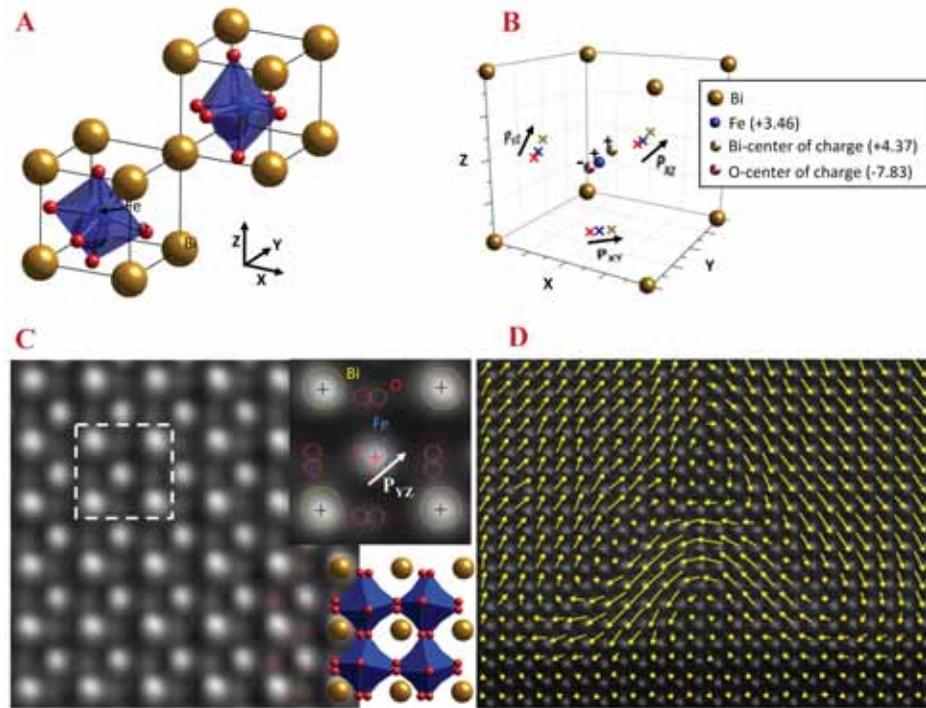
The fouling-resistant membranes synthesized by dip-coating or spraying are able to separate, with greater than 99% efficiency, free-oil, dispersed oil, oil-in-water emulsions, water-in-oil emulsions, and any combination of these phases (see fig. 1C). The Tuteja group has also engineered, for the first time, a setup to achieve continuous gravity-based separation of oil–water emulsions (see fig. 1D). In the designed setup, the oil–water emulsion enters from the top and is separated into pure water and pure oil, which are continuously collected. The flow rate of pure oil through this setup can exceed 200 liter/m<sup>2</sup>/hour.

# Atomic Imaging

continued from page 1

with powerful cutting-edge capabilities, thereby furthering our understanding of the fundamental science of materials and devices at the atomic level. Researchers can employ this instrument to analyze the atomic structure, composition, and chemical bonding characteristics of individual defects, surfaces, interfaces, and nanostructures. Using a tomography TEM holder, they can determine the 3-D atomic structures of nanostructures and defects, and using a high-resolution electron energy-loss spectroscopy (EELS), powered by the small energy spread of the cold FEG, researchers can determine the electronic structures of a nanoscale region in materials. In combination with a variety of in-situ TEM holders, the electronic, mechanical, and optical properties of nanostructures and defects can be determined along with the atomic structure and chemistry from the same region.

For example, the electric polarization of the ferroelectric  $\text{BiFeO}_3$  is imaged with atomic resolution using a spherical aberration-corrected transmission electron microscope (see fig. 1; Nelson et al., *Nano Letters* 2011, 11(2), pp. 828–34).  $\text{BiFeO}_3$  consists of two pseudocubic perovskite unit cells connected along the body diagonal (fig. 1A). The electric polarization is determined by measuring the atomic displacement between the centers of cations and anions (fig. 1B). Figure 1C shows the phase of the reconstructed electron wave upon exiting a  $\text{BiFeO}_3$  thin specimen determined from a focus-series of HRTEM images. The displacement of the oxygen and iron rela-



**Figure 1: A. Crystal structure of  $\text{BiFeO}_3$ . B. The projection of electric dipole moment and atoms in a unit cell of  $\text{BiFeO}_3$ . C. The phase component of the electron exit wave determined from a TEM focal series. D. The two-dimensional map of local polarization in  $\text{BiFeO}_3$  showing the existence of a polarization vortex.**

tive to the center of the bismuth sublattice is clearly visible and the atomic positions match the bulk structure. The polarization in the image plane is determined to be  $|\text{PYZ}|=82 \mu\text{C}/\text{cm}^2$  in agreement with the value for the bulk structure from figure 1B projected on the same plane,  $|\text{PYZ}|=80 \mu\text{C}/\text{cm}^2$ . This method allows us to map the polarization with atomic resolution in ferroelectric  $\text{BiFeO}_3$  thin film and leads to the first observation of spontaneous vortex nano-domain arrays intrinsically formed at ferroelectric hetero-interfaces with polarization closure similar to the magnetization patterns ubiquitous to ferromagnetic materials (fig. 1D). This discovery, made possible using one of the world's most advanced TEMs (the TEAM microscope at Lawrence Berkeley National Laboratory), represents the forefront of spatially resolved polarization "imaging," enabling the effect of interfaces and defects on the polarization in ferroelectric heterostructures rel-

evant to ferroelectric device structures to be seen.

This new generation aberration-corrected microscope is an historic milestone in the development of electron imaging technology and a significant move towards atomic resolution microscopy for understanding the structure-property relationships of materials at the atomic scale. The microscope achieving this unprecedented fineness of detail in atomic resolution is the first of its kind in the world, and the first JEOL will create for a lab in the United States. "This is the most powerful microscope that will ever be produced in the foreseeable future. People have been dreaming about getting resolution like this," says Peter Genovese, president of JEOL USA. As a unique resource, this microscope will promote collaborations and integrate scholarly activities in all areas of materials research in the region.

## SmartSurfaces: A Multi-disciplinary, Hands-on Think Tank



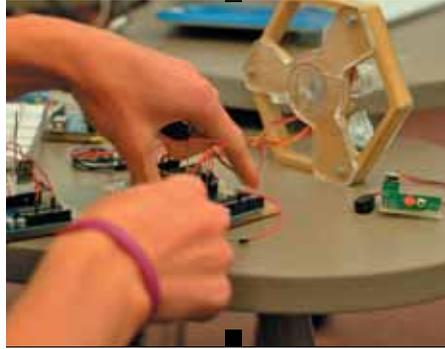
**Dynamically switched ferroelectric fluid, a project built by one of the teams to explore mimicry of various underwater creatures.**

*“The mission of the University of Michigan is to serve the people of Michigan and the world through pre-eminence in creating, communicating, preserving and applying knowledge, art, and academic values, and in developing leaders and citizens who will challenge the present and enrich the future.”*

Mary Sue Coleman,  
[www.umich.edu/pres/mission.php](http://www.umich.edu/pres/mission.php)

As educators in one of the premier universities in the world, we must ask ourselves whether we are indeed helping to “[develop] leaders and citizens who will challenge the present and enrich the future?” But before answering this question, two other questions should be considered: (1) What aspects of the present are worth challenging? and (2) What will enrich the future?

Successful innovation nearly always involves multi-disciplinary efforts, where people from vastly different backgrounds work together and for long hours to realize, say, the latest generation of the iPhone or extracting information from the Archimedes palimpsest. Max Shtein, associate



**A student assembling an autonomous tracking robot that will become part of a “colony” that can sense, respond to, and otherwise interact with human visitors.**

professor in MSE, and his colleagues from the other side of the Duderstadt Center, John Marshall (A&D) and Karl Daubmann (Arch.), wondered how they might be able to create a microcosm of multi-disciplinary innovation and teamwork, and all the frustrations and triumphs that might entail. Funded by a special grant from the Office of the Provost at U-M,\* they began SmartSurfaces—a risky experiment in collaboration, creativity, and hands-on design.

In the summer of 2009, preceding the launch of SmartSurfaces, they met for weekly breakfasts at Northside Grill, setting out the overall goals and challenges for this new course, working out logistics, procuring resources and space, and inviting star innovators to share their wisdom and experience during in-class workshops. Most importantly, they spent countless hours questioning nearly every premise of the course, and learning each other’s language.

SmartSurfaces turned out to be a class—an experience—that’s difficult to describe. The set-up: twenty-four students from three different programs



**An interdisciplinary student team brainstorming and troubleshooting their project.**

(Art & Design, MSE, and Architecture), divided into four teams of six (two from each program) to work on open-ended projects. Guided by the instructors, the students proposed project topics and received up to \$3,000 per team to bring their ideas into existence.

The major theme for 2009 was “Heliotropic Smart Surfaces”—a broadly phrased challenge to create an interactive, automated surface that would respond to light and provide some combination of practical benefit, aesthetic appeal, and societal impact. In 2010, the theme was “Biomimetic Smart Surfaces”—an open-ended challenge to take inspiration from biological systems, in terms of their form and function, and also in terms of the evolutionary way in which nature produces countless prototypes and “refines” its designs by testing their survival. Consequently, the students in both years were forced to “think with their hands,” and to practically negotiate their different viewpoints and backgrounds to realize concrete, physical designs.

At the students’ disposal were tools, materials, and resources that included



**Kevin Yien and his teammates demonstrate their final project, an illustration involving at least 0.25 million drinking straws stacked up, waveguiding light from smart LEDs toward sensors that are programmed to mimic visually the sensation of insects swarming.**



**The same student team earlier in the semester, showing and discussing a single module that will eventually become the interactive "wall" pictured at left. The piece exhibits a wonderful "crystalline" quality and auditory effect that cannot be reproduced in print, but must be experienced to be appreciated.**

making hardware (laser cutters, 3D printers, CNC machines, programmable microcontrollers, motors, relays, etc.); modeling software (AutoCAD, Rhino, Processing); several novel methodologies for teamwork, problem identification, and problem solving; as well as substantial potential for public embarrassment when designs fail. The class met once a week for six hours straight in Design Lab 1 (<http://grocs.dmc.dc.umich.edu/%7Edl1>), a rather unusual instructional/working space configured with whiteboards, screens, tables, and chairs on wheels, as well as comfortable couches. Lunches were brought into DL1 and were eaten as a group. During each weekly studio, the teams presented their solutions to specific challenges (e.g., design and build a solar-tracking biomimetic smart surface using available components), and participated in a classwide critique and discussion. Several times during the term, guest speakers (Julian Bleeker, Michelle Addington, Eugene Shteyn, Thorsten Klooster, Geoffrey Mann) who have achieved considerable renown for their innovation

and design work, provided instruction, participated in discussion, and led workshops with the students.

The succession of weekly assignments culminated in a final design project, preceded by countless all-nighters by the students, who were negotiating unexpected challenges and striving to make their projects better. The final demonstrations/critiques were open to the public, with students, members of the faculty, and staff invited to attend and offer their comments.

One of the most beneficial aspects of this course isn't necessarily the acquisition of a new learning or skill set (although undoubtedly learning the tools and approaches listed above was deemed valuable by all participants). Perhaps the most valuable consequence of the course for many was learning to appreciate, and gain mastery over, the intangibles, pieces of tacit knowledge that cannot be found in or learned from textbooks.\*\*

In 2011, Marshall, Daubmann, and Shteyn will teach the third edition of the course. They are exploring new themes and challenges for the class to

tackle, as well as methods for making this experience a sustainable one for a broader cross-section of students. Already they have several individuals interested in participating in, and supporting, this class. If you wish to become a part of this experience or help in making it possible again, please feel free to contact them.

**Course website:**

[www.SmartSurfaces.net](http://www.SmartSurfaces.net)

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\* To learn more about the program on Multidisciplinary Learning and Team Teaching (MLTT), visit [www.provost.umich.edu/programs/MLTT/](http://www.provost.umich.edu/programs/MLTT/)

\*\* Student feedback on this course can be found in an article appearing here: <http://playgallery.org/stories/smartsurfaces/>

## MSE Professor Leads Optics in the City of Light Program

Steve Yalisove is the principal investigator for a National Science Foundation (NSF) program that sends undergraduates to Paris, France, for nine weeks each summer. The Optics in the City of Light Research Experience for Undergraduates (REU) offers eight juniors the opportunity to perform research with a wide range of ultrafast lasers in labs in Paris. Optics, especially in view of recent discoveries made in extreme light, is one of the most exciting areas of science.

Students in REU experience a highly collaborative environment, owing to the increased teamwork occurring between U-M's MSE department, and U-M's Center for Ultrafast Optical Science (CUOS), the Ecole Polytechnique, the Ecole Nationale de Techniques Avancées (ENSTA), the Extreme Light Institute (ELI), the Musée du Louvre, and l'Institut d'Optique Graduate School. Each student receives guidance from a faculty team comprising one faculty member from U-M and one from Paris. Students spend their first week of the program in orientation at U-M, learning about safety training and living in France, and becoming immersed in REU faculty's labs, where they begin to acquire basic lab and reporting skills. Once in France, students begin a weekly reporting process that involves preparing a summary and analysis of the previous week's work. Each student maintains a blog-based notebook that all team members can access via the CTools data management system at U-M. Each week students post a one-page entry describing the work they performed in the labs that week, as well as their experiences of living in France. These entries serve to keep

faculty apprised of the progress students are making on their projects.

Among the premier ultrafast optics laboratories in the world, UM-CUOS, ENSTA, ELI, Ecole Polytechnique, and l'Institut d'Optique are all equipped with state-of-the-art instrumentation. For its first 13 years, CUOS was funded in part by a NSF Science and Technology Center. The Center's founding director, Dr. Gérard Mourou, and other original members (half of MSE's senior staff) have enjoyed longstanding relationships with LOA, the Louvre, and Ecole Polytechnique. Further, CUOS developed many of its experiments in collaboration with the institutions at Palaiseau. While CUOS currently has the world's highest intensity focused laser, the laser now being constructed at ELI under the direction of Dr. Mourou will surpass it by a factor of 10<sup>3</sup> in intensity. Both institutions have a large number of ultrafast lasers and diagnostic tools.

Students in REU have access to all of the facilities in the French institutions as well as to the libraries associated with them. They travel to Paris with a CUOS research scientist who helps them become established in their new French labs. During the program's final week, the students present the work they accomplished during a one-day symposium. The students live at Cité Internationale Universitaire in downtown Paris, located across the street from the RER Metro stop, which takes them to the labs at Palaiseau. The program covers all of students' travel, housing, and food expenses and provides each student with a \$4,500 stipend.

REU is open to all undergraduate students who have completed their



**Research in Paris: 2010 REU students at the Louvre**

junior year in college, are U.S. citizens or permanent residents, and come from institutions where research is not the primary focus. Currently the program is actively recruiting women and underrepresented minorities; last summer, half of the students were women, one was African American, and one was Hispanic. Further, six of the eight students were enrolled at institutions where research was not the primary focus. The program is very competitive: Last year 130 students applied for 8 spots with an average GPA of 3.9. To learn more about REU, go to <http://engin.umich.edu/ipe/iREU>.

## ABET to Make an Accreditation Visit

In the fall of 2011, the Accreditation Board for Engineering and Technology (ABET) will make an accreditation visit to MSE to determine if our undergraduate program continues to meet ABET's quality standards. ABET evaluates the credit status of programs in applied science, computing, engineering, and technology every six years. It is a non-profit organization, sanctioned by the U.S. government, which is made up of engineering professional societies. To maintain its accredited status, MSE must meet the quality standards established by the ABET as well as by The Minerals, Metals, and Materials Society (TMS). If you're interested, the details can be found at <http://abet.org>. In addition, two other materials societies provide input during the accreditation process: the Materials Research Society (MRS) and the American Ceramic Society, which is responsible for the four remaining ceramics programs in the U.S. (MRS participates in program evaluation and is an associate member of ABET, but it doesn't have a voting seat on ABET's board.)

In preparation for ABET's visit and evaluation, MSE is producing a self-study that will demonstrate the department's compliance with the nine criteria established by ABET and TMS. MSE must demonstrate that a continuous improvement process is in place for the undergraduate program along with metrics showing that students are meeting program outcomes and objectives. As part of the improvement process, faculty members participate in a retreat at the end of each term to discuss each undergraduate course taught that term. During the retreat, a list of action items is drawn up regarding how best to improve the elements of each class (e.g., the topics taught, the syllabus, and the metrics used to assess student achievement for each outcome). Time is also allotted for a general discussion.

The undergraduate objectives and outcomes for our program are published on our website. You can find them by clicking on Continuous Improvement in the Undergraduate Study section. Once the self-study is complete (around September 2011), we will post it on MSE's site.

**Students of Professor Kieffer's MSE 330 (Thermodynamics of Materials) discuss the key aspects of steelmaking with the plant engineers of Severstal North America in front of a blast furnace during tapping. In late fall, the class visited the company's installation in Dearborn, Michigan, to see how the principles of thermodynamics govern materials manufacturing in a real-life industrial application.**



## Undergraduate Program Update

The undergraduate program remains vibrant, as demonstrated by the rise in student enrollment. Currently, approximately 140 undergraduates have declared a MSE major, including 14 who are double majors, coupling a MSE degree with another degree here at U-M or at Shanghai Jiaotong University in China. An additional 20 students are pursuing MSE minor degrees.

In addition, entry-level job opportunities for MSE students are increasing, thanks to the growing presence of companies seeking MSE majors at the career exposition held each fall at U-M. MSE undergraduates are also increasingly being exposed to an unusual breadth of experiences: Several MSE undergraduates pursued study abroad opportunities this past summer, and Jonathan Carender (MSE '10) was named one of three Student Entrepreneurs of the Year by the U-M Center for Entrepreneurship for his efforts in founding a company called CrowdClarity Inc. We hear that since graduating from U-M, he has become involved in a new venture. Let us know how that experience unfolds and great work so far, Jonathan!

## Faculty Spotlight



In March of 2010, **Joanna Mirecki Millunchick**, was awarded the John F. Ulrich Education Excellence Award. Millunchick has distinguished herself as a tireless proponent of sophisticated instructional technologies, as an innovator in curriculum development, and as a committed educator. She continually seeks new ways to enhance student learning and shares her techniques and findings with colleagues university- and nationwide.

Since joining the faculty in 1997, Millunchick has explored new ways to incorporate technology into lectures and coursework. Recently, she examined the use of screencasts, web-based lecture recordings, audio discussions, and solution sets for homework, as well as videos explaining conceptually difficult topics. Rigorous assessments have shown that screencasts are an effective supplement to lecture materials, particularly in the case of large courses, and their use directly correlates with statistically significant improvements in student performance. Millunchick's work and discussions of screencasting applications around the college and university have led other instructors to try these techniques in

their classrooms. She takes the time to train graduate student instructors and postdoctoral fellows in them. Her work has drawn national attention. Millunchick was invited by the National Academy to present her findings at the inaugural Frontiers of Engineering Education Symposium.



**Anish Tuteja**, was awarded the 2011 Air Force Office of Scientific Research (AFOSR) Young Investigator Award for his proposed work on "Polymer-based and Polymer-templated Nanostructured Thermoelectric Devices." The AFOSR Young Investigator Research Program is open to scientists and engineers at research institutions across the United States who have received their Ph.D. or an equivalent degree in the last five years and shown exceptional ability and promise for conducting basic research.

The objective of the program is to foster creative basic research in science and engineering, enhance the early career development of outstanding young investigators, and increase opportunities for young investigators to help the Air Force achieve its

mission and related challenges in the fields of science and engineering.

Tuteja's research is focused on developing high-efficiency, nanostructured, thermoelectric devices by providing independent control over the material's electrical and thermal conductivity. Most thermoelectric materials in current use are based on exotic, inorganic materials and suffer from low efficiency ( $\eta \sim 4 - 8\%$ ) and high cost. As part of this work, Tuteja aims to develop polymer-templated, high-efficiency, nanostructured, thermoelectric generators based on earth abundant materials, as well as high-efficiency, nanostructured, polymer-based thermoelectric coolers.

*National, regional, and local awards continue to recognize the outstanding quality of our faculty.*

**John Allison**

Elected to the National Academy of Engineering

Henry Ford Technology Award, Ford Motor Company

**Rachel S. Goldman**

2011 College of Engineering Monroe-Brown Foundation Service Excellence Award

**John Halloran**

2011 MSE Outstanding Achievement Award

**Nicholas A. Kotov**

Top 25 Materials Scientists (Thomson Reuter)

Top 100 Chemists (Thomson Reuter)

**Jyoti Mazumder**

Elected Fellow of Indian Institute of Metals

Thomas A. Edison Patent Award from the American Society of Mechanical Engineering (ASME) for U.S. Patent #6,122,564, "Apparatus and Methods for Monitoring and Controlling Multi-layer Laser Cladding," J. Koch and J. Mazumder, September 19, 2000 and an associated patent on direct metal deposition and its impact on engineering.

**Michael Thouless**

Elected as an Overseas Fellow at Churchill College, Cambridge, 2010–11

2011 College of Engineering Trudy Huebner Service Excellence Award

**Anish Tuteja**

Young Investigator Award, Air Force Office of Scientific Research

**Anton Van der Ven**

2011 College of Engineering 1938E Award

**PROFESSIONAL SERVICE**

**John Allison**

Member, National Materials Advisory Board Committee on Benchmarking the Technology and Applications of Lightweighting, 2010–11

Co-organizer, TMS First World Congress on Integrated Computational Materials Engineering

Editorial Advisory Board of the *International Journal of Fatigue*

**Rachel S. Goldman**

Trustee, AVS The Science & Technology Society, 2009–12

Associate Editor, *Journal of Electronic Materials*, 2002–present

**Peter Green**

Advisory Board of the ACS Petroleum Research Fund

External Advisory Board, Sandia National Laboratory, Materials Science and Technology (MST) program

National Research Council Panel on Neutron Research

**Nicholas A. Kotov**

Associate Editor of the journal *ACS Nano*

Advisory Board of the ACS journals *Langmuir* and *Chemistry of Materials*; the RCS journal *Nanoscale*; and the Wiley-VCH journal *Advanced Functional Materials*

**Richard M. Laine**

Associate Editor for *Applied Organometallic Chemistry*, 1990–present

Editorial Advisory Board *Macromolecules*

**John Mansfield**

President-elect of the Microanalysis Society, through August 2011

**Emmanuelle Marquis**

Co-chair for the 2011 Gordon Conference on Physical Metallurgy

**Katsuyo Thornton**

Chair, TMS Integrated Computational Materials Engineering Committee

**Michael Thouless**

Opponent at a "Doctor Technices" (a higher doctorate) defence at the Technical University of Denmark (DTU), Lyngby, Denmark (Nov. 2010)



U-M engineering researcher Jinsang Kim and his colleagues have developed a new class of material that shines with phosphorescence—a property that has previously been seen only in non-organic compounds or organometallics. The new luminous materials, or phosphors, could improve upon current organic light-emitting diodes (OLEDs) and solid-state lighting. This work is the cover story in the March 2011 issue of *Nature Chemistry*.

**Caroline Dove** (BSE '09) is employed in research and development at Saint Gobain.

**Dr. Bogdan Lita** (PhD '02) is working in CdTe Photovoltaics for a start-up called Primestar Solar, where he is the manager of solar cell and module metrology, materials characterization.

**Erick Moy** (BSE '00, MS in BME '02) is a scientist at Pfizer, Inc., in the company's inflammation and immunology group, where he is examining the structure-activity relationship of small-molecule inhibitors in the JAK-STAT and IRAK-4 biological pathways in the immune system.

**Stephanie Prado** (BSE '10) is employed at ArcelorMittal in Indiana Harbor, Indiana.

**Dr. Xiaojun Weng** (PhD '03) is a research associate with the Materials Research Institute at Pennsylvania State University, where he works on structure-property correlations in group III-nitride thin films, graphene, multifunctional oxide thin films, and semiconductor nanowires.

## Alumni Society Merit Award Winner



From left: Corey Brooker, Dean David Munson, James Speck, and Peter Green at the 2010 Alumni Society Awards Dinner, held on October 15, 2010. Photo courtesy of Dwight Cendrowski.

James S. Speck (BSE '83) is professor and chair of the materials department at the University of California, Santa Barbara. His research interests revolve around understanding the relationship between thin film electronic materials growth and microstructure, and that between microstructure and physical properties.

Speck is a recipient of the Quantum Device Award from the International Symposium on Compound Semiconductors, and was an inaugural fellow of the Materials Research Society. In 2008, he received the JJAP Best Paper Award, and was named an American Physical Society fellow in 2009. He won a 2010 IEEE Photonics Society Aron Kressel Award in recognition for his work on nonpolar and semipolar GaN-based materials and devices.

After completing his BSE in metallurgical engineering at U-M, Speck received his SM and ScD in materials science from the Massachusetts Institute of Technology.

## Michigan Materials Society: A Growing Tradition



MMS lunch-and-learn with the 2011 TMS/AIST Elliott Lecturer and Professor David Robertson (left of center), held in October of 2010.

As a student in U-M's MSE department and president of the Michigan Materials Society (MMS), I have the privilege of seeing some of the nation's most promising up-and-coming minds in action both in the classroom and at leisure. Having homeschooled myself through high school and spent three years at a community college prior to transferring to U-M, I have greatly appreciated being with an amazing group of peers who have backgrounds as diverse as my own. Examples of these incredible students abound, such as Mingjie Xu, who is pursuing degrees in ME and MSE across two different continents; Garret Huff, who as part of the university's Formula SAE team, helps design, build, and finally drive a formula-style racecar (which can accelerate 0 to 60 mph in under 3.7 seconds) and is now taking that knowledge to the next level at an alum's start-up company; and Michael Abere, who has turned a summer research project begun at the Louvre in Paris into an exciting PhD project. The list goes on.

I find myself frequently challenged by the very talented student body at U-M, of which the individuals mentioned above are just a small sampling. As president of MMS, I see it as my responsibility to help create a collaborative environment that fosters the potential that exists within the MSE student body. This year, in addition to assisting with community events such as the ASM Materials Camp and with social events that build community within the department, such as the traditional fall and spring picnics at Professor Horsford's home (a tradition since 1964), MMS has sought to bring professionals from the materials community to U-M to speak to MSE students about their research, experiences, and career opportunities. Every Friday, students gather together for a lunch-and-learn event to hear about new frontiers of research or the types of careers for which their education is qualifying them. Last fall, we had the pleasure of welcoming representatives from organizations such as General Electric, Toyota, and NASA to speak with us. We also had several alumni return for

speaking engagements, including Jim Schroth (researcher at General Motors), James Speck (MSE department chair at UC Santa Barbara), and Jerry Madden (Mold Release Products, Inc). As MSE is an abstract field relative to such "hands-on" disciplines as mechanical engineering, I believe these talks will prove very useful to our students. They will not only help students understand what they're being prepared for, they will help them make informed career decisions while they're still in college. We're looking forward to finishing the year in aMAIZE-ing Blue style and would welcome any alumni reading this to share their perspective about how best to foster a winning social and intellectual environment. The MMS officer core may be contacted at [MMSofficers@umich.edu](mailto:MMSofficers@umich.edu).

Go Blue!

Josiah Cornett  
MMS President  
MSE Class of 2011

## MSE Senior Earns a Best Student Paper Award at the Fall 2010 Material Research Society Meeting

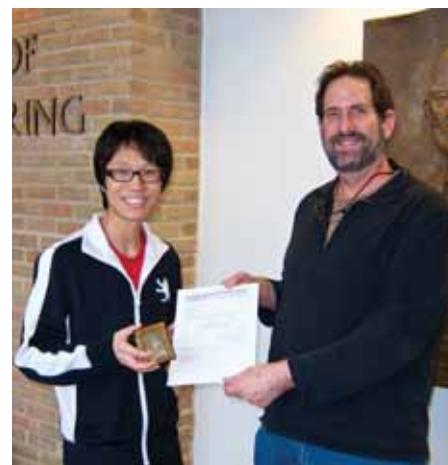
During his sophomore year at U-M, Michael Aberé began working in the lab of Professor Steve Yalisove. He quickly learned how to set up ultrafast laser-material interaction experiments and to use the lab's scanning electron microscope (SEM), atomic force microscope (AFM), and optical microscopes. His initial projects involved studying the formation of carbon nanotube (CNT) "hair" that resulted from the irradiation of monolayer CNT films on glass. These projects gave Aberé valuable experience in how to interpret data and to conduct accurate material removal threshold studies.

In his junior year, Aberé was accepted into the Research Experience for Undergraduates (REU) program in Paris (see p. 10) owing to his lab experience and high grade-point average. There, he joined a research project focused on using an ultrafast laser method to remove corrosion products from daguerreotypes, an area of study he had begun investigating while at U-M. This research project is the brainchild of Gerard Mourou, a U-M emeritus professor in electrical engineering and computer science (and the inventor of the chirped pulse amplifier, which has enabled ultrafast lasers to grow in power to beyond the petawatt scale), Yalisove, and John Mansfield, the manager of the Electron Microbeam Analysis Lab. Some years ago, Mansfield was working with a Detroit Institute of Art staff member, who asked if a focused ion beam could be used to remove corrosion from art objects. Mansfield responded that this was a feasible, but very time-consuming proposition. He then

spoke with Yalisove about using an ultrafast laser for the same purpose.

Around the same time, Mourou, in his new position as the director of the Extreme Light Institute in Paris, met Michel Menu, a synchrotron physicist, the director of the Research Laboratory of the Museums of France, and the world's expert on X-ray investigations of the *Mona Lisa*. Working together, the two scientists quickly identified ultrafast methods for cleaning art objects without collateral damage (as well as ultrafast generated terahertz spectroscopy methods for imaging frescos).

In France, Aberé began working in the labs of both researchers, where he gained valuable experience in using lasers as well as a superb education in the manufacture and corrosion chemistry of daguerrotypes. When he returned to U-M, he resumed working on daguerrotypes in Yalisove's lab. Cleaning daguerrotypes with a high-intensity ultrafast laser is a challenging undertaking, since the most prevalent corrosion products on these photographic images are sulfides and oxides, which serve to insulate the silver. Aberé and Yalisove fully expected that they would have to remove a thin (40nm) layer of silver beneath the corrosion product in order to extract the latter, since the threshold fluence needed to remove silver is a factor of 10 lower than the threshold for silver oxides and sulfides. They hoped that removing the very thin underlying metal wouldn't cause the particle density of the image to degrade. Astonishingly, Aberé discovered that the threshold for removing the sulfides and oxides was about a factor of two



**Michael Aberé, on left, receiving his student award from Steve Yalisove.**

lower than the threshold for removing bulk silver. This discovery has had a significant impact on the lab's other work with ultrafast lasers—both in the areas of solar energy and non-tamperable marking for nuclear proliferation verification. It has led to the development of models in which an interface plays a role in ultrafast laser material interaction.

The study has had a huge impact on the standard practice for cleaning daguerrotypes, since Aberé was able to show that he could maintain the density of image particles by doing a statistical survey in regions of very similar contrast before and after particle removal. Aberé also imaged the particles under the corrosion layer before and after ultrafast laser cleaning using a SEM. Remarkably, there was no change in the shape of the particle down to the sub-micron level.

Given this successful outcome, Aberé and Yalisove decided to conduct an experiment on newly made daguerrotypes, which they obtained

## MSE Photo Contest

from a photographer belonging to the Daguerrian Society. Using a SEM, they imaged the silver particles in the photographic images. They then artificially corroded the images using a rotten-egg technique developed by the Louvre, removed the corrosion, and, finally, compared the contrast to the new daguerrotypes. Already, they've found that the contrast that is visible in new daguerrotypes is identical to the kind of contrast seen in daguerrotypes cleaned with an ultrafast laser. This work has further demonstrated that corrosion can be cleaned from daguerrotypes without modifying the image particles or the substrate.

Earlier in the year, Abere and Yalisove submitted an abstract (with Abere listed as the first author) about cleaning daguerrotypes to the "Symposium WW, Materials Issues in Art and Archaeology," held during the fall 2010 MRS meeting. Though the abstract was initially accepted as an oral presentation, the symposium organizers decided to make it an invited talk, a real coup for Abere who was an undergraduate at the time. A week after the event, Abere discovered he had won a best student paper award for his presentation and received a \$150 check. On page 16 is the photo sent to MRS of Yalisove giving Abere the award letter while he holds a partially cleaned daguerrotype. Abere graduated in December of 2010 and has decided to pursue graduate studies at U-M in Yalisove's lab. His current work focuses on exploiting his past research to improve the efficiency of photovoltaic materials in U-M's Energy Frontier Research Center.



**This year's Grand Prize winners of the 4th Annual Imaging Microstructure Contest were Sarah Spanninga for Artistic Merit (see photo at top) and Kevin Yien for Scientific Merit (see photo at bottom). A total of 26 individuals entered more than 60 images for consideration. The panel of judges was made up of Justin Scanlon, staff member in MSE; John Mansfield, associate research scientist, MSE/EMAL; Theresa Reid, executive director of ArtsEngine; Terry Abrams, professor of photography, Washtenaw Community College; and Sam Daly, assistant professor of mechanical engineering. We sincerely thank them for their efforts. All winning entries can be seen at [www.mse.engin.umich.edu/internal/imaging-microstructure-contest-2010/winners](http://www.mse.engin.umich.edu/internal/imaging-microstructure-contest-2010/winners).**

## Scholarships and Awards

### GRADUATE

#### *Department Awards*

#### **MSE Graduate Service Award for Recruiting**

Kiersten Batzli, Katherine Becker, Eleanor Coyle, Ryan Marson, Kale Stephenson

#### **Best Overall Teaching Assistant**

Jennifer Lee

#### **Best Overall GPA**

Hyun Joon Oh

#### **MSE Graduate Student First Publication Award**

John Thomas and Guodan Wei

#### *College/University Awards*

#### **2011–2012 Rackham Predoctoral Award**

John Thomas

#### **CoE Distinguished Achievement Award**

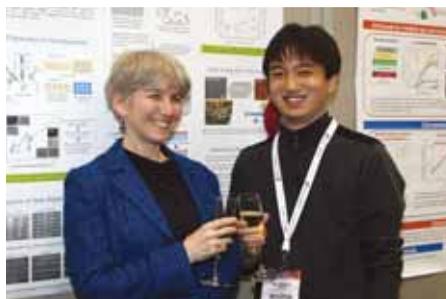
Yansha Jin

#### **CoE Outstanding Student Instructor Award**

Jennifer Dibbern

#### *External Awards*

Mr. Yen-Fu (Simon) Huang was selected as a finalist for the 4th Taiwan Semiconductor Manufacturing Company (TSMC) Outstanding Student Research Award. He presented “Growth and Characterization of InAs/GaAs Quantum Dots for Intermediate Band Solar Cells,” in Hsinchu, Taiwan in August, 2010.



Myungkoo Kang (PhD Candidate, MSE) received the poster award at the 2010 Materials Research Society fall meeting, for his poster entitled, “FIB-Assisted Molecular Beam Epitaxy and Optical Properties of Metal-Semiconductor Nanocomposites.” He is shown here with his proud advisor Professor Rachel S. Goldman.

### UNDERGRADUATE

#### *Department Awards*

#### **Richard A. Flinn Scholarship**

Justin Moyer

#### **Fontana-Leslie Scholarship**

Kyle Luck

#### **James W. Freeman Memorial Scholarship**

Josiah Cornett, Ellen Dupler, Tatsuya Kamiya

#### **John Grennan Scholarship**

Roger Jia

#### **Jack J. Heller Memorial Engineering Scholarship**

Kaelin Jensen

#### **William F. Hosford Scholarship**

Bethany Glesner, Jeffrey Haenke, Ga Ram Jun, Guangsha Shi

#### **Schwartzwalder Memorial Scholarship**

Afroze Ahmed, Cory Dubrish, Diana Goulding, Jiwon Kim, Joyce Loh, Ian McDonald, Alessandra McGinnis,

Chipo Mulaisho, Emily Nelson, Rachel Rademacher, Christopher Sketch, Margaret Tantillo, Kevin Wayne

#### **Clarence A. Siebert Memorial Scholarship**

Patricia McCormick, Joel Ondersma, Weimin Wang

#### **Alfred H. White Memorial Scholarship**

Steven Madsen, Victoria Miller

#### **Brian D. Worth Prize**

Stephanie Prado

#### **MMS Anvil Award**

Kelsey Poineau

#### **James P. Lettieri Undergraduate Award**

Roger Jia

#### *College/University Awards*

#### **Distinguished Achievement Award**

Victoria Miller

#### **Charles F. Barth, Jr. Prize**

Carrie Tamarelli

#### **Tom S. Rice Tau Beta Pi Award**

Jesse Tzeng

#### *External Awards*

Michael Abere received a Best Student Paper Award at the fall 2010 Materials Research Society Meeting.

Victoria Miller was awarded the Michael Warchol Scholarship by the Detroit/Windsor chapter of the American Foundry Society at the annual Management Night meeting held January 20, 2011.



**Clinique Brundidge monitors her creep experiments on nickel-base superalloy single crystals.**

### **MSE Student Named to the Edward Alexander Bouchet Graduate Honor Society**

Clinique Brundidge, a fourth-year graduate student in MSE, has been elected to the Michigan Chapter of the Bouchet Honor Society. She and seven other exceptional graduate students from U-M will be inducted into the society at Yale University later this year. The Edward Alexander Bouchet Graduate Honor Society is named for the first African American doctoral recipient in the United States (in physics from Yale University in 1876) and honors graduate students who exemplify academic and personal excellence; foster environments of support; and serve as examples of scholarship, leadership, character, service, and advocacy for students who have been traditionally underrepresented in the academy. Clinique is advised by Professor Tresa Pollock, and is conducting research on the mechanical behavior of cast single-crystal nickel-base superalloys.

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*Thank you for your generous gifts to our department or to the College of Engineering for the benefit of the department. If we have missed someone, please accept our sincere apology, and let us know so that we can correct our records.*



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