

Department of Materials Science and Engineering

The Department of Materials Science and Engineering (DMSE) continues to excel in innovative research and in offering relevant and vital undergraduate and graduate curricula. *US News and World Report* again ranked our graduate program first in the nation.

DMSE was saddened by the death of Professor Nicholas J. Grant after a long struggle with Alzheimer's disease. Professor Grant received the ScD from our department in 1944, became an instructor, and rose through the faculty ranks to become a professor in 1956. His contributions in the field of physical metallurgy of high-temperature alloys were legendary. He served on numerous national and international committees and his many awards and honors include being a member of the National Academy of Engineering. From 1968 to 1977 he served as director of MIT's Center for Materials Science and Engineering. Over his career, he was thesis advisor to 93 PhD/ScD students, 51 SM students, and 74 SB students.

After months of extraordinary effort on the part of department faculty and staff, MIT Facilities personnel, and many contractors, the DMSE Undergraduate Teaching Lab opened on September 2, 2003, with a celebration attended by many faculty and friends. Professor Subra Suresh, President Charles M. Vest, Provost Robert Brown, and dean of engineering Thomas Magnanti addressed the group and the nearly 100 Course 3 students and staff and other friends who watched the proceedings over MIT cable. Professor Suresh reviewed some of the history of the department and of the field of materials science and engineering. Teaching labs have been a part of the undergraduate curriculum since the department's founding, but the original materials studied were metals, then ceramics and polymers were added, and now the field also encompasses biomaterials, nanomaterials, and computational materials science. The Lord Corporation of Massachusetts and the Institute provided financial support for the lab construction.

In March, the Hanyang Undergraduate Teaching Laboratory, located in the DMSE Undergraduate Teaching Laboratory, was dedicated and the Hanyang University–MIT Department of Materials Science and Engineering Educational and Outreach Program was formally established. Dr. Chong Yang Kim, president of Hanyang University, and five members of the Hanyang University administration and faculty visited MIT and DMSE for the dedication. DMSE is grateful for Hanyang's support and looks forward to many years of friendship and research interaction.

Research Initiatives

DMSE faculty continue to participate in research through the Institute for Soldier Nanotechnologies (ISN), the Singapore–MIT Alliance (SMA), and the Deshpande Center for Innovation. Professor Angela Belcher will lead the MIT team of a new Institute for Collaborative Biotechnologies, funded by the US Army and made up of teams from MIT, the California Institute of Technology, and the University of California–Santa Barbara. This collaboration will perform research on biologically derived sensors, electronics, and information-processing devices.

Undergraduate Education

DMSE's undergraduate enrollment stands at about 124 students, of whom 55% are women, 11% are underrepresented minorities, and 10% are international students. The department undergraduate recruiting efforts include participation in Academic Expo during freshman orientation, an open house, the annual John Wulff Lectures, direct mailings to the freshman class, freshman advising seminars, and Independent Activities Period activities. The Internship Program continues to attract the majority of DMSE undergraduates; 34 DMSE students are working at 31 host institutions at 32 locations for the summer of 2004, including 4 overseas institutions.

In fall 2003, DMSE introduced a curriculum with a new set of integrated core subjects that provide a fresh, exciting experience for undergraduates. These subjects cover both theory (fundamentals) and practice (how these fundamentals are related to the real world) and include examples and applications in all lectures. For instance, students learn why viruses and proteins have such complex structures, why silicon is such a good material for making electronic devices, and why rubber is stretchy. Students also now have a much broader lab experience, with lab subjects closely tied to the lecture subjects. The new Undergraduate Teaching Laboratory contains a range of equipment, including facilities for biomaterials investigation, chemical synthesis, and processing of materials; equipment for the characterization of electronic materials; an optical bench; and a scanning electron microscope. Interest in the new curriculum is high, with nearly 50 sophomores having designated Course 3 in AY2003 and a similar number in AY2004. Renovation of additional laboratory space is nearly complete to accommodate new junior-year laboratory subjects that will commence in fall 2004.

Professor Linn Hobbs acts as faculty advisor for the department's undergraduate exchange program with Cambridge University as part of the Cambridge-MIT Institute (CMI) exchange. Four DMSE students and three Cambridge students participated in the exchange program in AY2004 and two DMSE students will attend Cambridge University in AY2005. Both DMSE and the Department of Materials Science and Metallurgy at Cambridge University continue to work together to integrate students into each institution's degree programs.

Graduate Education

The department has a very healthy graduate student enrollment, numbering 217 in fall 2003. Approximately 27% of the graduate students are women and 1% are underrepresented minorities. Fourteen DMSE students were enrolled in the Leaders for Manufacturing Program, 16 were enrolled in the Program for Polymer Science and Technology, and 4 were enrolled in the Health Science and Technology Program. For the fall of 2004, a total graduate student enrollment of about 246 is anticipated, approaching the largest DMSE graduate enrollment. An incoming class of 74 is expected, 52% of whom are domestic.

Master of Engineering in Materials

Master of Engineering (MEng) program students work with colleagues and faculty supervisors to design a focused program of study that suits their interests and goals. Sample programs are Materials for Micro- and Nanosystems, Computational Materials Science and Engineering, and Biomaterials and Materials for Biotechnology. A new MEng website was created with links for online application and brochure requests along with a color brochure and posters with information request cards. The fourth class of MEng students, 15 in number, will enroll in September 2004.

Other Educational Initiatives

MIT's Summer Institute in the Materials Science of Material Culture was held for the third year in June 2004. A group of 12 faculty from other US colleges enrolled in the National Science Foundation (NSF)-sponsored program and completed consecutive weeklong modules on "Acoustics and Culture in Mesoamerica: Metals and Sound"; and on "Cloth and Other Fiber Technologies in the Andean World." Instructors included DMSE professors Allen, Hobbs, Hosler, and Lechtman.

DMSE's Undergraduate 3-C Program in Archaeology and Materials has been recommended to move from experimental to permanent status by MIT's Committee on the Undergraduate Program, Committee on Curricula, and Faculty Policy Committee. Final approval is expected to be granted by vote of the MIT Faculty at its September 2004 meeting.

Student Organizations

Officers for the Society of Undergraduate Materials Scientists (SUMS) for 2004-2005 will be president, Kevin McComber; vice president, Robin Davis; treasurer, Ed Barnard; and secretary, Janet Leung.

The Graduate Materials Council officers for 2004-2005 will be president, Joel Williams; vice president, Scott Litzelman; treasurer, Neal Vachhani; DCGS representatives, Megan Frary and Jifeng Liu; social chairs, Chris Fischer, Andrew Detor, Pedja Djuranovic, and Ben Jackson; intramural chair, Carl Dohrman; research and careers chair, Asher Sinensky; GSC representatives, Catherine Tweedie, Rachel Pytel, and Nick Orf.

Personnel

Krystyn Van Vliet joined DMSE as assistant professor of materials science and engineering in January 2004. Professor Van Vliet holds a PhD from the department and is currently directing the Nanomechanical Technology Laboratory.

Professor Ron Latanision retired from MIT in August 2003 and will be a principal at Exponent, Inc. Over his career at MIT, he has directed the MIT Science and Engineering Program for Teachers, cochaired the New England Science Teachers organization, and served as co-PI of an NSF-sponsored Massachusetts Initiative on Partnerships Advancing Learning of Mathematics and Science. DMSE and MIT appreciate his dedication to teaching and research and wish him well in his future endeavors.

Effective July 1, 2004, Caroline Ross will be promoted to professor, Angela Belcher will be promoted to associate professor with tenure, and Christine Ortiz will be promoted to associate professor.

Dr. Olufemi Olowolafe was the Dr. Martin Luther King visiting professor in the department through December 2003.

Over the first nine months of 2004, Professor Suresh has been on sabbatical pursuing new research. In his absence, Professor Sam Allen has been acting department head.

Research Highlights

Professor Allen's research on three-dimensional printing of metal parts reached a new milestone. A process for liquid-metal infiltration of 3-D printed preforms has been demonstrated that allows fabrication of heat-treatable parts having the bulk composition of D2 tool steel with hardness and impact resistance after heat treatment comparable to wrought D2.

Professor Belcher's group has developed a virus-based toolkit for the directed synthesis of magnetic and semiconducting nanowires.

Professor Carter and his students published a definitive work on modeling of polycrystalline microstructural evolution and made significant advances on the effect of symmetry on photonic band gaps.

In a departure from current approaches, Professor Ceder and his group developed a truly new approach combining the accuracy of first-principles quantum mechanics with the optimization efficiency of data-mining algorithms currently used in consumer marketing. The new method has been shown to predict structure with a high probability of success and heralds a new direction for computational materials science.

Professor Chiang and his coworkers continued their research on new lithium battery materials and devices, including further development of lithium-iron-phosphate olivines as a low-cost, ultrasafe, high-power cathode material for rechargeable batteries.

Professor Cima's group published a paper in *Nature Materials* describing the operation of a fully resorbable microchip drug-delivery device capable of pulse delivery of proteins.

Professor Clark's research team has developed a systematic framework that integrates environmental, engineering, and economic analysis and is extending those tools to simultaneously calculate a "life-cycle emissions inventory" that includes data about the volume of chemicals and other materials released and consumed during the lifetime of a product, from manufacture through use and disposal.

Professor Eagar's group has shown that stressed joints can be made by optimizing the load and joining temperature in a simple, two-step process consisting of screen printing and brazing.

Professor Fink and his students have recently demonstrated a new class of fibers that combine conductors, semiconductors, and insulators in close proximity and mesoscale feature sizes to form functional optoelectronic fiber devices, providing a new paradigm for low-cost microtechnology fabrication.

Research in Professor Fitzgerald's group has shown that SiGe epitaxial and polycrystalline films can be oxidized in such a way that Ge precipitation can be controlled inside SiO₂ to create a plethora of nanostructures including our goal of isolated small GE dots. These dots may be useful in nonlinear optics.

Professor Gibson and her students have developed a model for fatigue-life prediction in trabecular bone based on the critical observation that the residual strain in the fatigue tests increased linearly with the number of cycles. The model allows fatigue-life predictions to be made based on the results of monotonic tests and fatigue tests at relatively few cycles of loading for a full range of normalized stresses.

Professor Hobbs continues with his two CMI-funded research programs on radiation stability and chemical durability of alternative nuclear waste forms and on early-stage bone mineralization in tissue apposing implanted prosthetic devices.

Professor Hosler's group continues the program of excavations at El Manchón, in the state of Guerrero, Mexico, the only ancient copper-smelting site known in Mesoamerica.

Professor Irvine's group made breakthroughs in the development of materials for creating multicomponent nano- and micropatterns of proteins at surfaces for cell biology and bioengineering applications, and they have developed synthetic virus-mimetic particles that dictate the trafficking and function of immune cells in vitro and in vivo for cancer and viral disease immunotherapy.

Professor Kimerling and his students determined conditions for fabricating silicon nanocrystals with emissions at $\lambda = 980$ nm and have shown their effectiveness in enhancing pump efficiency of Er₃SiO₂.

Professor Kirchain's group initiated research on the measurement of the sustainability of materials systems, focusing on the use of aluminum and on materials in consumer electronics.

Professor Lechtman is engaged in a long-term investigation of the bronze technologies that developed in the Andean zone of South America during the prehistoric period, focusing on determination of the rare ore source for the nickel component of a ternary Cu-As-Ni bronze.

Professor Marzari and his students develop and apply novel electronic-structure approaches to understand and predict the properties of complex materials, and they have proposed two novel classes of materials: semiconducting nanoparticles as ballistic-load absorbers and ultrathin film-supported transition metals as tunable catalysts.

Professor Mayes has fabricated high-throughput, high-selectivity nanofiltration membranes from amphiphilic graft copolymers and demonstrated their utility in applications including oily wastewater treatment, nanoparticle separations, and molecular sieving.

Dr. O'Handley's group has demonstrated novel hybrid actuator systems that combine piezoelectric and ferromagnetic shape-memory alloys.

Professor Ortiz's group has succeeded in directly imaging the nanoscale constituents of cartilage, bone, and natural exoskeletons and shells down to the single-molecule level, yielding previously unknown information on the dimensions, supramolecular structure, self-assembling properties, conformation, stiffness, and molecular mechanisms of deformation in these materials.

Dr. Paul and his students have completed a time-dependent model of variant (or grain) growth by twin-boundary motion including discrete lattice effects, twin-boundary/dislocation interaction, viscosity, and externally induced acoustical vibrations in the presence of directed external driving forces.

Professor Powell and his students developed a software code for multiphysics simulations involving fourth-order partial differential equations and complex couplings, and they are applying it to study fluid-structure interactions with solid-liquid interfaces whose topology changes with time.

Professor Ross and her students used research on the phase separation in thin films of block copolymers to generate nanolithography templates for making large-area arrays of magnetic dots that have great potential applications in magnetic media and magnetic random access memories.

Professor Roylance's research centered on process-structure-property investigations of polymers and composite materials, especially dealing with mechanical properties.

Professor Rubner and his students used microporous layer-by-layer assembled polyelectrolyte multilayers to produce thin-film coatings that exhibit a superhydrophobic "lotus leaf" effect; thin films of this material are not wettable by water and exhibit water-droplet advancing contact angles of 160° or higher.

Professor Russell is continuing to study precipitate coarsening and grain growth in austenite and its decomposition products.

Professors Sadoway and Mayes collaborated in research related to solid-state rechargeable lithium polymer batteries and completed the design, synthesis, and testing of a single-ion, solid polymer electrolyte that offers improved performance in a thin-film solid-state battery.

Professor Schuh's research team is studying the role that disorder plays in determining structural properties of metals and alloys; they have derived a new crystallographic rule that constrains the assembly of so-called coincidence grain boundaries in materials with cubic crystal structures and derived an analytical solution for the statistical distribution of triple-junction types in a polycrystal.

Professor Stellacci's group has discovered the first nanostructured nanomaterial class: metal nanoparticles coated with a mixture of phase-separated molecules. The presence of ordered phases with one dimension smaller than 8 Å on the ligand shell of a nanoparticle represents a major breakthrough in many fields.

Professor Suresh directs the Defense University Research Initiative in NanoTechnology, under the auspices of which his research group has discovered a number of mechanistic processes that offer possible avenues for improvements in mechanical properties of nanostructured materials.

Professor Thomas continues to direct the ISN in its work to help protect soldiers and first responders. His research group's long-standing efforts in self-assembly of block copolymers are bearing new fruit, especially vis-à-vis the tailoring of optical and mechanical properties via addition of inorganic particles to create hybrid organic-inorganic nanocomposites.

Recent work in Professor Thompson's group on stress evolution during growth of thin films has led to discovery of a correlation between measured stress changes and changes in the structure of evolving thin-film surfaces and demonstrates that high-sensitivity stress measurements provide a new tool for real-time in situ monitoring of surface and structure evolution during film growth.

Professor Tuller's group has invented means for integrating thin-film metal-oxide-based optical modulators into silicon, a key objective of the Microphotonics Center's effort to create silicon-based photonic devices.

Professor Vander Sande, in collaboration with Professor Jack Howard in Chemical Engineering, studies fullerenes and fullerene nanostructures by combustion synthesis; recent work has led to an understanding of the parameters of operation of the reactor that lead to optimizing the yield of fullerenes or specific fullerene nanostructures.

Professor Van Vliet completed postdoctoral work with Dr. Marsha A. Moses in the Vascular Biology Program at the Children's Hospital, Boston, and the Harvard Medical School, investigating the effects of mechanical stimuli on cell phenotype in the context of angiogenesis, the sprouting of new vasculature that is required for the growth and metastases of cancerous tumors.

Professor Wuensch's group is continuing experimental and modeling studies of cationic and anionic order-disorder transitions in pyrochlores and their influence on crystal properties.

Awards and Honors

Professor Angela Belcher received a four-star recognition award for “significant contributions to Army Transformation.” Professor Belcher was also named one of the Nanotech Power Elite by *Forbes/Wolfe Nanotech Report*. Professor Gerd Ceder received the 2003 Research Award of the Battery Division of the Electrochemical Society. Professor Yoel Fink received a National Academy of Sciences Award for initiatives in research. Professor Tom Eagar and his former student Patricio Mendez were awarded the Charles H. Jennings Memorial Medal by the American Welding Society. Professor Mert Flemings received an honorary doctorate at the Swiss Federal Institute of Technology in Lausanne in recognition of his role as a pioneer and his exceptional scientific contributions in the field of solidification and foundry. Professor Jim Livingston was recognized as an outstanding freshman advisor; he has led a freshman advising seminar on “Attraction and Repulsion: The Magic of Magnets” for 12 years. Professor Anne Mayes was named a fellow of the American Physical Society in recognition of her “outstanding theoretical and experimental research on the interfacial behavior of polymers and the phase behavior of polymeric behavior.” Professor Caroline Ross received the Irwin Sizer Award for the most significant improvement in MIT education. Professor Don Sadoway received the Everett More Baker Memorial Award for excellence in undergraduate teaching. Professor Chris Schuh received a 2004 Office of Naval Research Young Investigators Award. Professor Schuh also received the Robert Lansing Hardy Award from the Materials Society. Professor Subra Suresh was elected to the American Academy of Arts and Sciences (AAAS). Professor Suresh will receive a Humboldt Research Award in recognition of lifetime achievements in science; the awardees are invited to carry out research projects in Germany. Professor Suresh was also selected as a Gordon Moore distinguished scholar by the California Institute of Technology, was elected a foreign fellow of the Indian National Academy of Engineering, will hold the Brahm Prakash visiting professorship at the Indian Institute of Science in Bangalore, and will receive the Albert Sauvier Achievement Award from the American Society of Materials International at its fall 2004 meeting. Professor Ned Thomas was named an AAAS fellow in recognition of his “insightful studies of polymer-based nanocomposites, particularly mechanical and optical properties of ordered block copolymer nanoparticle materials and for leadership in materials education and nanotechnology.” Professor Harry Tuller was awarded an honorary doctorate by the Université de Provence, Marseille, France, for his lifelong achievements in the field of electroceramics.

Yu Huang, a postdoc in the Belcher Lab, was named one of *Technology Review's* Top 100 Young Innovators in 2003. Miguel Marioni, a postdoc in Dr. O’Handley’s group, was invited to present at this year’s Deshpande Innovation Showcase.

Kenneth E. Greene Jr. of DMSE Headquarters and Erminia Piccinonno of the Administrative Services Office both received Infinite Mile Awards recognizing their dedication to their jobs and the high level of service they provide. Among those joining MIT’s Quarter Century Club this year was Carol A. Roberts, administrative assistant in the Center for Materials Research in Archaeology and Ethnology.

AY2004 Undergraduate Awards

Tanya Cheng received honorable mention for the S. Klein Prize for Scientific and Technical Writing. Kasetta Coleman received the Ronald E. McNair Scholarship Award for her combination of strong academic performance and considerable contribution to the minority community. Nduka O. Enemchukwu was awarded the 2003 American Chemical Society Scholarship. Lesley Frame received the DMSE Outstanding Senior Thesis Award for "Investigations at Tal-I Iblis: Evidence for Copper Smelting during the Chalcolithic Period." David Gray was named Outstanding Sophomore. Timmie Ting-Wei Hong was named to the Phi Beta Kappa Society. Yuki Hori received the Best 3-B Internship Report Award for "Contamination-resistant Coatings in the Paper Machine Industry." Yuki Hori and Michelle Seitz received certificates recognizing their perfect 5.0 cumulative grade-point average over their MIT undergraduate education. Also, Yuki Hori, Ana Ramos, and Michelle Seitz were named Outstanding Students in DMSE Class of 2004. The "Surreptiles," a team including Byron Hsu, Forrest Liau, David Lin, and Han Xu, were second-place winners of an ISN-sponsored competition for students to design technology to benefit soldiers; they developed a glove that translates hand signals into voice commands by using sensors and radios. Jina Kim received a Service Award for renewing the MIT chapter of Best Buddies. Anita Kris received the Robert A. Boit Writing Prize—Short Story, First Prize. Kevin McComber's active and innovative role as SUMS president was recognized with an Award for Outstanding Service to the DMSE Community. Joanna Natsios and David Schoen were named Outstanding Juniors. Ana Ramos has received a Fulbright US Advanced Student Award to spend a year of study and research in France; she will be doing a master of science and technology in materials science and nano-objects in a program run by the Université de Pierre et Marie Curie. Michelle Seitz won the Henry Ford II Award.

AY2004 Graduate Awards

Lara Abbaschian and George Whitfield received the John Wulff Award for Excellence in Teaching. Manish Deopura's work on the "perfect mirror" was exhibited in the Talente 2004 Competition. Kristin Domike and her team, developing "TulipMed," were finalists in the 2004 National Institute for Entrepreneurship Competition and the Venture Bowl; this team won in the Life Science division of the \$1K Business Idea Warm-Up competition sponsored by the MIT \$50K Entrepreneurship Competition. Megan Frary and some of her collaborators at Caterpillar and Oak Ridge National Laboratory won an R&D 100 Award for developing one of the 100 most technologically significant new products of the year; the title of their product was "CF8C-Plus: New Cast Stainless Steel for High-Temperature Performance." Garry Maskaly was a Gold Medal winner at the 2003 fall MRS meeting in Boston. Karlene Maskaly and Agnieszka Stachowiak have been selected to attend GE's Technology and Innovation Day this July; this is a networking event for top female PhD students in the northeastern United States. Aaron Raphel won the Charles "Harrison" Smith Award from the Engineering Systems Division. Catherine Tweedie received the 2004 Pewter Bowl Award, presented to the female senior who has shown the highest qualities of inspiration and leadership in contributing to women's athletics. Ms. Tweedie also received the Betsy Schumacker Award for excellence in athletic competition, placed 8th in the nation at the NCAA track and field championships, and is a recipient of NDSEG and NSF graduate fellowships.

Faculty Notes

Faculty members of this department include these chairholders: Samuel Miller Allen, POSCO professor of physical metallurgy; Angela Belcher, John Chipman career development associate professor of materials science and engineering and biological engineering; W. Craig Carter, Lord Foundation professor of materials science and engineering; Gerbrand Ceder, R. P. Simmons professor of materials science and engineering; Yet-Ming Chiang, Kyocera professor of ceramics; Michael John Cima, Sumitomo Electric Industries professor of engineering; Thomas W. Eagar, Lord Foundation professor of materials engineering and materials systems; Yoel Fink, Thomas B. King assistant professor of materials science; Eugene A. Fitzgerald, Merton C. Flemings–SMA professor of materials engineering; Merton Corson Flemings, Toyota professor emeritus of materials processing; Lorna J. Gibson, Matoula S. Salapatas professor of materials science and engineering; Darrell J. Irvine, Karl Van Tassel assistant professor of biomedical engineering and materials science and engineering; Klavs Flemming Jensen, Lamot du Pont professor of chemical engineering and professor of materials science and engineering; Lionel C. Kimerling, Thomas Lord professor of materials science and engineering; Nicola Marzari, AMAX career development assistant professor of computational materials science; Anne M. Mayes, Toyota professor of materials science and engineering; Caroline A. Ross, Merton C. Flemings career development associate professor of materials science and engineering; Michael Francis Rubner, TDK professor of materials science and engineering; Donald Robert Sadoway, John F. Elliott professor of materials chemistry; Subra Suresh, Ford professor of engineering; Edwin Lorimer Thomas, Morris Cohen professor of materials science and engineering; Carl V. Thompson, Stavros Salapatas professor of materials science and engineering; and John Bruce Vander Sande, Cecil and Ida Green distinguished professor. Effective July 2004, Francesco Stellacci will be the Finmeccanica assistant professor of materials science and engineering.

Professor Harry Tuller chaired the International Conference on Electroceramics at MIT during the summer of 2003. Over 275 international attendees spent several days at the conference attending lectures and symposia and viewing exhibitions.

Future Plans

Design of the new DMSE Headquarters, Academic Office, Chipman Room, and faculty offices is complete and construction is scheduled to commence during AY2005, with occupancy in 2006. A cooperative exchange of space with the Department of Physics has enabled MIT funding of the renovation, and the department looks forward to occupying the new space on the first floor of Building 6 when the project is completed.

As our revised undergraduate curriculum enters its second year, we will be launching four new junior-year required subjects that combine lecture and laboratory learning. A significant effort is planned to monitor and assess the effectiveness of the entire revised curriculum.

The department anticipates hiring several new faculty members over the next few years and in preparation will conduct a significant strategic planning project to assess current strengths and areas of opportunity.

Subra Suresh

Head

Ford Professor of Engineering

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