

## **Department of Materials Science and Engineering**

The Department of Materials Science and Engineering (DMSE) is preparing to move into new headquarters in Building 6. The culmination of many years of planning and construction, the renovated area will contain improved meeting and display spaces. The department plans to expand seminar and outreach activities to take advantage of the new facilities.

One such activity is the MIT and Dow Materials Engineering Contest (MADMEC); in MADMEC, six student teams are designing and prototyping devices that harness, store, or exploit sources of alternative energy through principles of materials science. Supported by a gift from Dow Corporation, the contest began in April and will conclude with an evening event where the devices will be demonstrated to the MIT community.

With support from the Lord Foundation, we will expand this and other programs through the purchase of equipment that will enhance the department's hands-on capabilities. Tools like CAD-controlled lathes and cutters, 3D printers, and water-jet and laser cutters will allow our students to build their own custom experimental equipment, develop and test prototypes, and even make a new part for an unmanned air vehicle.

Our faculty continues to be recognized for outstanding research and a firm commitment to education: Professors Gerbrand Ceder, Yoel Fink, and Francesco Stellacci were honored with MIT teaching awards this past year.

### **Research Initiatives**

In July 2007, the Singapore-MIT Alliance Advanced Materials for Micro- and Nano-Systems program will hold its second weeklong short course, and Professors Francesco Stellacci and Carl Thompson will travel to Singapore as instructors. Many members of our faculty play integral roles in other major MIT initiatives, such as the Institute for Soldier Nanotechnologies, the Deshpande Center for Technological Innovation, the Global Enterprise for Micro-Mechanics and Molecular Medicine, and the DuPont-MIT Alliance.

### **Undergraduate Education**

DMSE's undergraduate enrollment stands at 114 students, with 52 percent women, 17.5 percent underrepresented minorities, and 6.1 percent international students. Undergraduate recruiting efforts include participation in Academic Expo during freshmen orientation, choice of major fair, an open house, the semiannual John Wulff Lectures, direct mailings to the freshman class, freshman advising seminars, and independent activities period (IAP) activities. Five students are designated Course 3A (a more flexible degree program designed for pre-med, business, or law students) and two students are in 3C, the SB in archaeology and materials.

The internship program continues to attract a large portion of DMSE undergraduates; 31 DMSE rising seniors and juniors are working at 30 host institutions at 31 locations for summer 2007, including six overseas institutions.

## Graduate Education

The department has a very healthy graduate student enrollment, numbering 239 in fall 2006. Approximately 32 percent of the graduate students are women and two percent are underrepresented minorities. The Program in Polymer Science and Technology has 16 enrolled students, five students are in the Leaders for Manufacturing program, and six have entered the health sciences and technology program. For fall 2007, we anticipate a total graduate student enrollment of 226. An incoming class of 62 is expected, approximately 35 percent of whom are domestic students.

Starting in academic year (AY) 2008, DMSE doctoral students will have the option of completing a teaching minor, a recommended 24-unit load that will provide the department with knowledgeable teaching assistants while formalizing an educational process for students planning careers in academia.

Our Master of Engineering program is in its sixth year with 59 alumni/ae. In September 2007, 16 students will graduate, and 26 students are expected to enroll for the coming academic year. This one-year degree program (September to September) has seen steady growth in enrollment, and companies at the forefront of technology hire its alumni.

## Student Organizations

Officers of the Society of Undergraduate Materials Scientists (SUMS) for AY2007 were Kimberly Kam, president; Anna Chen, vice president; Nathan Pfaff, secretary; and Jennifer Dibbern, treasurer. Among the social and informational activities planned for the coming year are a welcome back to school barbecue lunch for first-year students and Course 3 majors, which will highlight the MADMEC finalists, a graduate school panel of professors and representatives from the Course 3 graduate programs, a career workshop, and a lobster bake.

The Graduate Materials Council (GMC) organizes monthly departmental socials that allow faculty and students to converse outside the classroom or laboratory and thus build understanding and mentorship opportunities. GMC is actively involved in hosting the admitted graduate students during the two departmental visit weekends. In addition, a new initiative is to match each first-year doctoral-track student with a student mentor starting in September 2007. GMC officers for AY2007 were Jason Trelewicz, president; Trey Holzwarth, vice president; Tim Chin, treasurer; and Gabrielle Gaustad, academic resources. Representatives to the Departmental Committee on Graduate Students were Andy Detor and Asher Sinensky. Graduate Student Council representatives were Nathan Lovell, Timothy Lau, and Gagan Saini. Social chairs were John Maloney, David Bradwell, Megan Brewster, and Serena Povia. Chris Bettinger was the intramural chair.

Several DMSE graduate students hold key roles in activities inside and outside MIT. David Danielson founded MIT's Energy Club in May 2004; this group, open to the entire MIT community, currently has more than 450 members who participate in lecture and discussion series; socials; Energy Night, an annual event to showcase startups and affiliates; and an Energy Conference where some 600 attendees learn about MIT's most interesting energy technologies.

Alicia Jackson was one of the student organizers of MIT's Science Policy Bootcamp, a five-day IAP seminar for graduate students to learn about science policy topics. Also this year, six DMSE graduate students traveled to Washington, DC, to attend the March Congressional Visits Day (CVD) sponsored by the Materials Advantage Program; the CVD brings scientists and engineers to Capitol Hill to discuss policy issues and allows students and young scientists to express the necessity of federal science investment to the country's technological and economic well-being.

Gerardo Jose la O' and David Danielson collaborated with a team of undergrads from mechanical engineering who converted a 1974 Porsche 914 to run on electricity, powered by 18 rechargeable lithium phosphate batteries. The car has a range of 100 miles between charges from a normal household outlet and can reach a speed of 100 mph.

Mr. la O' was also an organizer of First-Step Coral, a group that has received MIT funding to utilize science and technology in rebuilding the Phillipine coral reefs, which are the home of one of the world's greatest areas of biodiversity.

Daniel Pressl was an organizer of 2fast4u, an exhibition of high-speed photography and videography, which was a collaboration that included MIT's Edgerton Center, students in Austria, and many others. From April 2 to 19, the exhibition presented photographs, interactive objects, and a live-camera hookup between the exhibition in Wolfsberg, Austria, two Austrian high schools, and MIT, allowing conversation and interaction among visitors to the separate locations.

## **Personnel**

Silvija Gradecak joined the DMSE faculty in October 2006. Her research focuses on nanophotonics and electronics and is based on the synthesis, characterization, and integration of low-dimensional systems. She holds a diploma (1999) from the University of Zagreb and a PhD from the Swiss Federal Institute of Technology (2003), both in physics. Most recently, she worked as a postdoc in Professor Charles Lieber's group in the Department of Chemistry and Chemical Biology at Harvard University.

Anne M. Mayes has retired and moved to her hometown of Mustang, Oklahoma. Professor Mayes came to MIT as a freshman and enrolled in Course 3, completed a PhD at Northwestern, and then became a postdoc at IBM Almaden. Professor Mayes joined the MIT faculty in 1993 and was the first woman tenured in DMSE. As of this writing, she has supervised 16 PhD candidates, seven MS degrees, and a host of Undergraduate Research Opportunities Programs. Some of her many contributions to MIT's materials science curriculum include introducing biomaterials to the department and redesigning laboratory subjects to be the types of subjects she would have wanted to take as a student. In recognition of her excellence in teaching, she was named a MacVicar Fellow in 2001.

Assistant Professor Stephanie Reich has left MIT for a senior tenured full professor position at the Freie University of Berlin in her native Germany.

Lorna J. Gibson became associate provost effective August 1, joining the large number of DMSE faculty who have assumed senior leadership positions in the Institute. Professor Gibson served as chair of the faculty from 2005 to 2006.

Subra Suresh, the Ford professor of engineering, will succeed Institute Professor Thomas Magnanti as the next dean of the School of Engineering on July 23.

Klavs Jensen, the Lamot DuPont Professor of Chemical Engineering who holds a joint appointment in DMSE, became head of the Department of Chemical Engineering.

Effective July 1, 2007, Nicola Marzari and Christopher Schuh will be promoted to associate professor with tenure. Also in July, Francesco Stellacci will be promoted to associate professor without tenure.

Robin Elices, the director of the Administrative Services Organization (ASO), has accepted the position of executive officer of the MIT Energy Initiative. Su Chung will assume the role of ASO director in July.

### **Research Highlights**

In this year's report, the department has chosen to profile exciting research performed by four of our young faculty members.

Professor Gradecak's group uses an interdisciplinary scientific approach to study semiconductor materials and low-dimensional systems. The research direction they pursue focuses on nanoelectronics and photonics and combines the synthesis, characterization, and integration of low-dimensional systems and exploring their unique physical properties. The group has demonstrated growth of GaAs nanowires via a vapor-liquid-solid growth mechanism using metallorganic chemical vapor deposition. They are working on electrical and structural characterization of GaAs/AlGaAs nanowire heterostructures for high electron mobility transistor applications. Professor Gradecak received a 3M Innovation Award to continue her group's studies of III-V nanowire systems.

The group is actively pursuing development of cathodoluminescence in transmission electron microscopy, an advanced and MIT-unique electron microscopy technique for the direct correlation of structural and physical properties of nanostructured materials with unprecedented resolution. This program is supported by the MIT Center for Materials Science and Engineering. Professor Gradecak's research is strongly bound to her educational efforts, and she recently received an MIT Alumni Funds Award for Teaching and Education Enhancement for the active development of a new graduate-level subject 3.074 Imaging of Materials/3.34 Imaging of Materials.

Professor Nicola Marzari's research on energy and catalysis has shown for the first time how it is possible to achieve a complete description of electron-transfer reactions (for which Rudolph Marcus won the Nobel prize in 1992): in these reactions, an electron, trapped on a donor site, can tunnel to an acceptor when a fluctuation of the environment (e.g., water) allows it (the reaction takes place in the "dark," without the need for

optical excitation). Electron-transfer reactions are ubiquitous in electrochemistry and in biochemistry, and this is the first time that they can be studied explicitly—i.e., with a donor, an acceptor, and the environment/solvent, all fluctuating around in thermal equilibrium.

Professor Marzari has also developed a means to make an accurate description of transition-metal complexes with affordable computational costs. His group studies central electrochemical or biochemical reactions related to energy harvesting or conversion from first principles, such as the reactions involved in fuel cells, photosynthesis, or the formation of natural antibiotics.

Professor Christine Ortiz's research group studies the amazingly complex, hierarchical nanostructures of biological materials (e.g., musculoskeletal tissues such as bone and cartilage as well as animal exoskeletons such as seashells and armored fish) using expertise in the field of high-resolution molecular-level imaging and "nanomechanics"—i.e., the measurement and prediction of extremely small forces within and between nanoscale constituents to determine the local origins of macroscopic physical phenomena. Professor Ortiz's research group studies the nanomechanics of diseased, aged, and injured tissues; the use of nanomechanics methodologies in regenerative medicine (e.g., as an optimization tool for engineered tissues); nanomechanical properties of single cells during growth of their pericellular matrix under different conditions; development of experimental and theoretical techniques for the measurement and analysis of nanoscale visco(poro)elasticity of biological materials and single cells; nanoscale heterogeneity and grading in biological materials; and the use of nanomechanical methodologies for medical diagnostics.

In 2006, Professor Ortiz postulated a theory for the strength in bone involving "nanogranular friction" and explored a new energy-dissipation mechanism arising from nanomechanical heterogeneity that offers a graceful means for ductility enhancement, damage evolution, and toughening. These theories were supported by a combination of novel nanomechanical experimental data and computational simulations. She went on to apply nanomechanical methodologies for the first time to genetically manipulated stem-cell-based tissue-engineered bone and showed how the increased sensitivity of such techniques could be used to quantify the mechanical quality of the produced neo-tissue.

Her group has also been working extensively over the past year in the field of cartilage nanomechanics as follows: the compressive nanomechanics of opposing aggrecan macromolecules, lateral nanomechanics of aggrecan including the development of a new lateral force microscopy calibration method, nanomechanical properties of individual chondrocytes and their developing growth factor-stimulated pericellular matrix, and nanoscale dynamic visco(poro)elasticity of individual chondrocytes and their pericellular matrix and whole bovine cartilage tissue. These studies have been extended to quantify the nanomechanical properties and structure of tissue-engineered cartilage generated *in vivo*.



Professor Christopher Schuh's group recently demonstrated a new capability in controlling the nanometer-scale structure of alloy coatings. With support from the Army Research Office under the Presidential Early Career Award in Science and Engineering, Professor Schuh's group introduced a new technique in the traditional aqueous electrodeposition processes common in industrial surface finishing. By introducing millisecond-scale current pulses that control the composition of a depositing alloy, a wide range of precisely tailored nanostructures is possible. One proposed application for the technology is as a replacement for the common "hard chromium" coating known for its wide use on plumbing fixtures and automotive trim; the current chrome-coating technology has severe environmental drawbacks and is a threat to worker safety. By engineering the structure of a deposited alloy coating, the Schuh group's process can avoid the use of toxic chromium chemicals and still deliver a coating with the same suite of properties. This MIT technology has been transferred to a local startup company (Xtalic Corporation, Medford, MA) via an exclusive license, and commercialization is under way.

In other related research, Professor Schuh's group is developing tools to probe the mechanical properties of advanced structural materials at the nanometer scale and at elevated temperatures common in materials processing and in many service conditions. In collaboration with an industrial partner, Professor Schuh's group has demonstrated stable nanometer-length and micronewton-force-scale mechanical testing at temperatures up to 500°C. This new testing technology is currently being commercialized and has broad potential applications in, for example, combinatorial alloy development, nondestructive evaluation of engine and turbine components, and microelectronics.

### **Awards and Honors**

Professor Angela Belcher was named Research Leader of the Year by *Scientific American* and a member of the "Scientific American 50," the annual list of individuals, teams, companies, and other organizations that demonstrate outstanding technological leadership. Professor Belcher also was appointed to the MIT Energy Council.

Professor Gerbrand Ceder, the instructor of Course 3.20 Materials at Equilibrium and 3.320 Atomistic Computer Modeling of Materials, received a Graduate Student Council Teaching Award.

Professor Yoel Fink was named a MacVicar Fellow; he also received DMSE's Joseph Lane Excellence in Teaching Award.

Merton C. Flemings is one of nine 2007 Franklin Institute Laureates. Winners are honored "for their significant discoveries and achievements, which directly impact our daily lives or contribute to our present and future well-being." Professor Flemings, director of the Lemelson-MIT Program, received the Benjamin Franklin Medal in Materials Engineering "for contributions to understanding aspects of solidification of metallic alloys [and] the development of [the] semi-solid metalworking industry, which helps make sporting equipment, house-hold appliances and cars strong and light."

Professor Anne M. Mayes received the Carl S. Marvel Creative Polymer Chemistry Award at the Spring Meeting of the Polymer Chemistry Division of the American Chemical Society. The award recognizes and encourages accomplishments and innovation in the field of basic or applied polymer science by younger scientists.

Professor Francesco Stellacci received the Junior Bose Award for Excellence in Teaching in recognition of his active role in developing innovative classroom experiences.

Professor Subra Suresh received the Acta Materialia Gold Medal. About 90 materials researchers attended “Nano- and Micro-scale Mechanics of Engineering Materials and Biological Systems—A Symposium in Honor of Professor Subra Suresh, on the Occasion of his Receiving the Acta Materialia 2006 Gold Medal” and a banquet to mark the event. Professor Suresh was also elected an honorary member of the Spanish Royal Academy of Sciences. The Madrid-based Academy covers the broad fields of physical, chemical, biological, and mathematical sciences. Professor Suresh received an honorary doctorate from Sweden’s Royal Institute of Technology (Kungliga Tekniska Högskolan, KTH). The Federation of European Materials Societies (FEMS) has selected Professor Suresh as the recipient of the 2007 European Materials Medal, its highest and most prestigious honor. FEMS comprises a group of materials science and engineering professional societies from 24 European countries.

Professor Edwin Thomas, graduate students Taras Gorishnyy and Chaitanya Ullal, and postdoctoral researcher Martin Maldovan received the Acoustical Society of America’s 2005 Science Writing Award for Professionals in Acoustics for their article “Sound Ideas,” published in the December 2005 edition of *Physics World*.

Harry Tuller was elected to the World Academy of Ceramics, a center for “promoting progress in the field of ceramics and fostering a better understanding of the social impact and cultural interactions of ceramics science, technology, history, and art.” Professor Tuller also was selected to present the 2007 Edward Orton, Jr., Memorial Lecture of the American Ceramic Society. He will be Distinguished Lecturer at University of Texas–Austin’s Nanotechnology and Materials Seminar Series in the upcoming academic year.

George LaBonte and Juliette Braun are 2007 recipients of SoE Infinite Mile Awards for Excellence. George LaBonte has worked as a research specialist in Professor Subra Suresh’s laboratory since 1993. He receives this award in recognition of his many years of committed service and the sustained excellence he brings to the work environment. Juliette Braun works in DMSE headquarters as administrative assistant to the department head. Leia Amarra, Sara Darcy, Edith Jaehne, and Richard Lay have been selected to receive the 2007 Infinite Mile Team Award from the Office of the Associate Provost and Vice President for Research. They have received this award in recognition of their work with the Center for Biomedical Engineering as well as with chemical engineering and DMSE.

Professors Ronald Ballinger, Linn Hobbs, Dorothy Hosler, and Carl Thompson all joined the Quarter Century Club this past year. Esther Greaves Estwick of ASO was also a Quarter Century Club inductee.

## **Undergraduate Awards**

Runye Helen Zha received the award for Best Internship Report for “Stability of Polypyrrole Films over Long-Term Redox Switching” and was also named Outstanding Senior Class of 2007.

Nathan Pfaff received the Horace A. Lubin Award for Outstanding Service to DMSE for his role as the SUMS treasurer (2006) and the Materials Advantage treasurer (2006–2007).

Hannah Reitzel received the award for Outstanding Senior Thesis for “Pottery Engineering in Ancient Guerrero, Mexico: The Site of Las Fundiciones.”

Jill Rowehl was named Outstanding Junior Class of 2008, and Johann Komander was named Outstanding Sophomore Class of 2009.

## **Graduate Awards**

Ardavan Farjadpour received the John Wulff Award for Excellence in Teaching.

Albert Swiston received the graduate student community service award.

Tiffany Santos received the Outstanding PhD Thesis Research Award for “Europium Oxide as a Perfect Electron Spin Filter.”

Megan Brewster received the First-Year Graduate Student Exceptional Performance Award.

Yeon Sik Jung received the award for Outstanding Paper by a First- or Second-Year Graduate Student.

Johnathan Jian Ming Goh and Haw Yun Soo received the Elsevier Outstanding Student Prizes.

Anna Bershteyn received the Hertz Foundation Award to pursue her graduate studies in our department. These five-year fellowship awards recognize qualities the Foundation believes are essential ingredients of future professional accomplishment.

David Danielson received one of the Karl Taylor Compton Prizes, one of the highest student awards at MIT. He was recognized for his tireless efforts in starting and growing the MIT Energy Club.

Alicia Jackson has been selected as the 2007–08 MRS/OSA Congressional Fellow. She completed the ScD in June with a thesis on “Phase Separation and Nanostructuring in the Ligand Shell of Nanoparticles.”

Emily Walton received a National Defense Science and Engineering Graduate Fellowship for 2006–07.



Gold medal winners at the MRS meeting in Boston in fall 2006 were Fabien Sorin for “Metal Insulator Semiconductor Mesostructured Fibers” and Ming Tang for “A Diffuse Interface Thermodynamic Model of Grain Boundary Transitions in Binary Alloys.” Kuangshin Tai received the silver medal for “Nanomechanics of Bone: Fundamental Insights Regarding Structure-Function, Mineral-Organic Deformation, and Heterogeneity.”

Three DMSE students were winners in the 2006 Materials Day poster contest: Daeyeon Lee “All-Nanoparticle Thin Film Coatings: A Versatile Means to Create All-in-One Coatings,” Xiaogang Liu “Highly Wettability-Reversible Nanowire Paper,” and Fabien Sorin “Multimaterials Integrated Fibers.”

### **New Faculty Chair Appointments**

Caroline A. Ross will be named Toyota professor of materials science and engineering effective July 1.

### **Future Plans**

During AY2008, we will assess and evaluate the Course 3 undergraduate curriculum, revised for AY2004; the upcoming ABET visit and the Report of the Task Force on the Undergraduate Educational Commons have served to focus our attention on how well the “new” curriculum educates students who will take a role as future leaders of technology and society. DMSE has two current faculty searches under way and is looking for candidates with a background in materials for energy applications, including novel solar energy systems, electrocatalysis, and electrochemistry; materials processing, including green materials processing; crystal chemistry; materials chemistry; combinatorial materials science; clinical biomaterials; soft materials, including modeling; and electronic materials.

A new departmental focus is on materials for energy and clean technology. During IAP 2008, we plan a series of activities exploring development of such materials and opportunities for entrepreneurship and venture capital in this area.

We continue to work toward providing fellowships to all first-year graduate students. A new fellowship named for our colleague Anne Mayes was established with discretionary funds allocated from Professor Mayes, generously supported by her MIT friends and colleagues and matched by Dean of Engineering Thomas Magnanti and Provost Rafael Reif. We will begin fund-raising among alumni and others and hope to award the fellowship in the near future.

Other priorities include fund-raising for purchases of further rapid-prototyping equipment and support and maintenance of the newly purchased equipment.

**Edwin L. Thomas**

**Department Head**

**Morris Cohen Professor of Materials Science and Engineering**

*More information about the Department of Materials Science and Engineering can be found at <http://dmse.mit.edu/>.*