Department of Materials Science and Engineering

The Department of Materials Science and Engineering (DMSE) continued its growth in academic year 2015. The department continues to address its goal of hiring promising junior faculty, with Rafael Jaramillo and Juejun Hu joining the department this year and three newly hired faculty to arrive in the 2016 academic year. The DMSE Visiting Committee met in fall 2014 and was pleased with the efforts that had been made toward improving student life, fundraising for fellowships, and renovating educational and research laboratories.

Professor Emeritus Harry C. Gatos passed away this spring at the age of 93. He joined the faculty in 1965 after holding positions as a research engineer at DuPont and as head of the Solid State Division at Lincoln Laboratories. His research interests in semiconductor materials, chemistry, and the physics of materials provided him with a broad and interdisciplinary view. That view led him to co-found the Materials Research Society (now the field's largest professional organization) and to serve as its first president, as president of the Electrochemical Society, and as head of MIT's Center for Materials Science and Engineering. He retired in 1989. In 1991, the Sumitomo Corporation established MIT's Gatos Lecture and Award in his honor.

Educational Initiatives

DMSE continued to dedicate energies to building resources for online education, for both *MITx* and the Semester from Anywhere. An award from the Engineers for a Small Planet Fund will support DMSE's global education initiatives, starting with 3.003 Global Principles of Engineering Practice. In this intensive subject, which is co-taught with the University of Tokyo and Masdar Institute, students form teams to work with faculty and industry on complex engineering problems to learn a technical toolkit, a social science toolkit, and a methodology for problem-based learning. The semester culminates in a trip to Japan, during which the MIT undergraduates experience another culture of work and education, ultimately fostering better collaboration and understanding for their academic and professional careers.

Undergraduate Education

With an incoming sophomore class of 35 students, DMSE's undergraduate enrollment will be 105 students, with 69.5% women, 22.85% members of underrepresented minority groups, and 4.76% international students. Seven students are designated Course 3-A (a flexible degree program often taken by students intending to continue their education in the fields of medicine, business, or law). This past academic year, six students graduated with a double major; four current students are declared double majors.

Graduate Education

The department's graduate enrollment remains strong, numbering 199 in fall 2014. Approximately 23% of the graduate students are women and 3.5% are members of underrepresented minority groups. Nine DMSE students participate in the Program in

Polymers and Soft Matter. For fall 2015, the department anticipates an incoming class of 26, approximately 23% of whom are women.

Student Organizations

DMSE's student organizations organize events and develop activities for their fellow students and for the community. This past year, they again created a Freshman Preorientation Program, welcomed new students to MIT during orientation, helped with recruiting efforts, developed demonstrations for the Cambridge Science Festival and the MIT Edgerton Center Science on Saturday and other venues, and arranged lunch and dinner events with faculty and alumni.

The 2015–2016 Society of Undergraduate Materials Scientists (SUMS) officers are president Mary Elizabeth Wagner, vice president Alexandra Rigobon, career development chairs Isabel Crystal and Rebecca Gallivan, secretary/publicity chair Nicole Effenberger, social chairs Jaclyn Belleville and Jennifer Pan, historian Marol Escajeda, and lounge chair Frances Lenahan.

The Graduate Materials Council officers for 2015–2016 are president Olivia Hentz; vice president Bradley Nakanishi; treasurer Zhibo Zhao; secretary Abigail Halim; academic committee members Seth Cazzell, Rushabh Shah, and Frank McGrogan; athletics chair Brendan Smith; social chairs Owen Morris, Jerome Michon, Kevin Bogaert, and Derek Kita; alumni committee members Xueying Zhao and Michael Rein; coffee hour chairs Jonathan Hwang and Alexander Senko; representatives to the Departmental Committee on Graduate Students Christopher Heidelberger, Daniil Kitchaev, and Michael Rein; Graduate Student Council representatives Sarah Goodman, Shuchi Ojha, and Edward Kim; outreach committee: Bradley Nakanishi and Erica Lai; publicity chair Erica Lai; Materials Research Society (MRS) student chapter president Scott Grindy; and sustainability chair Jeremy Poindexter.

Facilities

In the past year, DMSE completed renovations of the forge, foundry, and glass facilities in the basement of Building 8 that improved air handling and provided new equipment. These hands-on teaching facilities are important to the educational experience. Passersby are able to watch students and instructors at work through windows to the corridor. DMSE is delighted to have been able to name these spaces for two faculty members who served as inspirations to generations of materials scientists and to know that many more generations will be educated in the Merton C. Flemings Materials Processing Laboratory and the W. David Kingery Ceramics and Glass Laboratory.

In the spring, the department completed construction of the DMSE Commons, a new shared space for the department in which the department can collaborate and have informal discussions and meetings. The Commons is located directly across from the Laboratory for Engineering Materials on the first floor of Building 4. This space replaces the DMSE undergraduate and graduate lounges in Building 8, which will become office space for incoming faculty or graduate students.

Fundraising

DMSE saw a remarkably strong year in fundraising in FY2015, receiving $4.06 million, compared with an annual average of $1.16 million over the previous five years. The department received several remarkable gifts: $2 million from Vasilis (SM ’61, PhD ’66) and Danae Salapatas toward graduate fellowships, $783,000 toward the glass laboratory, forge, and foundry renovation, $150,000 from an anonymous foundation to support international student projects and collaborations, and a $1 million charitable trust gift from Ronald (’54, ’59, SM ’60) and Carol Kurtz for graduate fellowships in honor of Professor Merton C. Flemings. A generous gift from the Lemelson Foundation endowed the Lemelson-Vest Fund for Student Invention to support hands-on experiences for students to use the glass laboratory, foundry, forge, and other fabrication facilities within DMSE. The department is well aligned with the Institute’s priorities for the coming capital campaign. In FY2016, the department will seek to sustain giving well above previous averages.

Personnel

Over the past academic year, the department has continued its faculty searches, aiming to add to the department and to increase its teaching and research depth and breadth. Robert Macfarlane will join DMSE in September 2015 as assistant professor of materials science and engineering. Dr. Macfarlane received a BA in biochemistry from Willamette University and a PhD in chemistry from Northwestern University, where he was a recipient of the Ryan Fellowship for nanotechnology researchers, an International Institute of Nanotechnology Outstanding Research Award, and an MRS Gold Graduate Student Award. On graduating from Northwestern University in 2013, he was awarded a Kavli Nanoscience Institute post-doctoral fellowship to work at the California Institute of Technology. His research will focus on developing a set of design principles for synthesizing new inorganic/organic composite materials, where nanoscale structure can be manipulated to tune the emergent physical properties of a bulk material. These structures have the potential to affect energy-related research via light manipulation (e.g., photonic band gaps or plasmonic metamaterials), electronic device fabrication (e.g., semiconducting substrates or data storage devices), and environmental and medical research (e.g., hydrogels for sustained drug delivery).

Julia H. Ortony will join the DSME faculty in January 2016 as assistant professor of materials science and engineering. She holds a BS in chemistry from the University of Minnesota, Twin Cities, and a PhD in materials chemistry from the University of California, Santa Barbara. Most recently, she has held a postdoctoral appointment as a Baxter Fellow at Northwestern University. Dr. Ortony is an experimentalist in the field of soft materials, with a particular interest in experimental molecular dynamics methods, especially as they relate to self-assembled nanostructures for biomaterials and electronic materials applications.

Also in 2016, we will be joined by C. Cem Tasan will also join the department in 2016 as the Thomas B. King Assistant Professor of Metallurgy. Dr. Tasan received a BSc and MSc from Middle East Technical University, in both metallurgical and materials engineering,

and a PhD from Eindhoven University of Technology in mechanical engineering. He has held appointments at Max-Planck-Institut für Eisenforschung GmbH, working on micro-mechanics and alloy design. He aims to explore the boundaries of physical metallurgy, solid mechanics, and analytical microscopy to provide game-changing structural materials solutions to environmental challenges. At MIT, he hopes to utilize his research interests in the classroom, adding to the department's already strong elective offerings.

Effective July 1, 2015, Krystyn J. Van Vliet will be promoted to full professor; Alfredo Alexander-Katz and Geoffrey S.D. Beach will receive tenure. Professor Van Vliet received a ScB from Brown University and a PhD from DMSE. She joined the MIT faculty in 2004 after a postdoctoral appointment at Boston's Children's Hospital. Her research interests are diverse, leading to collaborations across the Institute and around the world. Her keen insight into technology and policy led to her appointment as MIT's faculty co-lead on the President's Advanced Manufacturing Program 2.0. In that capacity, she worked with Provost Schmidt to direct a team of representatives nationwide to develop programs to stimulate US manufacturing innovation.

Professor Alexander-Katz received a BS from Universidad Nacional Autónoma de México and a PhD from the University of California, Santa Barbara, both in physics. His research in soft materials science is at a frontier, combining disciplines and addressing questions with a variety of theoretical and modeling techniques. After postdoctoral positions at the National Science Foundation and the Centre National de la Recherche Scientifique, he came to MIT in 2008 and was promoted to associate professor in 2013.

Professor Geoff Beach joined the DMSE faculty in 2008, after receiving a BS from the California Institute of Technology and an MS and a PhD from the University of California, San Diego, all in physics. He held a postdoctoral fellowship at the University of Texas, Austin. He is widely recognized as a leader for his experimental work in magnetic materials, which is now leading not only to new developments but also to a new class of devices, called magneto-ionics. He is also recognized for his teaching excellence and is the recipient of a Bose Junior Teaching Award.

Effective July 1, Polina Anikeeva will hold the Class of 1942 Career Development Professorship and Yang Shao-Horn will be the W.M. Keck Professor of Energy.

Professor Gerbrand Ceder has accepted a position at the University of California, Berkeley.

James Hunter has joined the instructional staff. He completed a PhD in environmental chemistry at MIT in 2014 and a BS in chemistry at UC Berkeley in 2009. He discovered his passion for teaching during his graduate career, influenced both by his experiences with undergraduate field research in Civil and Environmental Engineering and volunteer work in the DMSE forge and foundry. He enjoys teaching the hands-on skills associated with laboratory work as well as the theoretical underpinnings. In January, Franklin Hobbs left DMSE to pursue graduate studies.

Heather Upshaw joined DMSE in 2014 as the development officer. She comes to MIT with more than eight years of experience in development, including previous positions at Wellesley College and the University of Chicago. Ms. Upshaw was educated at St. John's College. Her first projects have been raising endowed funds for graduate student fellowships and capital funds for the renovation of the Flemings Materials Processing Laboratory and the Kingery Ceramics and Glass Laboratory.

Adam Shervanian was hired as DMSE's facilities manager this spring. For the past two years, he managed facilities for CBRE. Prior to that, he spent eight years as the director of facilities and services for the School of Public Health at the University of Maryland. He also has eight years of experience working in facilities and event management for the athletic departments at Wagner College and Southern New Hampshire University. He is a graduate of Southern New Hampshire University (called New Hampshire College when he attended) and Wagner College. Gerry Hughes has joined the facilities staff at Lincoln Laboratories.

Research Highlights

Research in materials science and engineering is addressing current and future needs and challenges in energy storage, medicine, transportation, recycling, building materials, and communications. Over the past year, DMSE faculty and students have reported major research results in many areas; here are a few examples of recent work.

Professor Yoel Fink's group has developed a new process for creating silicon fibers, starting from low-cost silica glass preforms with aluminum cores. In the laboratory, the preforms are pulled into fibers under high temperature, which causes the aluminum core to react with the silica, leaving behind pure silicon. This inexpensive method could very well change the economics of silicon-core fiber production.

Professor Lorna Gibson's group has been analyzing the structure, density, stiffness, and strength of bamboo. Bamboo is an abundant natural resource, especially in developing countries, where it often used in structural applications. It is also a more renewable resource than traditional hardwood and softwood timbers because it grows at a much faster rate. Gibson's group is working to create improved bamboo wood composites, similar to plywood, that use specific parts of the bamboo plant chosen for particular mechanical properties.

Professors Caroline Ross and Geoffrey Beach are members of the Center for Spintronic Materials Interfaces and Novel Architectures (C-SPIN), a University of Minnesota-led team of professors, students, and postdoctoral associates. C-SPIN's goal is to create computing technology that operates using the spin of an electron, rather than the charge of an electron, as is typical of modern computers. They hope that by 2025, spin-based computing and memory will be 10 times faster and use 1% of the energy of current technologies. The project is working to develop methods to use ultra-small magnetic structures and insulators to control and switch spin.

Professor Donald Sadoway's group has continued to improve liquid-metal battery technology for grid-level storage. The group's innovation allows the battery to work at a temperature that is lower by 200 degrees Celsius than the previous iterations, without affecting voltage, and the battery will still retain 85% efficiency after 10 years of daily charge and discharge. Unlike the original formulation of liquid-metal batteries, the current version now has one electrode made of lithium and the other is a mixture of lead and antimony.

Awards and Honors

The Graduate Materials Council named Professor Alfredo Alexander-Katz the Best Advisor and Professor Michael Demkowicz was named the Best Teacher. The awards are determined by vote after all DMSE graduate students have the opportunity to nominate awardees.

Professor Polina Anikeeva received the BRAIN young investigator award from the Engineering in Medicine and Biology Society of the Institute of Electrical and Electronics Engineers. Professor Anikeeva gave a TEDx talk in Boston in June, "Rethinking the Brain Machine Interface," that can be viewed on YouTube. Professor Gerbrand Ceder was named a fellow of the Materials Research Society. Professor Darrell Irvine was inducted into the American Institute for Medical and Biological Engineering. Professor Ju Li has been named a fellow of the American Physical Society, nominated by the Division of Materials Physics.

Professor Michael Demkowicz joined the editorial board of *Scientific Reports* in the area of condensed matter physics.

Professor Lorna Gibson was named a MacVicar Fellow. Professor Jeffrey C. Grossman gave DMSE's 2015 Wulff Lecture, an introductory, entertaining lecture that serves to educate, inspire, and encourage MIT undergraduates to take up the study of materials science and engineering.

Professor Niels Holten-Andersen has received an Office of Naval Research Young Investigator Award for a proposal titled "Using Bio-Inspired Material Crosslink Dynamics to Engineer Energy-Dissipative Polymer Mechanics."

Professor Donald Sadoway was invited to give several addresses this year. At the Sidney Pacific Presidential Fellows Distinguished Lecture Series, he spoke on "Electrochemical Pathways Toward Sustainability"; at Crossroads 2015, a one-day event to discuss innovations to supply chains, he spoke on "Advancing the Energy Revolution"; and as the keynote speaker at the Technology Innovation Forum, he deilvered an address on "Inventing Inventors: Faculty at Their Best."

Undergraduate Awards

Inbar Yamin '15 was named Outstanding Senior. In addition to repeating her outstanding academic performance this year (she was recipient of the Julian Szekely Award for the Outstanding Junior last year), she was the teaching assistant (TA) for 3.032x, tutored for 3.034 Organic and Biomaterials Chemistry, and graded for 3.054

Cellular Solids: Structure, Properties, Applications. She is the president of the Friends of Israel Club and taught beginning Hebrew over the Independent Activities Period. Through a connection with D-Lab, she helped out with ayzh, a company that makes clean birthing kits for women in developing countries.

Christina Tringides received the award for Outstanding Senior Thesis. Christina's thesis, "Materials Selection and Processing for Reliable Neural Interfaces," describes a suite of materials processing methods that she has developed to engineer the interfaces between fiber-based probes and neural tissues. The results that were detailed in her senior thesis are included in a *Nature Biotechnology* paper and a non-provisional US patent application on which she is a co-author and co-inventor. Her work has also resulted in both a talk and a poster presentation at the spring MRS meeting. She is graduating with a double major in physics.

Jennie Zheng '15 was the recipient of the Horace A. Lubin Award for DMSE Community Service. Jennie served as the SUMS president this past year. During her time as president, Jennie worked to create a SUMS website and arranged numerous study breaks, student-faculty lunches and pub nights, and industry/graduate school panel sessions for the benefit of her fellow students.

Jose Burgos '15 was awarded the Joseph M. Dhosi Outstanding Internship Award. His internship report, "Comparison of Machined and Metal Injection Molded Components with Respect to Mechanical Properties and Behavior," on his work at Boston Scientific Group was supervised by Professor Niels Holten-Andersen.

Raku Watari '16 received the Julian Szekely Award for Outstanding Junior.

Rebecca Gallivan '17 was named Outstanding Sophomore.

The Undergraduate Teaching Award was received by Carolyn Joseph '15 for her significant contributions to 3.091 Introduction to Solid-State Chemistry.

Khetpakorn Chakarawet '15 and Inbar Yamin '15 were invited to join Phi Beta Kappa. Jesus Moreno '16 and Chimdimma Okwara '16 were named Burchard Scholars for the School of Humanities and Social Sciences. Shruti Sharma '15 received a Gates Scholarship to study at the University of Cambridge.

Graduate Awards

At Commencement, the department presented the Best Ph.D. Thesis award to Uwe Bauer of the Beach Group for "Voltage Programmable Materials." Uwe's thesis work has led to 10 papers, including first-authored papers in *Nature Nanotechnology* and *Nature Materials*, and three filed patent applications. Professor Beach said of Uwe, "He led every aspect of the work, and it is with no exaggeration that I say without his insights, attention to detail, and extraordinary engineering and laboratory skills, this work never would have happened, neither in my group nor in the many competing groups exploring magneto-electric effects in thin metallic ferromagnets at the time." Uwe is working as a senior engineer at the MIT start-up Liquiglide Inc.

The Graduate Student Teaching Awards were presented to Zachary Cordero for his work in 3.22 Mechanical Behavior of Materials and to Michael Gibson for his work in 3.20 Materials at Equilibrium.

The DMSE Community Service Award was presented to Michael Campion for his dedication to the department and to the community around MIT. Michael spends most Sundays teaching advanced mathematics topics to students in the fourth- through sixth-grade; he is also a mentor for MITxplore.

The John Wulff Excellence in Teaching Award was presented to Eric Jones for his work as a TA for 3.022 Microstructural Evolution in Materials.

The Best Paper Award for Second- or First-Year Student was received by Sai Gautam Gopalakrishnan, who was the first author of the paper, "The Intercalation Phase Diagram of Mg in V_2O_5 from First Principles." The paper was recently accepted for publication in *Chemistry of Materials*.

Jinhyuk Lee of the Ceder Group was awarded a Gold Medal at the fall MRS meeting. During the spring MRS meeting, Neelkanth Bardhan of Professor Belcher's group received a Gold Medal and Priyank Kumar of Professor Grossman's group received a Silver Medal.

Future Plans

In the coming year, DMSE will continue to assess its undergraduate and graduate curricula to determine whether they are meeting the needs of the department's students, both now and in the future. DMSE hopes to continue to hire promising young faculty with research and educational interests that will complement the department's existing strengths and to hire academic and administrative staff who will help maintain and build the department with outreach to the materials community, to prospective students, to alumni, and to sponsors and donors. DMSE will also put together a facilities plan to address modernizing laboratory spaces, purchasing equipment, providing laboratory and office space for incoming faculty and students, and, most important, integrating some DMSE labs and equipment in the MIT.nano building.

Christopher A. Schuh
Department Head
Danae and Vasilis Salapatas Professor of Materials Science and Engineering