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). In September 2008, NSF awarded CMSE a renewed six-year $19.2 million MRSEC center grant to fund CMSE's research and educational outreach programs as well as its shared experimental facilities from September 2008 to August 2014. This award was the culmination of an extensive two-year internal and external review process and preparation of proposals at CMSE headquarters that enabled CMSE to compete with over 100 other national institutions to win one of 14 NSF MRSEC center awards for this six-year period.

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 160 faculty members in 14 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 (SEFs). The clear and important mission of CMSE is to enable—through interdisciplinary fundamental research, innovative educational outreach programs, and directed knowledge transfer—the development and understanding of new materials, structures, and theories that can impact the current and 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 researchers from other universities, industry, and government laboratories.

CMSE promotes collaborative research through several mechanisms: interdisciplinary research groups (IRGs), seed and initiative projects, 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 of redefining the direction of an existing IRG or leading to the creation of a completely new IRG. Seed funding provides CMSE with the flexibility necessary to initiate high-risk, transformative research. Our research programs typically support a total of 30 to 40 faculty members from 10 or more departments. Over the life of our 2002–2008 MRSEC grant, our CMSE faculty published 645 papers in which research results were either primarily or partially supported by MRSEC funding or related to our SEFs and awarded 91 patents. During the first 20 months of our 2008–2014 MRSEC award, researchers published results in 79 papers and were awarded seven patents related to their MRSEC research.

Our SEFs are used by numerous research groups from MIT as well as by outside academic and industrial communities. During the March 2009 to February 2010 period, 1,010 people used our SEFs, including 737 students and postdocs of MIT faculty in 22 academic departments, labs, and centers; 75 students and staff of faculty from 15 outside academic/research institutions; 180 students from MIT lab subjects; and 18 staff of 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. During the summer of 2009, 94 people participated in our various core programs with support from CMSE-funded faculty, graduate students, and postdocs. CMSE MRSEC faculty also devoted many hours to tutoring students, making presentations to students and teachers, supervising high school students in their labs, and hosting groups of students visiting CMSE labs. In addition, nearly 800 people attended workshops and public events in which CMSE took part.

Interdisciplinary Research Programs and Scientific Accomplishments

The MRSEC grant supports three IRGs, two initiative projects, and five seed projects involving 32 principal investigators. These groups and their FY2010 results are summarized below.

IRG-I: Design of Nanomaterials for Electrochemical Energy Storage and Conversion

The objective of this IRG is, on the one hand, to use electrochemistry to accurately determine how thermodynamics, phase stability, and kinetics are modified at the nanoscale, and, on the other hand, to apply that knowledge to engineer materials with high-energy, high-power Li storage capabilities and to design nanocatalysts with superior oxygen reduction reaction activity and reduced noble metal content. The supply of sustainable energy is arguably the most important scientific and technological challenge in the 21st century. Meeting this challenge will require not only increased energy efficiency but also new energy storage platforms to displace existing carbon-based fuels with carbon-neutral energy such as solar energy. Electrochemical devices such as Li batteries and fuel cells that operate on hydrogen produced from solar energy are promising technologies to buffer the supply and demand of energy, particularly for portable power and hybrid propulsion in transportation. Meeting the demands of these applications requires new ideas to design materials with tailored reactivity toward lithium for Li batteries and catalysts with markedly higher activity toward oxygen reduction reactions in fuel cells.

Faculty participants and department affiliations: G. Ceder, coleader (Materials Science and Engineering [DMSE]); Y. Shao-Horn, coleader (Mechanical Engineering); A. Belcher (DMSE and Biological Engineering); K. Hamad-Schifferli (Mechanical Engineering and Biological Engineering); N. Marzari (DMSE); and C. Thompson (DMSE).

FY2010 IRG-I Results

IRG-I members have demonstrated that a fundamental understanding of the surface reactivity of battery cathode materials based on $LiFePO_4$ can be used to control particle shape and hence optimize the power performance of Li-ion batteries. In addition, surface functionalized multiwall carbon nanotubes (MWNTs) containing electrodes were assembled by using the layer-by-layer technique (in collaboration with IRG-II) and found to produce materials that outperform other competitive systems significantly in terms of electrochemical properties. This work shows the clear benefit of using functionalized MWNTs as part of a next-generation energy storage device with high power, high energy, and a very long cycle life. IRG-I researchers also utilized a virus scaffold to template the growth and assembly of nanoscale electrode materials.

The genetically engineered M13 virus (E4 virus) successfully provided a platform for the growth of amorphous iron phosphate, which can be used as a promising positive electrode material. Preliminary electrochemical data show that more than 120 mAh/g of capacity (the theoretical capacity of $FePO_4{\cdot}2H_2O$ is 140 mAh/g) can be delivered. Because of self-replication, virus growth of nanomaterials can be easily scaled up as an effective way to fabricate novel battery materials.

IRG-II: Mechanomutable Heteronanomaterials

This IRG proposes to develop a new class of "mechanomutable heteronanomaterials," which we define as possessing spatially localized and controlled nanoscale units of different types of materials that change their mechanical properties reversibly in response to an external stimulus. This research will significantly advance the existing body of literature on responsive materials, which are typically single- and two-component systems (e.g., hydrogels, magnetorheological elastomers, shape memory alloys, piezoelectrics) that have been focused on actuation, swelling, and controlled permeability. The use of heteronanostructures provides many exciting possibilities for mechanomutable materials design that have not yet been realized, in particular high-spatial-resolution interactions with nanoscale objects and unique and amplified mechanical robustness. For this reason, we plan to explore the possibility of utilizing these materials as high-throughput, high-spatial-sensitivity tunable sensors (e.g., for cells, proteins, localized impacts, and pressure in liquids).

Faculty participants and department affiliations: R. Cohen, coleader (Chemical Engineering); C. Ortiz, coleader (DMSE); M. Boyce (Mechanical Engineering); M. Buehler (Civil and Environmental Engineering); P. Hammond (Chemical Engineering); and K. Van Vliet (DMSE).

FY2010 IRG-II Results

IRG-II research has demonstrated that surface-anchored arrays of polymer nanotubes can exhibit reversible, pH-dependent mechanical properties. The mechanomutable properties of these surface-bound nanotube forests were modeled with continuum-level, elastic finite element analysis simulations and further tested with nanoindentation probes developed by the group. These results open the door to the use of mechanomutable materials in a wide range of applications including 2D dynamic substrates for cell biology studies, 3D locally tunable tissue-engineered scaffolds, and tunable adhesives, lubricants, and penetration-resistant coatings. In the area of dynamically self-oscillating Belousov-Zhabotinsky gels, IRG-II research has confirmed theoretical predictions that the mechanical oscillation of such gels can be systematically manipulated by an externally applied stimulus. The mechanomutable properties of electroactive multilayer films consisting of either Prussian blue nanoparticles or polyaniline nanofibers were also designed, tested, and modeled theoretically. In both cases, changes in mechanical properties could be reversibly activated in an electrochemical cell. This works shows promise for electrochemically driven mechanomutable devices and patterned surfaces.

IRG-III: Multimaterial Multifunctional Nano-Structured Fibers

This IRG will explore the materials science, design, fabrication, characterization, and potential identification of novel physical phenomena of a truly unique class of fiber materials systems that are composed of conductors, insulators, glassy semiconductors, and especially crystalline semiconductors with more than 10 nanometer feature sizes. The uniqueness of our materials science approach should ultimately enable the creation of fiber structures. These fibers, while comprising all of the essential crystalline semiconductor device attributes, will be processed using conventional fiber draw processing approaches, thus yielding kilometers of fiber structures with engineered electronic, optical, thermal, and acoustic properties and exploiting photonic bandgap phenomena wherever needed.

Faculty participants and department affiliations: Y. Fink, coleader (DMSE); M. Soljačić, coleader (Physics); J. Joannopoulos (Physics); S. Johnson (Mathematics); and E. Ippen (Electrical Engineering and Computer Science [EECS]).

FY2010 IRG-III Results

IRG-III researchers have fabricated a novel fiber structure wherein a large number of devices with nanometer feature sizes are integrated in a single fiber and operate collectively to deliver novel functionalities over unprecedented areas. Key to this development is the successful fabrication of an eight-device cascaded optoelectronic fiber structure in which components down to 100 nm are individually electrically addressed. The remarkable functionality of these polymer fibers with built-in nanometer-scale devices has further resulted in the demonstration of how a single wavelength discriminating fiber web can image a complex object with polychromatic light, noninterferometrically and without lenses, by taking an intensity measurement at a single diffraction plane. IRG-III researchers also report experimental observation of photonic crystals that restrict light to travel in only one direction without back-scattering, even in the presence of large disorders. Rather than bounce back or reflect, the light is able to move around obstacles and defects in its path without scattering. This concept could be used to create one-way conduits in lightwave circuits, such as fiber-optic communication links, by increasing their capacity and efficiency.

Initiative-I: Engineering Living Cells via Nanomaterials

This Initiative will develop a fundamental, generalizable understanding of how nanoparticles and polymer multilayers can be designed to integrate with living cells in ways that preserve cell viability and cellular processes while allowing materials to carry out engineered functions. These basic principles will enable rational selection of nanomaterials for diverse applications (such as drug delivery, tissue engineering, lab-on-chip/microfluidic technologies, biosensors and medical imaging, and therapeutic strategies based on nanomaterial-modified cells), suggest directions for the development of new materials for these applications, and allow us to systematically explore societal concerns relating to the potential toxicity of nanomaterials in vivo. Further, the new materials developed in this work will expand our understanding of synthetic nanomaterial structure/property relationships per se.

Faculty participants and department affiliations: D. Irvine, coleader (DMSE and Biological Engineering); M. Rubner, coleader (DMSE); M. Bawendi (Chemistry); and F. Stellacci (DMSE).

FY2010 Initiative-I Results

Initiative-I researchers report that they have successfully added a bioresorbable, hydrolysable component to the polymer multilayer cell backpacks used to functionalize living immune system cells. This now provides a controlled drug release capability to cells carrying polymer backpacks. In related work, strategies to stably decorate the surface of cells with nanoparticles that could carry drugs or sensing agents designed to act on the carrier cells or their surroundings were also investigated. Biodegradable particles 100–200 nm in diameter were found to slowly release drug compounds that stimulate stem cells and promote their survival and proliferation. Although still in the early stages of development, this work opens up the exciting possibility of dramatically shortening the time that a patient receiving a bone marrow transplant is immunosuppressed following the procedure.

Initiative-II: New States of Frustrated and Correlated Materials

This initiative will focus on materials based on two-dimensional triangular and kagomé lattices, an area we pioneered as a small initiative during the previous funding cycle. The materials developed during the initiative period attracted much interest and will serve as launching points for delving further in exciting new directions, such as probing exotic states of quantum matter that contain "topological order." This new order leads to a host of fascinating properties, such as fractional quantum numbers, non-Abelian statistics, emergent photons, and more. Quantum spins on a kagomé lattice may exhibit this novel type of topological order, which would have possible applications in quantum computing. The addition of mobile charge carriers into these systems may lead to unconventional superconductivity and non-Fermi liquid ground states. There is clearly much interesting territory to explore once candidate samples are synthesized. Our objective is to identify and synthesize new states of matter based on frustrated spin systems.

Faculty participants and department affiliations: Y. Lee, coleader (Physics); D. Nocera, coleader (Chemistry); S. Chu (CMSE); E. Hudson (Physics); and D. Shim (Earth, Atmospheric, and Planetary Sciences).

FY2010 Initiative-II Results

Initiative-II researchers have synthesized and characterized a new series of spin-frustrated kagomé compounds, $Mg_xCu_{4-x}(OH)_6Cl_2$, that are isostructural with paratacamite and successfully grown millimeter-size crystals of this material. Preliminary results suggest that the lack of a magnetic ordering transition in materials with this structure type is not due to chemical disorder but is a result of the high spin frustration within the kagomé planes. Another recent success has been developing a hydrothermal zone technique that can be used to grow sizable single crystals of the $Zn_xCu_{4-x}(OH)_6Cl_2$ family. New findings imply that the lack of a magnetic ordering transition in this system is also the result of the high spin frustration within kagomé planes. These results have great bearing on the theoretical framework for understanding the rich observations of the ground state physics of herbertsmithite.

Seed Research and 2010 Results

During the fall of 2008, the center conducted an Institute-wide competition for new seed proposals with funding to begin on March 1, 2009. The goal of this funding is to support research that has the potential to redefine the direction of an existing IRG or initiative project, to lead to the creation of a completely new IRG or initiative project, or to foster a newly appreciated opportunity for high scientific discovery or technological impact. Five projects were chosen to receive $70,000 per year for two years. The research and FY2010 results are summarized below.

Seed I: Nanoparticle Control and Transport Using Mobile Magnetic Domain Wall Traps

This research seeks to develop an on-chip system for the capture, manipulation, and transport of individual magnetic nanoparticles for applications in such areas as magnetic sorting of biomolecular entities. It is expected that a working prototype of a nanoparticle transport system with integrated single-particle detection will be developed and demonstrated. The results are widely relevant to a variety of key research areas including cell sorting, pathogen detection, chemical and biological agent detection, and controlled nanoscale assembly. Faculty participant and department affiliation: G. Beach (DMSE).

2010 Research Results

Magnetic nanowire conduits have been designed and fabricated on silicon wafers using electron beam lithography. The conduits are intended to guide magnetic domain walls and trapped particles controllably over long distances. Terminal velocities of domain walls in straight magnetic nanowires exceed 100 m/s, much too fast for shuttling superparamagnetic particles through a viscous medium. To overcome this problem, conduit structures composed of long chains of linked semicircular subunits are being tested. An in-plane rotating magnetic field advances a magnetic domain wall along one subunit for each half-revolution of the field. Hence, the rate of progression of a domain wall/trapped nanoparticle along the conduit can be controlled simply by setting the rotation rate of the drive field. To characterize the devices, a scanning magnetooptical microscope has been built, incorporating a compact vector-field projection electromagnet specifically designed for controlling domain wall motion in the fabricated structures. Characterization of domain wall motion and particle transport in these devices is currently under way, in order to optimize the structure geometry. An important aspect of this phase has been training a new graduate student in advanced thin-film deposition and patterning techniques, instrumentation development, and device characterization.

Seed II: Ultrafast Dynamics of Low Energy Excitations in Frustrated Materials

The goal of this seed project is to understand the emergent macroscopic properties of magnetically frustrated materials by studying the dynamics of their low energy excitations and phase transitions with the use of novel time resolved techniques. In these experiments, the material is excited by an ultrashort laser pulse, and the recovery of the resulting state back to the ground state is probed with femtosecond temporal and sub-Angstrom spatial resolutions. The principal investigator has developed different methods to selectively generate and probe charge, spin, or lattice excitations in quantum materials. The information that will be obtained from these measurements will help us to understand the properties of the ground state (i.e., test whether a spin liquid behavior is realized), low energy excitations, and phase diagrams. Faculty participant and department affiliation: N. Gedik (Physics).

2010 Research Results

Professor Gedik has developed time resolved Faraday rotation spectroscopy to probe the dynamics of spin excitations in $ZnCu_3(OH)_6Cl_2$. The setup is now fully functional; the test signal was recently obtained in liquid CS_2. To study the spin-Peierls state in TiOCl, ultrafast electron diffraction was used. In this technique, the sample is excited with an ultrashort laser pulse and a movie of the resulting laser-induced structural change is obtained by recording the diffraction pattern of short electron pulses at different time delays. These electron pulses are obtained from a frequency-tripled portion of the laser pulse through the photoelectric effect. In order to capture fast structural dynamics, electron pulse characterization at the sample position is necessary. This was recently achieved by using the ponderomotive scattering of electron pulses from a transient laser intensity grating formed by two counterpropagating ultrashort laser pulses. After measurement of the pulsewidth, electron diffraction patterns were obtained from several test samples, and it was verified that laser-induced changes could be resolved.

Seed III: Tailoring Optical Properties of Semiconductor Nanomaterials

This project will concentrate on direct correlation of structural/optical properties with high spatial resolution, where semiconductor nanowires will serve as a model system. Ultimately, it seeks to answer the following questions: What are the critical structure-property relationships in semiconductor nanowires and nanowire heterostructures that govern electrical and optical properties on the nanoscale? How can this knowledge be used to predict and tailor properties of semiconductor nanowires (materials-on-demand) for specific applications in nanophotonics and nanoelectronics? Faculty participant and department affiliation: S. Gradečak (DMSE).

2010 Research Results

Professor Gradečak has concentrated on the controlled growth of wide-bandgap III-V nitride nanowires because of their potential for electronic, photonic, and optoelectronic applications including high-power transistors, light-emitting devices (LEDs), and short-wavelength lasers. Chemical vapor deposition (CVD) in combination with thermal evaporation has been used to study the influence of growth parameters (temperature, pressure, and gas flows), growth substrates, and metal catalysts on the growth of nonpolar GaN nanowires. Epitaxial growth of GaN nanowires on a-GaN substrates has been realized and diameter-dependent growth rates measured. It has been determined that the preferred nucleation in GaN nanowires occurs at vapor/liquid/solid (gas/catalyst/nanowire) and continues through a combination of mononuclear and polynuclear growth. Growth rates at various hydrogen flows can be successfully explained using this model. Future studies will concentrate on the growth of ternary InGaN nanowires, to be used for more complex axial nanowire heterostructures.

Seed IV: Suspended Graphene Devices for Quantum Electronics and Nanosensing

The objective of this seed project is to investigate electronic transport in ultra-high-mobility suspended graphene devices (GDs), both to study fundamental quantum electronics and to assess their potential as chemical and mass nanosensors. A crucial element of this research is the fabrication of high-quality suspended GDs. Multiterminal devices will be used to study fundamental quantum phenomena, such as the fractional quantum Hall effect or the spin Hall effect, while high-quality suspended grapheme nanoribbons (GNRs) will be actuated as tunable high-frequency nanoresonators. In addition, the possibility of passivating the edges of GNRs with desired chemical groups will enable ultra-sensitive chemical and mass detection. Faculty participant and department affiliation: P. Jarillo-Herrero (Physics).

2010 Research Results

This seed has made great strides toward producing high-quality graphene nanoresonators. These resonators will be used as the basis of advanced nanosensors as well as a platform for exploring fundamental physics. Efforts so far have seen the successful suspension of graphene devices and the development of new etching techniques using two different ion beams. Graphene nanoresonator design begins with suspension of a graphene sheet between contacts. The SiO_2 substrate is removed using hydrofluoric acid, which leaves behind a graphene bridge hanging between the electrodes. Once suspended, the device is transferred into a critical point dryer where it is dried by circumventing the critical point of carbon dioxide. This technique avoids any surface tension, which may collapse the graphene bridge. Suspended devices can offer a dramatic improvement in quality. Doping levels can decrease by more than an order of magnitude. Mobility has been measured as high as 30,000 cm^2/Vs, resulting also in highly symmetric devices near the ambipolar ideal.

Seed V: Large Area, Few-Layer Graphene Films for Various Applications

Graphene is the hexagonal arrangement of carbon atoms forming a one-atom thick planar sheet. This layer is the building block of graphite and carbon nanotubes, and it has been studied widely by theorists since the middle of the last century. Graphene sheets show great potential as another materials option for electronics applications. The overall goal of this seed project is to engineer the underlying metal substrate to achieve regular grain boundaries and facilitate graphene films with controlled morphology. Faculty participant and department affiliation: J. Kong (EECS).

2010 Research Results

Graphene syntheses using low-carbon solubility catalysts (Cu)- uniform growth of monolayer graphene using Cu catalysts in a low-pressure CVD (LPCVD) process have previously been reported. However, the role of kinetic factors in graphene syntheses using Cu growth is not clearly understood. In this work, both atmospheric pressure CVD (APCVD) and LPCVD processes were utilized to elucidate the role of kinetic factors in graphene syntheses using Cu catalysts. Results demonstrated that APCVD as well as LPCVD processes led to large area monolayer graphene growth (approximately 100 cm^2) as characterized by optical techniques. In an APCVD process, the graphene synthesis at high temperatures (approximately 1,000˚C) largely proceeds in a mass-transport limited regime. In contrast, synthesis in an LPCVD process proceeds in a surface-reaction limited regime. Moreover, LPCVD synthesis resulted in higher uniformity and fewer defects than in grown graphene samples, suggesting that LPCVD is suited better for large-scale fabrication. Monolayer graphene grown using LPCVD is currently being explored in applications ranging from components in solar cells to desalination of water using microfluidics. This work is being done in collaboration with other MIT faculty members.

Shared Experimental Facilities

Our SEFs are a critically important resource to our MRSEC program and to the MIT community, as well as 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. These facilities are staffed by a team of highly motivated professionals. During the year ending February 2010, 1,010 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 programs. Undergraduates participating in the summer internship programs (Research Experiences for Undergraduates [REU] and Community College Students) 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 the past year are highlighted below.

A Helios NanoLab 600 dual-beam focused ion-beam milling system was purchased from FEI Company to serve the needs of the research community at MIT as well as adjacent areas. It is configured to carry out nanoscale characterization and nanomachining on a wide range of materials from various study areas such as biotechnology and materials and energy research, the focal points of the next economic engines of the nation. The Helios NanoLab 600 has magnetic immersion electron optics that allow 0.9-nm resolution at 15 kV. A high brightness field electron emitter can deliver a beam current up to 22 nA and accelerating voltage from 350 V to 30 kV. The ion optics produce a resolution of 5.0 nm at 30 kV, and the liquid gallium emitter delivers a 20-nA ion current, with voltage ranging from 0.5 kV to 30 kV. The instrument was installed during the fall of 2009, was successfully certified, and is now fully operational. Not currently available to the MIT user community, it will be used for preparation of transmission electron microscopy (TEM) specimens, for nanolithography, and for serial sectioning and subsequent 3D reconstruction of solid samples.

The SEF staff has been an important element of many of our educational outreach programs and enthusiastically embraces this role. For example, our staff play a special role in the training of MIT graduate and undergraduate students and our summer educational outreach participants. During the past academic year, 180 undergraduate students used the facilities as part of their laboratory subjects.

On October 5 and 7, 2009, the SEF staff hosted a group of 33 students from cell biology and biotechnology classes at Bunker Hill Community College (BHCC) for tours of the Materials Analysis, Electron Microscopy, and X-ray facilities and demonstrations of X-ray, scanning electron microscopy (SEM), and TEM techniques.

SEF staff members offered a number of mini-courses during MIT's 2010 Independent Activities Period (IAP) to train students to operate SEF equipment and apply the latest techniques to their research problems. In January of 2010, a total of 122 students and postdoctoral associates attended courses taught by the SEF staff.

The SEF staff is actively encouraged to participate in local or national meetings, publications, professional societies, or other professional growth opportunities appropriate to the staff member's position and responsibilities. From October 26–29, 2009, Dr. Scott Speakman of the X-ray SEF was a guest instructor at a workshop on Rietveld refinement of x-ray diffraction data using the HighScore Plus program; the workshop, offered by PANalytical Inc., was held in Westborough, MA. The class was attended by 11 professionals from organizations and universities such as the Institut de Recherche Robert-Sauvé en Santé et en Sécurité du Travail, Shell Global Solutions, BP Products NA, Jacobs ESCG, Georgia Tech, Activation Laboratories Inc., the United States Environmental Protection Agency, and Lakehead University. Free attendance was also provided for three MIT graduate students. In addition to providing a service to the community at large, Dr. Speakman's involvement as an instructor in this course resulted in better dialogue with the developers of the analytical software used and translated into better experience in teaching these techniques to CMSE users, both in the X-ray lab and in courses during MIT's IAP session.

Dr. Speakman also attended the March 2010 meeting of the International Center of Diffraction Data, the nonprofit organization that publishes the Powder Diffraction File reference database and promotes education and development of diffraction analysis. In addition, he continues to serve as the chairperson for the Micro and Meso Subcommittee of this organization, which addresses concerns and opportunities relating to nanoscale and mesoscale organized systems such as quantum dots, mesoporous membranes, and self-assembled nanocrystalline thin films.

Dr. Yong Zhang, of the Electron Microscopy SEF, attended the Microscopy and Microanalysis conference in Richmond, VA, from July 26–30, 2009. He will return for the 2010 meeting to present a paper titled "Microstructure Refinement by Hydrogen Heat Treatment in a Ti-6.6Al-3.4Mo-0.3Si-1.7Zr Titanium Alloy." Dr. Zhang's SEF work has also been acknowledged in papers recently published by MIT professors Christopher Schuh and Gerd Ceder.

From March 2–17, 2010, Dr. Shaoyan Chu, of the Crystal Growth SEF, visited the Center for Condensed Matter Sciences at the National Taiwan University and the National Cheng Kung University in Taiwan, where he presented talks on crystal growth techniques to faculty, students, and staff and explored international research collaborations between the crystal growth facilities at these universities and the CMSE crystal growth facility. Currently, the crystal growth facility at the National Taiwan University's Center for Condensed Matter Sciences is led by professor Fungcheng Chou, a former MIT principal scientist and manager of the CMSE crystal growth facility.

Libby Shaw was a co-author on a paper published in the *Journal of the American Chemical Society* titled "Nanoscale Zirconia as a Non-Metallic Catalyst for Graphitization of Carbon and Growth of Single- and Multi-Wall Carbon Nanotubes."

Patrick Boisvert hosted a visit and tour in the Electron Microscopy facility for Tavares Strachan, a young Bahamian artist at MIT through the List Visual Arts Center's residency program. This program allows contemporary artists to engage with the extraordinary intellectual richness of MIT's students, faculty, and staff. Strachan was particularly interested in exploring how nanoscale fabrication and materials characterization techniques can be applied to a sculptural practice.

Collaborations, 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). These organizations combined have more than 200 member companies. Our faculty engaged in at least 50 ILP-organized meetings with representatives from a broad range of domestic and foreign companies, including visits from industrial representatives, faculty visits to different firms, briefings to company executives, and teleconferences. A partial list of these companies includes Bosch, Chevron, Johnson & Johnson, Novartis, Procter & Gamble, Sappi, Sharp, Shell, and Siemens. CMSE director Michael Rubner gave an overview of all MRSEC research during meetings with Sappi Ltd., Mars Inc., and Lintec of America, in addition to his presentation at the 2009 MIT Research and Development Conference.

CMSE has strengthened its involvement in one of the showcase MIT materials events, the annual Materials Day at MIT organized by MPC; CMSE now jointly sponsors this symposium and contributes significantly to its technical program. One important objective of this event is to connect MIT materials research to managers and researchers from industry and government laboratories. The theme of this year's event was "Materials for Energy." CMSE speakers and moderators included professors Carl Thompson and Gerd Ceder. The meeting was attended by nearly 120 registered guests from industry, government laboratories, hospitals, MIT, and other universities, as well as by an additional 65 researchers and students from MIT who joined throughout the day on a walk-in basis. Representatives from more than 70 US and foreign companies attended the event, including employees of 3M, A123 Systems, Analog Devices, BP Solar, Corning, Energizer, General Electric, Lord Corporation, National Semiconductor, Northrop Grumman, Raytheon, and Saint-Gobain. The capstone poster event included posters from CMSE students and others from the MIT materials science community. Albert Swiston, supervised by professors Cohen, Rubner, and Irvine, won a prize for his poster, "Backpack Functionalized Living Immune Cells." The poster session was judged by a panel of judges from MPC's advisory board.

CMSE continued collaboration with the Department of Materials Science and Engineering and the Materials Processing Center to bring a wide variety of speakers from outside of MIT to meet with faculty and students and deliver lectures to which the entire MIT community was invited. These lectures typically drew audiences of 80–140 people. The fall 2009 speakers were Richard Register (Princeton), Amit Misra (Los Alamos National Laboratory), Stephen Forrest (University of Michigan), Sharon Glotzer (University of Michigan), Andrew Parker (Oxford University), Alex Zettl (University of California, Berkeley), and Debra Rolison (Naval Research Laboratory). The spring 2010 speakers were Eric Fullerton (University of California, San Diego), Mark Brongersma (Stanford), L. Mahadevan (Harvard MRSEC), Sumio Iijima (Meijo University), Andrea Hodge (University of Southern California), and Roberto Car (Princeton MRSEC).

MRSEC-supported faculty presented an overview of their research in three ILP-sponsored conferences: the 2009 MIT Research and Development Conference (A. Belcher, K. Hamad-Schifferli, D. Nocera, M. Rubner, Y. Shao-Horn), the MIT-KAIST (Korea Advanced Institute of Science and Technology) Joint Conference in Korea (G. Ceder), and "Nanostructure to Infra-structure: An MIT Perspective on the Future of Materials Processing," sponsored by MPC and hosted by Robert Bosch GmbH in Stuttgart, Germany (G. Ceder, F. Stellacci, C. Thompson). These conferences were attended by a total of 638 representatives from companies including BAE Systems, General Electric, Olympus, Raytheon, Siemens, SK Telecom, SK Energy, LG Display, Daewoo E&C Co. Ltd., LG Chem, Robert Bosch, EADS, ThyssenKrupp, Metso, Shell Global Solutions, Draegerwerk AG, Daimler AG, Bayer Technology, EON Engineering, Sirius, Umicore Research, and Insamet.

We continue to enhance our knowledge transfer and outreach capabilities through the MIT-wide materials website and a completely revamped CMSE MRSEC website. In the former case, a collaborative effort involving MPC and DMSE resulted in the launch (in October 2006) of the Materials@MIT gateway website (http://materials.mit.edu/). This website provides a single point of access to information on the various researchers; departments, labs, and centers; educational opportunities; and SEFs on campus that are involved in materials research. A key feature of the site is a database of all materials-related shared equipment at MIT, including all CMSE user equipment. The CMSE MRSEC website (http://web.mit.edu/cmse/) presents a well-organized design that facilitates access to important research information such as "hot articles," nuggets, and new research developments. In addition, there is a section under Educational Outreach for downloading teaching modules and lesson plans.

Another important mechanism for knowledge transfer is the creation of new companies and businesses (and related jobs). Currently active CMSE-related companies that were started by MRSEC faculty, students or postdocs include OmniGuide Inc., LumArray, Luminus Devices Inc., QD Vision, Kateeva, WiTricity Corporation, and Svaya Nanotechnologies. These various companies were founded to develop novel devices and components based on discoveries made within the MRSEC program and funded, in several cases, exclusively through NSF. Additionally, Nanosys and Quantum Dot Corporation (bought by Invitrogen) are companies whose technology platform is based in part on CMSE-supported fundamental research. Four CMSE-related start-up companies have seen considerable growth and industry attention.

Luminus Devices Inc., a spin-off from fundamental research under previous CMSE microphotonics activities, has raised a total of $19 million in its most recent round of funding. Luminus plans to use this significant influx of capital to support growth and the expansion of the company's products and applications, including "Big Chip" light-emitting devices (LEDs) in specialty lighting applications, projection displays, digital signage, and ultraviolet industrial processes. The company's PhlatLight LEDs are currently used by Acer, LG, Philips Vari*Lite, Sony, Samsung, and Toshiba.

WiTricity Corporation, founded to commercialize a new technology for wireless electricity pioneered by professor Marin Soljačić, has continued to attract the attention of industry watchdogs and reviewers. The early theoretical and experimental work that forms the foundation of this technology was published in 2007 in two CMSE-supported papers. In the past year, the company has received several accolades: *Mass High Tech* named WiTricity to its list of 2009 All-Stars of the New England Innovation Economy; AlwaysOn Network recognized the company as one of its "GoingGreen 100 Top Private Companies of 2009"; and the Mass Technology Leadership Council named it as one the top Emerging Innovative Companies of 2009. The company has received a great deal of global press coverage from, among others, CNN, the BBC, the *Boston Globe*, and dozens of online publications.

QD Vision, founded by CMSE-supported students supervised by professor Vladimir Bulovic under prior MRSEC grants, has obtained over $15 million in seed funding in recent months. The company has developed its first commercial product in conjunction with Nexxus Lighting of Charlotte, NC: the Array™ Quantum LED bulb, which is expected to go on sale in 2010. This product uses quantum dots to convert blue light to warm-colored white light with an efficiency approaching 100%. The bulb will offer the performance of a 70-watt incandescent bulb but will draw only 11 watts, as opposed to the compact fluorescent light (CFL) bulb standard 15 watts, and will fit directly into 400 million lighting fixtures already in place in the United States (*The Economist*, March 4, 2010). While there are a number of companies around the globe developing quantum dot technology, this Massachusetts start-up is the first to apply the technology commercially, according to QD Vision president and CEO Dan Button.

The Array™ LED lamp with Quantum Light™ optic technology was demonstrated to President Obama by professor Vladimir Bulovic, QD Vision scientific advisor, during the president's October 2009 visit to MIT.

Svaya Nanotechnologies, the newest CMSE-related start-up, was founded by Professor Hammond and colleagues in 2008. This Boston-area company will commercialize a new thin film manufacturing process that is more flexible and scalable than existing methods. The technology is based on an aqueous solution self-assembly process that emerged, in part, from layer-by-layer research pioneered by an IRG funded during the previous MIT MRSEC grant (IRG-II). The goal of Svaya is to make photovoltaic panels more efficient at generating electricity. The company, based in Sunnyvale, CA, has raised $3.1 million of a $6.3 million round of equity, according to a filing with the Securities and Exchange Commission.

We estimate that total direct job creation by the most closely CMSE-related companies (OmniGuide, LumArray, Luminus Devices, QD Vision, Kateeva, WiTricity, and Svaya) is about 300 jobs to date.

MIT's Technology Licensing Office is kept aware of new discoveries emanating from CMSE research and helps researchers file patents and issue licenses. Since the start of the current CMSE MRSEC grant, seven new patents have been issued and 12 new patent applications/provisional patents are pending that are related to MRSEC. In addition, there are currently 17 active industrial, academic, and governmental licenses of CMSE-patented research.

The center's MRSEC-supported faculty enjoy a high level of outside collaboration. During this academic year, there were 10 MRSEC-related industrial collaborations, 27 collaborations with outside academic researchers, and 12 collaborations with government laboratories and agencies. In addition, a number of CMSE faculty members supervised students in departmental co-op programs that carry out research projects in a wide variety of industrial laboratories.

Education and Human Resources

CMSE has 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.

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.

For the past five years, CMSE has collaborated with Roxbury Community College (RCC), a minority-rich two-year college in Boston, to make research experiences available to its students. The objective of this dedicated REU program is to engage community college students in current materials research and encourage them to pursue careers in science and engineering. In 2007, the program was expanded to include students from BHCC as well as RCC. Both colleges have significant enrollments of minority students.

Precollege Education

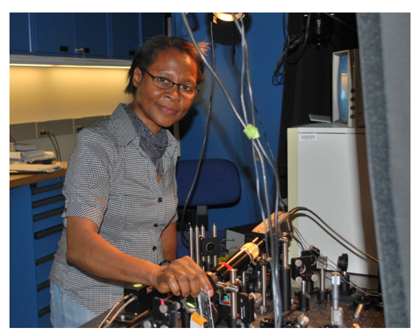
Materials Research Experience for Teachers

For the past 11 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 and 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. In the summer of 2009, three new teachers worked on research and four returning teachers worked on creating classroom materials. These participants are listed below.

RET Participants, Summer 2009

Name	School/Subject(s) Taught	Research Project
Carol Cafasso	Gloucester High School, Gloucester, MA/chemistry, physical science	Tunable photonic gels
Gift Jaja	Community Academy, Boston, MA/physics, chemistry	Light scattering measurement of thin film thickness
Craig Hovey	O'Maley Middle School, Gloucester, MA/general science	Synthesis and characterization of polymers developed for artificial blood vessels
Holly Marcus	Somerville High School, Somerville, MA/physics	Synthesis of materials for rechargeable lithium batteries
Sean Muller	Merrimack High School, Merrimack, NH/chemistry	Nonintrusive utility monitoring
Sarah Page	Boston Community Leadership Academy, Boston, MA/biology, physiology	Nonintrusive water utility monitoring
Arielle Saavedra	Boston Community Leadership Academy, Boston, MA/biology, chemistry	Synthesis and characterization of novel iron-based oxide superconductors

Relationships between CMSE and the RET participants extend beyond the summer program. The teachers bring students to campus and arrange for MRSEC researchers to visit their classrooms. For instance, Jaja brings small groups of high school students to the laser lab to make thin film samples and conduct thickness measurements on them using equipment in the Electron Microscopy and Materials Analysis SEFs in addition to the laser equipment in the research lab. Another example is MIT professor Markus Buehler's visit to the Boston Community Leadership Academy. This was arranged by Page as a result of meeting Professor Buehler at one of the weekly RET meetings last summer. During the visit, he presented talks on nanoscience to five different biology classes, ranging from freshman to AP classes. He also made a presentation to an assembly at Gloucester High School last year at the request of Cafasso.



Gift Jaja, 2009 RET participant, working on a project in professor Keith Nelson's lab.

Feedback from recent participants in the RET program indicates that they were satisfied with the program and that it has had a meaningful impact on their teaching. The most frequently cited enhancement of their classroom teaching as a result of their research experience at CMSE is the incorporation of more hands-on lab projects. The program participants often share their units and RET experience with fellow teachers at their schools and at regional and national meetings.

Science Teacher Enrichment Program and Women's Technology Program

CMSE offered its Science Teacher Enrichment Program (STEP) for the eighth time in the summer of 2009. The goal of the program is to deepen the teachers' content knowledge in areas related to the stated learning standards. It consists of a one-week, hands-on workshop, "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 hand-held vacuum, the physics of its operation, and the properties of the materials involved, the participants design and construct motors to meet performance specifications. The program includes presentations on polymers and new battery materials. The final day 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.

MRSEC supports five teachers in this program each year. Participants receive a small stipend and professional development points. They are recruited from local school districts, from former applicants to the RET program, and through alumni of CMSE's education programs. Of the five teachers who participated in the 2009 STEP, three teach at middle schools in Gloucester, Ayer, and Boston, MA, and the remaining two teach at a pilot high school in Boston. All of the participants were women, including three who were African American.

On exit surveys, participants in the 2009 STEP indicated that the program increased their confidence in teaching the engineering design process, as well as their knowledge of motors and magnetic fields. Two teachers from Gloucester who have participated in STEP (one in 2009 and one in 2008) worked with their colleagues to include the design and construction of motors in the curriculum of the district's middle school, where 260 students were introduced to the motor project this past academic year.

A companion effort to STEP is CMSE's collaboration in the Women's Technology Program (WTP) in EECS. In this four-week summer residential program, 40 high school girls from across the country 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 eight years, this has been an extremely successful collaboration. WTP alumni report that this motor-building lab is an exciting part of the program. CMSE continued to support WTP by providing the curriculum and supplies for this part of the program in 2009 and will continue to do so in 2010.

Workshops and Public Events

Over the course of the year, MRSEC faculty and students contributed content to a variety of programs and events on campus, at local schools, and at other public venues. Three programs held on campus last year benefited from CMSE participation. At the Sally Ride Science Festival held at MIT, Professor Leeb worked with two graduate students to run a workshop titled "Blowing in the Wind" in which 35 middle school students built wind turbine blades. The festival's objective is to encourage fifth- to eighth-grade girls' interest in science.

The Research Science Institute, sponsored by the Center for Educational Excellence, is held on the MIT campus each year. It is an intensive six-week research program for outstanding high school students from across the US. Professor Leeb taught a four-day materials and energy class to 25 students in the 2009 program. Finally, professor Pablo Jarillo-Herrero presented a talk on his research to 60 teachers attending the Science and Engineering Program for Teachers, a weeklong professional development program offered by MIT.

The MIT Museum regularly involves faculty and graduate students in special programs designed to inform the public about current research being done at the Institute. Professors Angela Belcher and Paula Hammond, along with their graduate students, participated in two such events last fall. At "Sampling MIT," they presented an exhibit titled "Nanotechnologies for Better Living" featuring a battery using a virus, Prussian blue electrochromism, and drug delivery research, all related in some way to MRSEC research. Approximately 200 people attended. They also conducted a nanotech workshop for 20 adults that began with a talk by professors Belcher and Hammond titled "Nanomaterials and Biomaterials Related to Energy, Healthcare, and the Environment," which described their research. This was followed by two hours of hands-on activities led by graduate students. Attendees made solar cells, tried layer-by-layer assembly via spray coating, precipitated DNA, and used biological agents to separate carbon nanotubes.

Professor Leeb continues to conduct short programs or workshops for K–12 students. During the past CMSE grant period, these included four different events. He and graduate student Sabrina Neuman led a workshop on "Materials in Scientific Photography" for two Girl Scout troops in which 34 girls participated. Professor Leeb also presented a class on motors and electricity to 24 first-grade students at the Winnbrook Elementary School. In addition, he led a Boy Scout troop of seven boys through a design project in which they built electromagnetic ping pong ball launchers. Finally, Professor Leeb operated a station at Belmont Science Night, a local town-wide public event. During the course of the evening, 225 students and parents stopped by the station, 80 of whom built simple DC motors. In addition to the efforts of Professor Leeb and several

Students at Ambrose School in Winchester, MA, making slime.

graduate students, CMSE administrative staff member Jei Lee Freeman presented a set of CMSE-created polymer demonstrations to a kindergarten class of 15 students at the Ambrose Elementary School in Winchester, MA.

Science and Engineering Program for Middle School Students

The center has operated a science and engineering program for seventh- and eighth-grade students from two Cambridge public schools for the past 18 summers. The objectives of the program are to introduce students to the field of materials science and engineering, demonstrate that science and engineering can be fun, and provide students with an opportunity to experience a college environment. The program consists of a full summer week of hands-on and inquiry-based science and engineering classes for students from each school. The 2009 middle school program took place during the weeks of August 3–7 and August 10–14. Twenty seventh- and eighth-grade students attended with their science teachers. Five of them were girls, and eight were members of underrepresented minority groups.

2009 CMSE middle school program glassblowing project.

The program covers a wide variety of topics. Most activities take place during 90-minute periods, and some include multiple sessions. The 2009 program included glassblowing, polymer demonstrations, electric circuitry, metal casting, and an engineering design contest. Each year the program concludes with the "Shoot-the-Hoop" design competition, to which families of program participants are invited. Activities offered are evaluated and modified each year by Professor Leeb and the program staff. Program activities are designed and taught by MIT faculty, staff, graduate students, and undergraduates. CMSE has developed collaborative relationships with MIT's Edgerton Center, the MIT Museum, the Department of Physics, EECS, and DMSE, which contribute to the development and implementation of projects. Some activities are modified versions of material used in MIT undergraduate classes.

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 year, six undergraduate students (including two women and two members of underrepresented minority groups) participated in the program with support from CMSE. In addition to the students paid by MRSEC, 10 undergraduates (including four women and two minority students) conducted research with an MRSEC-funded research group on a volunteer basis or with MIT funding. Some students continued their UROP research through multiple terms.

Summer Research Internship Program

In collaboration with MPC, CMSE sponsors the Summer Research Internship Program (through the NSF 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 received 144 applications for the summer of 2009, which were reviewed by a committee consisting of the CMSE director and staff from both centers. Participants were chosen from this pool on the basis of academic performance, interest statements, and faculty references. The 10 students accepted into the program for the summer of 2009 included five women and five men, two of whom were from underrepresented minority groups.

The students were paid stipends and worked full time for nine weeks. Most of them lived in a dormitory on campus. Weekly meetings were 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 completed the program by producing posters that reported on their summer's research. The resulting poster session was held during the final week and was open to the entire MIT community. It included posters produced by participants in CMSE's RET and Community College programs as well and served the dual purpose of functioning as a final report by the interns and teachers and informing the broader MIT materials community about the wide range of research supported under the auspices of the two centers.

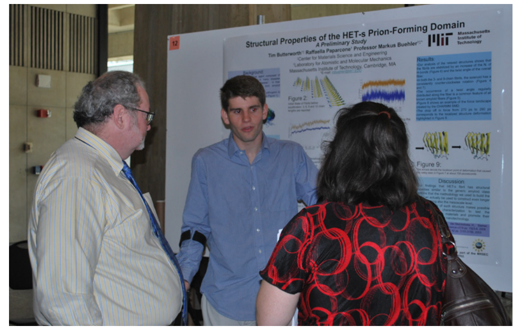
Diversity Enhancement Activities

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.

Community College Partnerships

CMSE developed the Community College Program (CCP) in 2005 with RCC and in 2007 added participants from BHCC. The overall objectives of this targeted REU program are to engage community college students in current materials research, help them develop their research skills, and encourage and enthuse them to pursue four-year degrees and careers in science and engineering. The program includes participants from two local community colleges that enroll significant numbers of minority students (40% at one and 55% at the other) who do not have opportunities to gain research experience at their home institutions. Students were chosen to participate in this program by faculty at their home institutions. Over the five-year history of the CCP, 68% of the participants have been minority students and 48% have been women. This program continues with strengthened partnerships with the two community colleges. CMSE expanded its partnership with BHCC over the past year to introduce an additional 81 students to the research tools in CMSE's SEFs. The BHCC faculty involved have indicated that this was important as it exposed their students to broader career options.

During the summer of 2009, two RCC students and two BHCC students, including two African Americans and one woman, participated in the program. Also, for the first time in 2009, one of the CCP participants was a student with a disability.



Bunker Hill Community College student Tim Butterworth discusses his poster with Bunker Hill and Roxbury Community College faculty.

The community college students spent nine weeks during the summer working on CMSE research as part of faculty-led research groups for which the students were awarded stipends. They chose their research projects from several presented by the MRSEC director during a preliminary seminar. Once on campus, the community college students participated in all REU meetings and activities.

The CCP students were very enthusiastic about their research experience at CMSE. On exit surveys, all four students indicated that they learned new computer skills and/or how to operate research equipment over the summer and that the program met or exceeded their expectations. Two of the 2009 CCP participants continue at community college. One student has transferred to MIT and has not yet declared a major. The fourth has transferred to the University of Massachusetts, Boston, where he is pursuing a degree in biology in preparation for application to medical school.

REU Outreach to Students from Underrepresented Minority Groups

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.

An exciting new program in CMSE’s education portfolio designed to enhance the research skills and experience of students at Puerto Rican universities is an emerging partnership with the Universidad Metropolitana (UMET) in San Juan, Puerto Rico. The collaboration was launched with the inclusion of two UMET students in CMSE’s Summer Research Internship Program during the summer of 2008 and another UMET student participated in the summer of 2009.

In June of 2009, two additional UMET students spent two weeks at MIT being trained to use equipment in the SEFs as they worked with graduate student mentors on MRSEC research. The students learned to use the atomic force microscope and scanning electron microscope and they reported that the experience provided them with useful skills while opening their eyes to career possibilities in the field of materials science and engineering.

A third component of the partnership took place in December 2009, when the CMSE graduate student mentors spent several days at UMET making presentations to precollege students and teachers and training their undergraduate partners to make similar presentations throughout the year. Aside from enhancing the students’ presentation skills, the objective of this portion of the program is to broaden its impact and to recruit and retain Puerto Rican science, technology, and engineering graduates. Significant communication between CMSE and UMET has taken place to develop this program. The MRSEC director has visited UMET several times to meet with Dr. Juan Arratia, who is the director of an NSF-funded Model Institution of Excellence and is leading the effort in Puerto Rico.

In an effort to recruit REU participants from institutions that have significant numbers of students from underrepresented groups, each year the CMSE director sends 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, and Centers of Research Excellence in Science and Technology, asking them to encourage their students to apply to the program. To date, the return on this effort has been limited.

Educational Outreach Collaborations and Materials Science Content Expansion

Other areas of effort include collaboration with other units at MIT to enhance educational outreach programs and to add materials science content to programs of other departments and centers. For many years, we have collaborated with the Edgerton Center and MIT Museum on our middle school program, school visits, and Family Adventures in Science and Technology (FAST) Sundays at the museum. We have established strong working relationships and collaborations with other administrative units at MIT, including MPC and departments in the School of Science and the School of Engineering.

In addition, the CMSE director is regularly engaged in discussions with deans and department heads concerning strategies for the recruitment and retention of postdoctoral associates and young faculty who are members of underrepresented groups. 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.

Collaborations with Other MIT Units

CMSE works with other departments and centers at MIT to present targeted education programs and to achieve mutual diversity objectives. The WTP is an example of such a program. The education director is a member of the MIT K–12 committee of educational outreach program directors on campus, allowing her to be aware of the wide range of programs available at the Institute and to participate in coordinating and planning on a larger scale.

The CMSE director is regularly engaged in discussions with deans and department heads concerning strategies for the recruitment and retention of postdoctoral associates and young faculty who are members of underrepresented groups. While MRSEC does not directly hire faculty or postdoctoral associates, it offers opportunities for interdisciplinary research and access to research equipment that helps academic departments attract researchers.

CMSE is making steady progress toward the diversity goals outlined in the MRSEC proposal. As stated, those goals include 50% participation by women and 50% by minority students in our combined undergraduate programs (Summer Internship Program, UMET, and CCP). We continue to make good progress toward this goal. In 2009, 43% of the students were women and 29% were minority students.

Postdoctoral Mentoring

CMSE supported 24 postdoctoral associates during the past MRSEC grant year, including MRSEC-funded postdocs as well as postdocs who participated directly but had other support (i.e., fellowships). They were mentored on a regular basis by their faculty supervisors. As part of a new CMSE mentoring plan, the director has met with the postdocs as a group to discuss their research activities, career paths, and professional progress. The director will also invite CMSE faculty to give presentations on important career challenges such as how to write a research proposal, how to interview for both industrial and academic positions, and how to organize and manage a research group. In addition, the postdocs will be encouraged to refine their communication and teaching skills through participation in professional events such as Materials Day at MIT and in CMSE's education programs.

Administration, Management, and Research

Our MRSEC program is administered by a proactive and effective management team that responds quickly to emerging needs of the program. Currently, seven administrative and seven SEF staff support the program. Administrative staff include an education officer, facilities and safety coordinator, financial administrator, financial and operations assistant, assistant to the director, assistant director, and director. SEF staff include one technical associate, four research specialists, a project technician, 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. At present, CMSE has a faculty education program leader who marshals our educational outreach plans with our education officer.

CMSE continues to host the MIT-wide Facilities Managers Group. This group was formed to better coordinate the synergistic activities of the large materials community at MIT. The CMSE director and one of the CMSE SEF managers, chosen each year by the CMSE director, chair the group, and meeting arrangements are made by CMSE headquarters staff. Five new lab managers were welcomed at the January 29, 2010, meeting. Vicky Diadiuk, associate director of the MIT Microsystems Technology Laboratories, updated the members of the group on the common object representation for advanced laboratories (CORAL) facilities software program developed and extensively beta tested by MIT, Stanford, and Berkeley. This software offers a comprehensive lab management system that includes online user registration, real time instrument status, and a complete billing module. CMSE has decided to adopt this system and is in the process of beginning a rollout of the tool to each of its SEFs. To ensure adequate time for data transfer and parallel testing, this rollout will be staged during the summer and fall of 2010 by adding each center SEF to the system one at a time. The Materials Analysis SEF will be first. CMSE will also continue to encourage other units on campus to explore this lab management tool for use in their labs and coordinate efforts to explore the possibility of obtaining support for a campus-wide adoption with the vice president for research. Several other MIT lab managers have expressed interest in this software tool as a result of this meeting.

CMSE activities are guided and supported by three internal committees and one external committee. The Committee on CMSE, Internal Advisory Committee, and Space Committee are internal MIT committees that offer guidance to CMSE on research, large equipment purchases, space, safety, and educational matters. The Science and Engineering External Advisory Board offers guidance on ways to enhance collaborations and supports major efforts in long-range materials research and engineering.

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

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