Center for Materials Science and Engineering

The Materials Research Science and Engineering Center (MRSEC) at MIT, funded by the National Science Foundation (NSF), was established in 1994 as the core program of the Center for Materials Science and Engineering (CMSE). CMSE promotes and facilitates interdisciplinary research and education in the science and engineering of materials. MIT has an exceptionally strong and broad effort in materials science and engineering involving more than 110 faculty members in 12 different departments in the School of Engineering and the School of Science. CMSE plays the critical role of bringing this diverse materials community together by encouraging and supporting collaborative research and innovative educational outreach programs and by providing state-of-the-art shared experimental facilities. The clear and important mission of CMSE is to encourage fundamental research and education in the science and engineering of materials for long-range applications that will address the future needs of society. The complexities of such research clearly require input from industry and the expertise of many faculty working collaboratively in a team-based approach. To accomplish this important mission, CMSE enables collaborative, interdisciplinary research among MIT faculty and among MIT faculty and the researchers of other universities, industry, and government laboratories.

CMSE promotes collaborative research through several mechanisms: interdisciplinary research groups (IRGs), seed and initiative projects, shared experimental facilities (SEFs), and outreach programs. While seed funding preference is given to young faculty, CMSE uses seed and initiative funds to support research that has the potential to redefine the direction of an existing IRG or lead to the creation of a completely new IRG. Seed funding provides CMSE with the flexibility necessary to initiate high-risk research. Our research programs typically support a total of 35 to 40 faculty members from seven departments.

Our SEFs are used by numerous research groups from MIT, as well as by outside academic and industrial communities. Last year, approximately 650 people used our SEFs, including students and postdocs of 110 MIT faculty in 23 academic departments, labs, and centers; students and staff of 55 faculty from 19 outside academic/research institutions; and the staff of 12 senior-level industrial managers.

Our educational outreach programs encompass a broad range of activities and age levels, with participation from K–12 students and teachers and undergraduates from other institutions. Last year, over 160 people participated in our various programs with support from CMSE-funded faculty, graduate students, and postdocs.

Our industrial interactions/knowledge transfer activities have resulted in the establishment of new products, applied funding, a new MIT center (the Microphotonics Center), and numerous start-up companies. For example, several small companies have emerged from, or are based in part on, CMSE research, including Clarendon Photonics (now defunct), Little Optics (now part of Nomadics), Cumulus Photonics (now defunct), OmniGuide Communications, American Superconductor, Quantum Dot Corporation (now part of Invitrogen), LumArray, Luminus Devices Inc., QD Vision, Nanosys Inc.,

Gel Med, and Gel Sciences. All of our activities are highly integrated and often combine elements of research with educational and industrial outreach.

Administration, Management, and Research

Our MRSEC program is administered by a proactive and effective management team capable of responding quickly to the emerging needs of the program. Currently six administrative and eight SEF staff support the program. The administrative staff includes an education officer, facilities and safety coordinator, financial administrator, financial and operations assistant, assistant to the director, assistant director, and director. The SEF staff includes one technical associate, four research specialists, a project technician, a principle research scientist, and a research scientist. The CMSE director reports directly to the vice president for research and associate provost, the assistant director reports to the director, and all other staff, including the facilities manager, report to the assistant director. Our current director also serves as CMSE's chemical hygiene officer. CMSE also has a faculty education program leader who marshals our educational outreach plans with our education officer.

During the past year CMSE completed a review and evaluation of all staff positions, realigning job descriptions/positions with emerging needs to provide the best possible service to the community. On September 30, 2005, Jennifer Crockett, assistant director, left CMSE to take a new position at the University of Cincinnati. On November 1, 2005, Susan Dalton, former administrative officer of the MIT Clinical Research Center, became assistant director of the CMSE. The center also hired a financial administrator to fill a vacant position, a full-time research specialist in the electron microscope facility to replace a retiring staff member, a full-time research specialist in the X-ray facility to replace a retiring staff member, and a part-time research specialist in the crystal facility to replace a staff member who left the center.

The activities of CMSE are guided and supported by four internal and two external committees. The Education Committee, Safety Committee, Space Committee, and Internal Advisory Committee are internal MIT committees that offer guidance to CMSE on educational matters, space, safety, and research. The External Science and Engineering Advisory Board and the Committee on CMSE offer guidance on ways to enhance collaborations and support major efforts in long-range materials research and engineering.

In July 2002, CMSE was awarded a $22.2 million grant from NSF through the MRSEC program. This grant covers the funding period from September 1, 2002, through August 31, 2008. In September 2005, we hosted a mid-grant site visit from NSF. The visiting panel proclaimed CMSE "one of the premier research programs in the country" and "the world leader in a number of the research areas described in the IRGs." The panel also went on to say, "the Center has tremendous impact on the materials research community at MIT and technology development." They recommended continued support for CMSE's MRSEC grant through August of 2008, the end of the present grant. This past winter we submitted a noncompeting continuation proposal that described our activities during the fourth period of funding of our MRSEC grant.

Interdisciplinary Research Programs

CMSE currently supports four IRGs, one initiative, and five seed projects involving 36 principal investigators. Seed and initiative funding plays a critical role in the vitality of MRSEC. The primary goals are to support research that has the potential to: (a) redefine the direction of an existing IRG, (b) create a new IRG, or (c) provide an opportunity to move quickly into new research areas. These activities are summarized below.

IRG-I: Microphotonic Materials and Structures

Microphotonic materials are rapidly emerging as one of the most promising new platforms for future optical devices and device components. Such materials allow an unprecedented level of control over the confinement and propagation of light, at dimensions that enable the design and eventual integration of a large number and variety of optical microdevices on a single chip. The objective of this IRG is to explore materials issues and fundamental properties of photonic crystals, to discover physical phenomena associated with photon states that have never been possible before, and to exploit this knowledge with the ultimate aim of the design, fabrication, and characterization of novel microphotonic devices and components.

Participating faculty and departmental affiliations: John Joannopoulos, IRG leader (Physics); Erich Ippen, Leslie Kolodziejski, and Henry Smith (Electrical Engineering and Computer Science); Yoel Fink (Materials Science and Engineering); and Keith Adam Nelson (Chemistry).

IRG-II: Nanostructured Polymer Assemblies

Polymers and polymer nanocomposites with functional electronic, optical, and biointerface properties are becoming increasingly important in many new technologies that exploit nanoscale-related properties and effects. This IRG seeks to gain a fundamental understanding of the factors that control the way multicomponent, functionally active polymer systems organize at the molecular and nanoscale levels, and to use this knowledge to control and significantly enhance the performance of electronic, magnetic, biosensor, and optical devices based on these materials.

Participating faculty and departmental affiliations: Anne Mayes, IRG leader (Materials Science and Engineering); Robert Cohen (Chemical Engineering); and Paula Hammond, Caroline Ross, Michael Rubner, and Edwin Thomas (Materials Science and Engineering).

IRG-III: Electronic Transport in Mesoscopic Magnetic and Semiconductor Structures

Modern electronics have provided the foundation for the scientific and technological advances of the last few decades, but will soon face serious obstacles that may further limit miniaturization and development. Nanoscale elements, with properties dominated by quantum mechanics, are expected to play an important role in overcoming many of these barriers. The focus of this IRG is to explore charge and spin transport in solid-state electronic structures whose building blocks are in the nanometer size regime in order to understand the fundamental physical principles governing transport through and between these potentially important building blocks of future electronic devices.

Participating faculty and departmental affiliations: Moungi Bawendi, IRG leader (Chemistry); Raymond Ashoori, Marc Kastner, and Leonid Levitov (Physics); and Vladimir Bulovic and Rajeev Ram (Electrical Engineering and Computer Science).

IRG-IV: Science and Engineering of Solid-State Portable Power Structures

The need for efficient portable power is extremely important in today's society and is becoming critically important to many new technologies that will impact consumer electronics and communication, health monitoring, entertainment, environmental oversight, and national security. This IRG seeks to develop the basic science and engineering of materials for solid-state electrochemical power sources, and to use this fundamental knowledge to design devices with energy and power delivery capabilities far superior to those of anything available today. The knowledge gained from fundamental materials studies is expected to have a real impact on practical advances in the battery field.

Participating faculty and departmental affiliations: Gerbrand Ceder, IRG leader (Materials Science and Engineering); Eugene Fitzgerald, Anne Mayes, and Donald Sadoway (Materials Science and Engineering); Yang Shao-Horn (Mechanical Engineering); and Martin Bazant (Mathematics).

Initiative Project I: Exotic States of Correlated Electrons in Single Crystals

The overall objective of this initiative is to discover and understand the exotic phases that arise in materials with strongly interacting electron systems. Materials of this type can exhibit unusual properties such as superconductivity, anomalously high thermopower, or infinite ground-state degeneracy. Single crystals of the newly discovered superconductive cobaltates will be synthesized and studied with the specialized techniques of neutron and synchrotron X-ray scattering and scanning tunneling microscopy (with atomic resolution).

Participating faculty and departmental affiliations: Young S. Lee (Physics) and Daniel Nocera (Chemistry), initiative coleaders; Fangcheng Chou, collaborator; and Shaoyan Chu (CMSE).

Seed Projects

The five CMSE-sponsored seed projects and their participating faculty are:

- Regular Nanofluidic-PEM Membrane as a Model System for Studying Ion Transport in Charged Membrane, J. Han (Electrical Engineering and Computer Science and Biological Engineering)
- Modeling and Design of Three-dimensional Nano-Acoustic Devices and Phononic Crystals, S. G. Johnson (Mathematics)
- Electron Transport Studies in Single-walled Carbon Nanotubules, Jing Kong (Electrical Engineering and Computer Science)

- The Thermodynamic Costs of Electron-Transfer: Diabatic Marcus Free Energy from First-Principles Molecular Dynamics, N. Marzari (Materials Science and Engineering)
- Engineering Nanoscale Polymer Films as Tunable Mechanical Substrata, Krystyn Van Vliet (Materials Science and Engineering)

Scientific Accomplishments during the Past Year

IRG-I explorations of cylindrical photonic crystal waveguides and microcavities have resulted in techniques to precisely control the thickness and location of a defect layer within an otherwise regular multilayer structure. This has resulted in a photonic band-gap fiber that is effectively a mechanically tunable optical resonator. This IRG has also designed and fabricated a 2-D photonic crystal slab structure that can behave as a superprism.

IRG-II research has led to the development of potentially long-lasting antifogging coatings based on molecularly assembled silica nanoparticles. These coatings also provide antireflection capability and can be readily applied to most surfaces. This group has also demonstrated that a new class of materials developed in this IRG, baroplastic core-shell nanoparticles, exhibits mechanical properties comparable to those of commercial thermoplastic elastomers. Thus, these new materials have the mechanical properties of conventionally processed polymers, but can be molded into objects essentially at room temperature

IRG-III has successfully fabricated a photovoltaic device based on a 200 nm thick layer of CdSe nanocrystals in a layered morphology. This device exhibits an external quantum efficiency of approximately 15% at the absorption wavelength of the first exciton (roughly 560 nm) with -6V applied. This group has also developed a new theoretical paradigm to explain the observation of power law decays in the current when a voltage step is applied across a nanocrystal array. This development challenges the conventional wisdom about charge transport in nanocrystal arrays.

IRG-IV members have developed a high-energy density battery material ($Li(Ni_{0.5}Mn_{0.5})O_2$) that is inexpensive, non-toxic, stable, and can cycle repeatedly up to 200 mAh/g capacity. This is a very promising material for portable power applications. All-solid block copolymer electrolytes with significantly increased Li^+ transport characteristics have also been fabricated and tested. Such materials have the potential to solve a long-lasting problem (low ionic mobility) with polymer electrolytes.

Initiative I has recently synthesized an ideal S=1/2 Kagomé material. This system is extremely exciting in that it may be the first physical realization of the resonating valence bond state in 2-D.

Shared Experimental Facilities

Our SEFs are a critically important resource to the MRSEC program and to the MIT community, as well as to a number of outside academic and industrial organizations. Currently we run four major facilities: Materials Analysis, Crystal Growth and Preparation, Electron Microscopy, and X-ray Diffraction. A team of highly motivated professionals staffs these facilities. During this past year, about 650 different individuals utilized our facilities.

Beyond the special role our SEFs play in the training and education of MIT students, they are also an important part of CMSE's educational outreach programs. Undergraduates participating in the summer internship programs (Research Experience for Undergraduates [REU], and Roxbury Community College Partnership [RCCP]) are trained to use equipment in the SEFs to conduct their research. Teachers in the Research Experience for Teachers (RET) program spend one morning each week learning about the capabilities and research applications of the equipment in the SEFs. Some of them are also trained to use the instruments for their research projects. Finally, the SEFs are included in visits to CMSE by various groups of middle and high school students.

Key activities during this past year included the following:

- The MIT-wide working group put together by vice president for research and associate provost Alice Gast to coordinate the needs assessment and purchase of major equipment and to establish best practices for operating user facilities at MIT had two meetings this year. During these meetings extensive discussions on best practices were carried out.
- Two of the shared equipment facilities were expanded during the year. The Materials Analysis facility was expanded by the addition of a new 322 sq ft laboratory. This new space has allowed the creation of separate and less-crowded areas for thermal characterization, optical characterization, surface probe instruments, and surface analysis techniques. In addition, we added a new 424 sq ft laboratory to house our superconducting quantum interference device (SQUID) magnetometers and new Industrial Personal Computer (IPC) spectrograph. These two new laboratories increase our total SEF laboratory space to 11,927 sq ft.
- Two new PhD-prepared research specialists, one in the Electron Microscopy lab and one in the X-ray lab, were hired during the year.

Collaboration, Outreach, and Knowledge Transfer

Our MRSEC-supported faculty has ongoing collaborations with numerous industrial partners that range from the funding of applied projects (often based on fundamental work carried out within the center) to the development of new technologies and products. We work closely and effectively with MIT programs and centers, such as the Materials Processing Center (MPC) and the Industrial Liaison Program (ILP), which connects MIT research to industry. These organizations combined have more than 200 member companies. This past year, ILP arranged some 160 meetings between our

MRSEC-supported faculty and representatives from a broad range of different domestic and foreign companies. Presentations made by CMSE faculty at MPC and ILP-sponsored conferences reached more than 500 individual representatives from companies such as Boeing, BMW, Chevron, ConocoPhillips, Cooper Tire & Rubber, Kodak, Exxon Mobil, Ford, General Electric, and Panasonic.

In addition, a "Materials Day at MIT" outreach symposium in October 2005 featured a CMSE-focused program entitled "Frontiers in Materials: Interdisciplinary Research in Materials Science and Engineering." This full-day symposium, which included a poster session at the end of the day, was attended by representatives from 42 different US and foreign companies. Also in attendance were about 65 members of the MIT community, including faculty, graduate, and undergraduate students.

Technologies developed based on fundamental discoveries made within our MRSEC program have helped to launch a number of new start-up companies, including the most recent, QD Vision, which was established in 2004 using technology licensed from MIT, based on IRG-III research. These companies were founded to develop novel devices and components based on discoveries made within our MRSEC program and funded in many cases exclusively through NSF. In 2005, 15 new patents were issued, and 20 new patent applications/provisional patents were submitted.

During this funding period our faculty reported collaborations with 12 different industrial organizations, 28 outside academic institutions, and 15 government laboratories and agencies that were MRSEC-related, representing a total of 70 different individuals. Of these numbers, one of the industrial organizations, 10 of the academic institutions, and six of the government laboratories and agencies are foreign.

Education and Human Resources

Over the past six years, we have worked hard to establish a wide-reaching and diverse portfolio of educational outreach programs that are both innovative in nature and responsive to the needs of educators and students. We have now put in place a broad range of well-received programs that impact high school students and teachers as well as undergraduate and graduate students. Our programs are managed by a full-time education officer who works closely with a faculty education program leader, the center director, and the assistant director. In addition, the center's educational outreach committee consults on the direction of the education programs and the coordination of those programs with other outreach programs on campus. The committee's membership is comprised of personnel from MIT who are actively involved in educational outreach efforts. Besides involvement in CMSE's formal education activities (outlined below), MRSEC-supported faculty, research scientists, and graduate students participate in outreach activities with local schools and with religious communities and professional organizations. Our faculty reported that over the past grant year they devoted about 571 hours to tutoring students; making presentations at schools, youth groups, and teacher meetings; or hosting groups of students visiting MIT laboratories. The 151 students and 62 teachers who participated in these efforts are affiliated with 10 different organizations external to MIT.

With the help of supplemental MRSEC funds in 2005, CMSE launched a new collaboration with Roxbury Community College (RCC), a two-year college in the local area. This is the first step in building a relationship with community colleges in the Boston area that enroll a higher percentage of underserved students. CMSE gratefully acknowledges the vice president for research and associate provost, the dean of the School of Science, and the dean of the School of Engineering for their financial support of the 2006 RCC program. Each group provided funding for the stipend of one RCC student for this year's program. (This program is described in more detail below.)

Also this past year, President Susan Hockfield initiated an effort to engage and coordinate all educational outreach providers on campus. CMSE will play an important role in helping to implement this new coherent vision for educational outreach at MIT. CMSE's education officer is a member of this new steering committee.

Precollege Education

Materials Research Experience for Teachers

For the past seven years, CMSE has operated a successful Research Experience for Teachers (RET) program. This program brings high school and middle school teachers to MIT to participate in CMSE research. The teachers spend seven weeks immersed in research during the first year of the program, then are invited to return the following summer for a flexible period of time devoted to the development of material that will transfer their research experience to their classroom teaching. The major components of the program are research, weekly discussion meetings, SEF tours, and the development of classroom materials. An important goal of the program is to document the materials developed by the teachers so that they can be shared with other educators. Lesson plans written by the teachers are distributed to other science teachers and used in teacher workshops. One lab unit has been published in the *Journal of Chemical Education* (vol. 81, no. 11 [November 2004]: 1620). Ten teachers participated in this program during the summer of 2006, five working on research and five creating classroom materials.

Science Teacher Enrichment Program and Women's Technology Program

CMSE is offering its Science Teacher Enrichment Program (STEP) for the fifth time in the summer of 2006. The goal of the program is to deepen the teachers' content knowledge in areas related to the state learning standards. It consists of a one-week, hands-on workshop titled "Dustbusting by Design," in which the participants enhance their knowledge of the engineering design process by immersing themselves in it. After considering the special features of a handheld vacuum, the physics of its operation, and the properties of the materials involved, the participants design and construct motors that meet the machine's performance specifications. The final day of the program is devoted to a brainstorming session among the teachers and Professor Steven Leeb, CMSE's faculty education leader, about classroom projects to transfer the teachers' experience to their students.

A companion effort to STEP is CMSE's collaboration in the Women's Technology Program (WTP). The Department of Electrical Engineering and Computer Science administers this four-week summer residential program for 40 high school girls from

across the country, during which the participants take classes in math, computer science, and engineering. The program is designed to address a gender imbalance in the field of engineering by increasing the girls' interest and confidence in pursuing engineering careers. CMSE invites the WTP participants to join the lab portion of STEP to gain hands-on engineering experience. For the past four years, this has turned out to be an extremely successful collaboration. WTP alumni report that the motor-building lab was the most exciting part of the program. CMSE continues to support WTP by providing the curriculum and supplies for this part of their program in 2006.

Science Teacher Workshops

CMSE offers workshops that address specific content enrichment needs to groups of science teachers. These are developed in consultation with the teachers, particularly with former participants in the RET program and STEP. On November 29, 2005, Professor Leeb conducted a demonstration and discussion with teachers from the Cambridge Rindge and Latin School (CRLS) on designing and building robots. These robots can be programmed to follow a predetermined path and are useful for collecting environmental data. Professor Leeb introduced the teachers to the design-and-build activity and solicited their ideas for how the robots might be used in their classrooms. The teachers were very excited about the robots. One of them, Margaret Hart from CRLS, planned to incorporate a project using the robots into her applied physics class in the spring to explore their connection to the school's curriculum. In addition, Professor Yang Shao-Horn worked with an RET participant to develop a workshop on energy and battery technology, to be held in the summer of 2006.

High School Student Workshops

During the past year, CMSE presented hands-on workshops to two targeted groups of high school students. In March 2005, Professor Leeb conducted a half-day motors workshop with approximately 20 students who attended an "Engineering at MIT is Fun" program during the National Society of Black Engineers annual meeting in Boston. The high school students attended a lecture on magnets and electricity, and then each built a simple DC motor.

Another workshop targeted high school girls. A group of 60 girls spent October 1, 2005, on campus attending the Women in Science and Engineering conference organized by the Public Service Center at MIT. The conference agenda consisted of a series of hands-on workshops intended to promote interest in science, engineering and technology, provide the girls with opportunities to interact with MIT female students, and inform the students about potential career choices. CMSE sponsored one of the workshops, which was taught by Professors Krystyn Van Vliet and Luis Ortiz, with assistance from six women graduate students. Eighteen girls participated in this lab activity on nanoreactors and bacteria. After a brief presentation, the attendees synthesized Ag nanoparticles within a polymer multilayer through a reduction reaction. Then they correlated the Ag content with the ability of the Ag-loaded multilayers to kill bacteria that were seeded and cultured on the surface. This activity grew out of IRG-II research conducted by Professors Rubner and Cohen.

Science and Engineering Program for Middle School Students

For the past 14 summers, CMSE has operated a science and engineering program for up to 24 seventh- and eighth-grade students from two Cambridge public schools, and it will operate the program again in the summer of 2006. The program's objectives are to familiarize the students with the field of materials science and engineering, demonstrate that science and engineering are fun and interesting, introduce students to a college environment, and expose them to some of the exciting resources at MIT. The program consists of a full week of hands-on and inquiry-based science and engineering classes for students from each school.

The program covers a wide variety of topics. Most activities take place during 90-minute periods, and most include multiple sessions. The 2005 middle school program took place during the weeks of August 15 and August 8–12 and the 2006 middle school program will take place during August 7–10 and 14–18. In 2005, twenty students from the Morse and Peabody Schools attended with their science teachers. The group included 11 boys and 9 girls. Eleven of these students are members of underrepresented minority groups. As the teachers know their students personally, they are responsible, with the assistance of other school staff, for selecting the participants. Program activities are designed and presented by MIT faculty, staff, graduate students, and undergraduates.

The 2005 program consisted of glassblowing, blacksmithing, polymer chemistry demonstrations, constructing a dual sine wave oscillator, building a simple motor, and a design contest. Each year the program concludes with the "Shoot-the-Hoop" design competition, to which the families of the program participants are invited. CMSE has developed collaborative relationships with MIT's Edgerton Center, the MIT Museum, and the departments of Physics, Materials Science and Engineering, and Electrical Engineering and Computer Science, which contribute to the development of projects and their presentation to the middle school students.

Participants in the Science and Engineering Program for Middle School Students were asked to complete brief surveys on the first and last days of the program. The questions were designed to determine whether the students' attitude about science was affected by their experience in the program and whether or not they learned anything about materials science and engineering. The results indicate that overall the students enjoyed the program and found it more interesting than science in school because it required active engagement. As in previous years, 100 percent of them said they would recommend it to a friend. Several thought the program was too short. Most of the group were not familiar with the term "materials science and engineering" when they entered the program. By the end of the week, they understood the term in a very basic way. For instance, they could describe how heat and cold affect the properties of materials and the functions of capacitors and resistors.

Undergraduate Education

Undergraduate Research Opportunities Program

CMSE continues to sponsor undergraduate involvement in MRSEC research through MIT's Undergraduate Research Opportunities Program (UROP). During the past grant year, nine students (including five women and two members of an underrepresented minority group) participated in the program with support from CMSE. In addition to the students paid by MRSEC, 10 undergraduates, 5 of whom were women, worked on CMSE research. These students were either were supported by other funds or received academic credit.

Summer Research Internship Program

In collaboration with MPC, CMSE sponsors a Summer Research Internship Program through the NSF Research Experiences for Undergraduates (REU) program. The program's major goals are to provide undergraduates from other institutions an opportunity to perform cutting-edge materials research and to attract students to graduate studies in materials science and engineering. The two centers intend to continue this collaboration. The program is open to US citizens and permanent residents who will be juniors or seniors the following fall. We receive approximately 150 applications each year, which are reviewed by a committee consisting of the CMSE director and staff from both centers. Participants are chosen from this pool on the basis of academic performance, interest statements, and faculty references. The 15 students accepted into the program for the summer of 2006 included six women and eight men, four of who are from underrepresented minority groups.

The students are paid stipends and work full time for 10 weeks. Most of them live in a dormitory on campus. Weekly meetings are devoted to research discussions and informal seminars with guest speakers on topics such as the graduate school admissions process, research funding, and intellectual property. The interns complete the program by producing posters that report on their summer's research. The resulting poster session is held during the final week and is open to the entire MIT community. It also includes posters produced by participants in CMSE's RET and RCC programs as well and serves the dual purpose of serving as a final report by the interns and teachers and informing the broader MIT materials community about the wide range of research being done under the auspices of the two centers.

Diversity Enhancement Activities

CMSE has a history of promoting and encouraging traditionally underrepresented minority groups and women to participate in materials research. This is accomplished through educational outreach efforts, special programs for graduate research assistants, and efforts to coordinate activities with faculty, postdoctoral associates, and graduate and undergraduate students. A few of these activities are summarized below.

Roxbury Community College Partnership

In an attempt to build a relationship with community colleges in the Boston area that enroll a higher percentage of underserved students, we launched a new program in 2005 in collaboration with Dr. Ray Turner, executive dean of academic affairs at RCC. The initial phase of this program established a formal research experience program for RCC students at MIT. This program began in the summer of 2005 with five RCC students and is continuing in 2006 with five new RCC students and two returning RCC students. The overall objectives are to engage community college students in current materials research and to encourage and inspire them to pursue advanced degrees and careers in science and engineering.

The RCC students spend 10 weeks during the summer working on CMSE research as part of a faculty-led research group, similar to our summer internship program. They attend all of our REU meetings and activities as well. Faculty at RCC assist in the selection process for this program. Students are chosen on the basis of their interest, academic preparation, and faculty recommendation. To prepare them for this experience, the students complete the RCC lab course Research Techniques in Science. Similar to the summer internship program, the students select research projects after attending a symposium to learn about the different projects offered, and are paid a stipend. At the end of the summer, participants present posters on their research at the REU/RET poster session. CMSE will work with RCC to track these students once they complete the program.

A special feature of this program is that an RCC faculty member has joined a CMSE research group as an RET participant for the summer. In this capacity, he is furthering his own professional development and, at the same time, is available on campus to mentor and interact with his students.

It should be noted that a CMSE-supported faculty member, Professor Donald Sadoway, has had an informal relationship with RCC for a number of years. For the past six years, working with Ray Turner, Professor Sadoway has placed RCC students in CMSE/MIT research groups during the summer and, in some cases, on a part-time basis during the academic year. By all accounts, this has been a very successful collaboration. CMSE seeks to leverage this success by building a more formal and far-reaching program.

To help jump-start this program, NSF awarded CMSE an additional $25K in 2005 in supplemental support for MRSEC. This additional funding supported the RCC students in 2005 and provided a stipend for the RCC faculty member. If this program is successful, with suitable funding, we will expand it to include underserved community colleges in the Boston area in future years.

REU Outreach to Underrepresented Minorities

We plan to enhance participation by students from underrepresented minority groups in the REU program through targeted marketing and the development of potential partnerships with other NSF-sponsored sites. For example, to achieve a higher level of exposure to the local minority community, the CMSE director and education officer participate in an annual minority internship fair at the Science Network organized by

the New England Board of Higher Education. To date, we have contributed to two of these internship fairs (2004 and 2005). The October 2005 event was attended by 168 minority students attending colleges and universities in New England. Interested students who spoke with us that day gave us their contact information and we reminded them about the online application and application deadline for 2006. At least three students who visited the CMSE table at the 2004 fair applied to our internship program in February of 2005. Although last winter we had planned to host some of these students at a special faculty-led symposium to introduce them to the field of materials science and engineering, a preliminary poll indicated that only a handful would attend. The program was intended to address the fact that few of the students we met at the internship fair were familiar with the field of materials science and engineering. We are still interested in offering such a program and are considering dates and logistical arrangements that might make it more available to the students.

In an effort to develop potential partnerships with institutions that have students from underrepresented groups, last fall the CMSE director sent letters, brochures, and posters directly to 85 project directors of NSF-funded Historically Black College and University Undergraduate Programs, Louis Stokes Alliances for Minority Participation (LSAMP), and Centers for Research Excellence in Science and Technology, asking them to encourage their students to apply to the program. The return on this effort was limited (it increased the percentage of minority applicants to our program from 8.5 percent to 11 percent), resulting in a couple of useful conversations with faculty at the targeted institutions and five REU applications. Of these five applicants, one student (from Oakwood College) participated in our summer 2005 REU program. We sent recruiting material to these institutions again for the 2006 program. Clearly we will have to develop deeper discussions with faculty and administrators at the identified institutions to significantly impact our pool of applicants. Efforts will therefore be made to establish direct connections to faculty at some of these institutions. In addition to the targeted advertising, in January of 2006, the CMSE education officer presented the internship program at a symposium sponsored by the University of Connecticut/University of Rhode Island/Northeastern University/Worcester Polytechnic Institute LSAMP. This event is designed to impress on students the importance of involvement in cocurricular academic enrichment activities for their academic growth and professional development.

Outreach Collaborations and Materials Science Content Expansion

Additional areas of effort include collaboration with other units at MIT to enhance educational outreach programs and to add materials science content to the programs of other departments and centers. For many years, we have collaborated with the Edgerton Center and the MIT Museum on our middle school program, school visits, and Family Adventures in Science and Technology Sundays at the museum. We have established strong working relationships and collaborations with other administrative units at MIT, including MPC and various departments in the schools of Science and Engineering. Recently, we had preliminary discussions with staff of the School of Engineering's Special Programs Office about including hands-on materials science units in the Saturday Engineering Enrichment and Discovery Academy or Science Technology Engineering and Math programs. CMSE has participated in discussions of the recently formed Committee on MIT K-12 Educational Outreach led by Professors Eric Klopfer and Kim Vandiver.

CMSE has been very successful in offering educational enrichment opportunities to a broad and diverse range of individuals. We continue to enthusiastically support the participation of women and members of underrepresented minority groups in all of our education programs.

Graduate Education

IRGs, initiatives, and seed projects supported by CMSE include research assistantships for graduate students. CMSE provides additional funds to support three full-year and four summer assistantships for graduate students from underrepresented minority groups. Two Electrical Engineering and Computer Science graduate students are being supported in the summer of 2006, along with one from Physics and one from Chemical Engineering. This targeted funding is supplemental to a faculty member's existing CMSE funds, thus providing incentive to include minority students in his or her research group.

Colloquia

Last year, CMSE launched a new joint colloquium series with the Department of Materials Science and Engineering. This partnership allows us to pool resources and bring in speakers from outside of MIT. The objectives of the colloquium series are to provide an opportunity for faculty, research staff, and students from different disciplines to meet on a regular basis to hear about the latest breakthroughs in materials research, and to inform the greater MIT community about materials research. This joint series also strives to promote inter-MRSEC knowledge transfer. The 22 total lectures over both semesters included one by a MRSEC director (Thomas Russell) and seven by MRSEC participants (Mike Aziz, Emmanuel Giannelis, Sossina Haile, Jay Kikkawa, Chad Mirkin, Paul Nealey, and Daniel Nocera).

A complete list of speakers for the Fall 2005 and Spring 2006 series follows:

Fall 2005: Mike Aziz (Harvard University), Giulia Galli (Lawrence Livermore National Lab), Sossina Haile (California Institute of Technology), Jennifer Lewis (University of Illinois at Urbana-Champaign), Chad Mirkin (Northwestern University), Paul Nealey (University of Wisconsin-Madison), Frances Ross (IBM), Thomas Russell (University of Massachusetts Amherst), Natalie Stingelin-Stutzmann (Queen Mary, University of London, UK), Jerry Tersoff (IBM), and Chris Wolverton (Ford Motor Company).

Spring 2006: Jay Kikkawa (University of Pennsylvania), Joanna Aizenberg (Lucent), Daniel Nocera (MIT), Orlin Velev (North Carolina State University), David Pine (New York University), Joanna Millunchick (University of Michigan), Emmanuel Giannelis (Cornell University), Elizabeth Holm (Sandia National Laboratories), David Goodstein (California Institute of Technology), Paul Alivisatos (University of California Berkeley, Lawrence Berkeley National Laboratory), Louisette Priester (Université Paris-Orsay, CECM-CNRS Vitry).

Michael F. Rubner
Director
TDK Professor of Materials Science and Engineering
MacVicar Faculty Fellow

More information about the Center for Materials Science and Engineering can be found at http://web.mit.edu/cmse/.