Department of Materials Science and Engineering

The Department of Materials Science and Engineering (DMSE) is seeing the fruits of years of planned growth and outreach. As the Physics, DMSE, Spectroscopy, and Infrastructure (PDSI) construction project continues, departmental headquarters and some faculty, staff, and student offices have relocated to Building 35. We have maintained our strong reputation for academic excellence, and our graduate program was again ranked first in the nation by *U.S. News and World Report*. Edwin L. Thomas, Morris Cohen professor of materials science and engineering, became head of the department in January of this year, and he is enthusiastically learning more about the activities and innovations developed in every area of this department.

Research Initiatives

In September 2005, the second phase of the Singapore–MIT Alliance (SMA) began, and DMSE continues to be a large part of this initiative. In July 2006, the SMA Advanced Materials for Micro- and Nano-Systems program will hold its first weeklong short course, and Professors Subra Suresh 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 Innovation, the Global Enterprise for Micro-Mechanics and Molecular Medicine, and the DuPont–MIT Alliance.

Undergraduate Education

DMSE's undergraduate enrollment stands at 112 students and currently includes 51 percent women, 4.6 percent underrepresented minorities, and 2.8 percent international students. The department undergraduate recruiting efforts include participation in Academic Expo during freshman orientation, Choice of Major Fair, an open house, the semiannual John Wulff Lectures, direct mailings to the freshman class, freshman advising seminars, and IAP activities. Nine students are designated Course 3-A (a more flexible degree program designed for premed, business, or law students) and three students are in 3-C, the SB in archaeology and materials.

The internship program continues to attract a large portion of DMSE undergraduates; 38 DMSE rising seniors and juniors are working at 31 host institutions at 32 locations for the summer of 2006, including 6 overseas institutions.

Graduate Education

The department has a very healthy graduate student enrollment, numbering 253 in fall 2005. Approximately 27 percent of the graduate students are women and 1 percent are underrepresented minorities. The Program for Polymer Science and Technology has 19 enrolled students, 7 students are in the Leaders for Manufacturing program, and 5 have entered the Health Sciences and Technology program. For the fall of 2006, we anticipate a total graduate student enrollment of 245. An incoming class of 59 is expected, more than 50 percent of which are domestic students.

Our Master of Engineering program is in its fifth year. In September 2006, 22 students will graduate, and 18 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 AY2006 were Kimberly Kam, president; Louise Giam, vice president; Jane Yoon, secretary; and Sally Lou, 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, 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 officers for AY2006 were Andrew Detor, president; Brian Hohmann, vice president; Tim Chin, treasurer; and Gabrielle Gaustad, academic resources. Representatives to the Departmental Committee on Graduate Students were Elisa Alonso and Asher Sinensky. Graduate Student Council representatives were Pedja Djuranovic, Suelin Chen, and Gagan Sanai. Social chairs were Jay Trelewicz, Binu Oomen, Biraja Kanungo, Trey Holzwarth, and Federico Villalpando, and Rick Rajter was the intramural chair.

Personnel

Dr. Silvija Gradecak will join the DMSE faculty this fall. Her research focuses on nanophotonics and electronics and is based on the synthesis, characterization, and integration of low-dimensional systems. By taking advantage of unique material properties on a nanoscale, she explores novel optoelectronic applications such as nanoscale light-emitting sources, single photon sources, or nanowire lasers. 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 has worked as a postdoc in Professor Charles Lieber's group in the Department of Chemistry and Chemical Biology at Harvard University.

In July, Professor Adam C. Powell IV will leave MIT for a position at Veryst Engineering in Needham, MA. Professor Powell is a Course 3 alumnus who has been a valued member of this department as an advisor to undergraduates and graduate students and an instructor of several subjects.

As Professor Lorna Gibson becomes associate provost effective August 1, she joins the large number of DMSE faculty who have assumed senior leadership positions in the Institute. Professor Gibson has served as chair of the Faculty since 2005.

Effective July 1, 2006, Professor Yoel Fink and Professor Christine Ortiz will be promoted to associate professor with tenure.

Kathleen Farrell, DMSE's academic administrator, left her position at MIT effective June 30 to devote her efforts fulltime to raising her new baby, Sean. Ms. Farrell joined DMSE Headquarters as an administrative secretary in 1989 and was an essential part of the Department, working in a variety of roles, before becoming academic administrator in 2000. Angelita Mireles joined DMSE as the academic administrator at the end of June. Ms. Mireles received the SB from MIT in 1999, majoring in biology. She worked in the Administrative Services Organization (ASO) parttime while a student and in the DMSE Academic Office as the graduate assistant after graduating. She then worked at Stanford as an undergraduate administrator for the Political Science, Public Policy and Urban Studies Department and then as the program administrator for the Public Policy Program.

Research Highlights

This year we highlight exciting research developments from four of our faculty. Professor Yet-Ming Chiang's group has developed an ultrahigh-energy density mechanical actuation approach based on solid-state electrochemistry. In a Defense Advanced Research Projects Agency–supported collaboration with Professor Steven R. Hall (Department of Aeronautics and Astronautics) aimed at enabling shape-morphing structures, this concept was proven and then applied in a full-scale active helicopter rotor blade section. This first demonstration of electrochemical actuation can dramatically influence the traditional compromise in rotorcraft design between hover payload and forward-flight capabilities.

Professor Chiang is also collaborating with professors Angela Belcher (DMSE) and Paula Hammond (Department of Chemical Engineering) in a project that demonstrated the virus-enabled growth of nanoscale materials into lithium battery structures, paving the way to more efficient bioassisted assembly of electrochemical devices.

A milestone was reached in the area of industrial collaboration and technology transfer whereby battery materials research conducted in the Chiang laboratory and published in *Nature Materials* in 2002 reached commercial fruition in a new class of high-power lithium ion rechargeable batteries, developed by the MIT spin-off company A123Systems (Watertown, MA) and currently implemented in a new category of professional power tools.

Professor Michael Cima's group is applying micro- and nanotechnology to solving the looming energy crisis and advancing medical technology. They are developing a multireservoir device for in vivo sensing of cancer-related analytes. The reservoirs in the device contain nanosized magnetic relaxation switches that have been surface functionalized. The nanoparticles aggregate in the presence of analyte, and the aggregation can be detected using nuclear magnetic resonance or magnetic resonance imaging technology. A semipermeable membrane contains the sensing nanoparticles in the reservoir while allowing diffusion of the analyte into the reservoirs. Several commercially available molecular weight cutoff (MWCO) membranes that retain the nanoparticles have been identified, and the diffusion kinetics of several different model analytes through these MWCO membranes have been studied. Currently they are performing proof-of-principle in vitro sensing experiments using a model magnetic

relaxation switches/analyte system. The Cima group is also investigating advanced microelectricalmechanical system (MEMS) drug delivery systems and developing an implantable MEMS device capable of delivering a vasoconstrictor agent on demand in seconds to injured soldiers to prevent hemorrhagic shock during safe evacuation for medical treatment.

Other recent work in the Cima group has contributed to the fundamental understanding of colloidal nanoscience. The electroosmotic behavior of the rutile polymorph of titanium dioxide was investigated as a function of both crystallographic orientation and exposure to ultraviolet irradiation. High-resolution force spectroscopy and advanced X-ray photoelectron spectroscopic techniques were employed to quantify changes in physical properties such as isoelectric point and electron affinity. Changes in both surface orientation and UV exposure were found to significantly influence these properties, and important structure-property relations have been developed. These studies lay the foundation for future work in utilizing external stimuli (such as UV) to tune the colloidal behavior of a given surface.

The Cima group is also working on a number of green technologies in the energy sector. They have made progress on a new technology for detecting nitric oxide (NO_x) emissions from diesel engines. Molten carbonate salts could be used as the sensing elements and promise to allow for inexpensive and very sensitive NO_x sensors. Methods have been developed to allow for rapid screening of device parameters. New commercially viable pathways toward producing high-temperature superconducting cables are being investigated. These cables could be used in extremely efficient motors and generators, environmentally friendly high-power transformers, and power-dense AC and DC cable links. Their research is focused on characterization of superconducting thin films and the development of less expensive and cleaner production techniques for yttrium barium copper oxide–coated conductors. Recently, an epitaxial cerium oxide coating method using a solution of aqueous nitrates and a common polymer that can be used as a buffer layer on coated conductor stacks was developed.

Professor Darrell Irvine's laboratory recently demonstrated a novel approach based on a photoresist copolymer developed in their laboratory for creating complex protein patterns on surfaces under mild aqueous conditions (reported in *JACS* and *Langmuir*). Building on this fundamental work, they have created patterned surfaces that can be used to dissect important cell–cell interactions in biology T cells, which are normally activated when they make contact with a second cell type known as an antigen presenting cell (APC) and form an immunological synapse—an organized arrangement of cell surface receptors and intracellular signaling molecules at the T cell–APC interface. Professor Irvine and colleagues replaced the living APC with synthetic patterned surfaces presenting proteins to T cells in regular arrays. By analyzing the responses of T cells seeded onto these synthetic "immunological synapse arrays," they showed for the first time a correlation between the geometric organization of synapses and T cell triggering and also uncovered new insights into events leading up to T cell division following triggering. This work was reported in the *Proceedings of the National Academy of Sciences, USA.*

In other ongoing studies, the Irvine lab has demonstrated the use of synthetic hydrogel microspheres loaded with cell-attracting proteins for the guidance of immune cell migration. Immune cells normally home to sites of infection by migrating "up" concentration gradients of molecules known as chemokines secreted at the site of inflammation, a process known as chemotaxis. By encapsulating and controlling the slow release of these factors from synthetic microspheres, Professor Irvine has shown that immune cells can be directed to migrate hundreds of microns to specific points defined by the location of these chemokine-releasing microspheres. These particles can be used to dissect the biology of chemotaxis, enhance vaccines and immunotherapies, and direct cellular organization in tissue engineering applications.

Professor Krystyn J. Van Vliet, who joined DMSE in January 2004, uses experimental approaches and computational simulations to develop fundamental understanding and prediction of atomic-level defect nucleation in materials. Prior to joining the MIT faculty, she undertook postdoctoral studies in a clinical research environment, the Vascular Biology Program at Children's Hospital Boston. The Van Vliet research group focuses on the chemomechanics of material surfaces and interfaces, including hydrated (bio)polymers such as living mammalian cells. As she is interested in the atomistic and molecular mechanisms that govern this coupling between chemical and mechanical states in nanoscale experiments, her group also develops multiscale computational simulations of these dynamics. She has developed a nanomechanical contact-based cell surface imaging approach to map the distribution, identity, and binding properties of cell surface molecules that are key to mechanobiological processes, including differentiation of stem and cancer cells. In 2006, Professor Van Vliet received the 3M Innovation Award and the Arnold and Mabel Beckman Foundation Young Investigator Award to continue her group's studies of chemomechanics in biological and synthetic material systems.

Awards and Honors

Professor Sam Allen and his coauthors received the award for the best oral presentation at the 2005 Solid Freeform Fabrication Symposium for their paper, "Improving Accuracy of Powder Sintering-based SFF Processes by Metal Deposition from Nanoparticle Dispersion."

Professor Belcher was named to *Fortune* magazine's 2005 list of "10 People to Watch," innovators who will have a direct impact on our lives.

The American Society of Materials International presented Professor Mert Flemings with the Albert Easton White Distinguished Teacher Award for unusually long and devoted service in teaching, significant accomplishments in materials science and engineering, and an unusual ability to inspire and impart enthusiasm to students. Professor Flemings received the Gold Medal of the Japan Institute of Metals in 2005 for his outstanding achievements in advancing the science and technology of metallurgy and materials science. In March, he was appointed an honorary member of the American Institute of Mining, Metallurgical, and Petroleum Engineers.

Professor Nicola Mazari was professeur invitée of the Institute Univérsitaire de France in 2006.

Professor Francesco Stellacci received the Packard Award, the DuPont Young Professor Award, the 3M Non-Tenured Faculty Award, and the 3M Innovation Award. He was also named one of *Technology Review*'s "Top 35 Innovators under 35."

Professor Subra Suresh was named to the Tan Chin Tuan centennial professorship (overseas) by the National University of Singapore.

As mentioned above, Professor Krystyn Van Vliet received the Beckman and 3M Awards. The GMC Outstanding Advisor Award was also presented to Professor Van Vliet.

The GMC presented the Outstanding Graduate Teaching Award to Professor Bernie Wuensch.

In May, School of Engineering Infinite Mile Awards were presented to Aza Gevorkian, human resources representative in ASO, and to Gerry Hughes, DMSE facilities manager. Amanda Tat, fiscal officer in ASO, received an Infinite Mile Award from the Office of the Associate Provost and Vice President for Research.

L. Gabrielle Joseph, Dr. Robert C. O'Handley, and Charlotte L. Peed all joined the Quarter Century Club this past year.

Undergraduate Awards

Antonella Alunni received the DMSE award for Outstanding Senior Thesis.

Anna Bershteyn and Michael D'Auria each received the DMSE award for Best Internship Report.

Kimberly Kam was recognized for her outstanding service to the DMSE community.

Forrest Liau was named Outstanding Student, DMSE Class of 2006. Nan Yang was named Outstanding Junior, and Victor Brunini was named Outstanding Sophomore.

Charles G. Cantrell was inducted into Phi Beta Kappa.

Rene Chen received honorable mention for the Harold and Arlene Schnitzer Prize in the Visual Arts.

Michael D'Auria received the Howard W. Johnson Award.

Louise Glam and Jacqueline Greene were January Scholars in France for Excellence in the French Language.

Jin Kim and Jina Kim both received Public Service Fellowships from the MIT Public Service Center.

Yoa-Chung King was a winner of the Karl Taylor Compton Prizes.

Graduate Awards

Philippe Bertreau was named Elsevier Outstanding Graduate Student in 2006; in 2005, Kathleen Huffman received the Elsevier Outstanding Graduate Student Award.

Andy Detor was named Outstanding TA in a Graduate Class.

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

Heather Kulik received the award for an Outstanding Paper by a First- or Second-Year Graduate Student.

Celia Macias received the Graduate Student Community Service Award.

Ki Tae Nam received the Outstanding PhD Thesis Research Award.

Shiyun Ruan was recognized for Outstanding Performance as a First-Year Graduate Student.

Gerardo Lao was a winner in the IDEAS Competition for FirstStepCoral, an innovative project that makes a positive change in the world.

Kenneth C. Avery was a recipient of a Martin Fellowship for Sustainability.

Ismaila Dabo was made a member of the Martin Society of Fellows.

In recognition of his exceptional technical contribution in the field of silicon materials science, particularly in the area of ultrathin silicon-on-insulator dewetting, David T. Danielson received the 2005 Outstanding Student Research Award from the Si Wafer Engineering and Defect Science Center, an industry/university cooperative research consortium.

Kisuk Kang was an MRS Gold Medal winner. He also received a Student Research Award from the Electrochemical Society.

Alicia M. Jackson received the MRS Silver Medal at the MRS fall meeting 2005.

Sunyoung Lee received a continuation of the Hugh Hampton Young Memorial Fund Scholarship for service and scholarship.

John Mills was an MRS Gold Medal winner in fall 2005.

Jack Milwid received the DuPont–MIT Alliance Fellowship for his first year of studies (2005–2006).

Nate Quitoriano received a Graduate Student Award from the Institute of Electrical and Electronics Engineers/Materials Society Electronic Materials Committee for his research work presented at last year's conference.

Arum A. Yu received the MRS Silver Medal at the MRS spring meeting 2006.

New Faculty Chair Appointments

New chair appointments during AY2006 were Angela Belcher, Germehausen professor of materials science and engineering and biological engineering; Darrell J. Irvine, Eugene Bell career development associate professor of tissue engineering; Stephanie Reich, Thomas B. King assistant professor of materials science and engineering; and Krystyn Van Vliet, Thomas Lord assistant professor of materials science and engineering.

Future Plans

DMSE aims to maintain our reputation for academic and research excellence through recruiting and retaining the best materials science students and faculty in the world. While our excellent facilities and innovative curriculum are cornerstones of our program, we also wish to foster collaborations and an esprit de corps within the Department, the Institute, and the field. Through the renovation of our labs, teaching facilities, and offices in Building 6 and 8, DMSE will be able to create a welcoming and open atmosphere for our students, faculty, and staff.

We hope that the success of our "new" integrated undergraduate program continues to attract enthusiastic and brilliant undergraduates to the field of materials science and engineering. As our graduates increasingly follow careers in medical device, biotech, and pharmaceutical industries, we see the need for a biomedical materials track in our undergraduate curriculum. We are continuing to make a concerted fund-raising effort to fund all first-year graduate students through fellowships; through the generosity of the late Professor Morris Cohen, fund-raising for Cohen Memorial Fellowships is underway.

Each of our standing departmental committees will have diversity tasks to increase the number of underrepresented minorities in both faculty and students. We will continue to build world-class research facilities in order to attract a high caliber of faculty.

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/.