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 November 2014, NSF awarded CMSE a renewed six-year $16.2 million MRSEC center grant to fund CMSE's research and educational outreach programs as well as its shared experimental facilities from November 2014 to October 2020. This award was the culmination of an extensive two-year internal and external review process and proposal preparation at CMSE headquarters that enabled CMSE to compete with over 150 other national institutions to win one of 12 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 200 faculty members in 13 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 the researchers of 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. During the period of our 2008–2014 MRSEC award, researchers published results in over 500 papers and were awarded 52 patents related to their MRSEC research, with 82 more patents issued or pending.

Our SEFs are used by numerous research groups from MIT as well as by outside academic and industrial communities. During the August 2014 to July 2015 period, 1,056 people used our SEFs, including 820 students and postdocs of MIT faculty in 22 academic departments, labs, and centers; 36 students and staff of faculty from 11 outside academic/research institutions; 180 students using the facilities for MIT lab subjects; and 20 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 2014, 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.

Interdisciplinary Research Programs and Scientific Accomplishments

AY2015 was a year of transition from the 2008–2014 MRSEC grant IRGs, initiatives, and seeds to the 2014–2020 grant IRGs and seeds. During the 2014–2015 academic year, CMSE supported three IRGs, two initiatives, and two seeds from the 2008–2014 grant, and in November the center began three IRGs and four seed projects for the new 2014–2020 MRSEC grant. The new grant supports 26 faculty from nine MIT departments and, through a subaward, one faculty member from the University of Central Florida. Selected research highlights from FY2015 are reported below.

Research Results: 2014–2020 Grant

IRG-I: Harnessing In-Fiber Fluid Instabilities for Scalable and Universal Multidimensional Nanosphere Design, Manufacturing, and Applications

IRG-I research is directed at the development of unique, multicomponent nanostructured fibers and nanoparticles through the use of a newly discovered processing paradigm involving nonlinear fiber fluid instabilities. Using this approach, this group has developed a number of methodologies that make it possible to selectively break up a semiconducting core into discrete spheres while maintaining continuous regions of conductive electrodes connected to the spheres. The net result is active, in-fiber electronic devices (more than 100,000 per meter of a fiber) obtained through a one-step assembly process. The group has also implemented a laser-induced capillary breakup setup and used it to create silicon spheres. The setup consists of two lasers with different wavelengths, one mainly absorbed by the fiber cladding and the other mainly absorbed by the fiber core. Thus, a high controllable temperature profile is obtained. IRG-I researchers have further demonstrated that it is possible to fabricate a meter-long crystalline silicon-core, silica-cladded fiber from a preform that does not contain any elemental silicon but, rather, contains aluminum and silica (glass). On the theoretical side, a large-scale parallel Stokes solver has been developed that better scales up to the experimental parameters of the fiber drawing process.

In the applications area, IRG-I researchers are developing synthetic fiber scaffolds that may eventually replace nerve autografts for peripheral nervous system repair in the clinic. In order to better integrate these scaffolds with severed nerves, this group is moving past the current passive structures with cylindrical geometries and creating grooved geometries that improve axonal growth by up to two times, a result of the alignment of the developing processes and cell bodies along the grooved topographic features. Next steps will involve combining the topographic features with optical stimulation capabilities and integrated electrodes for monitoring of neural activity during axonal growth and development.

Metallic nanoparticles are well known for strong but narrow visible-range extinction peaks due to plasmon resonance effects. IRG-I researchers hypothesized that by normalizing optical extinction to particle volume (σ_{ext}/V) over a broad range of incoming wavelengths, the extinction coverage produced by the smallest possible particle could be maximized over the entire visible range. They have now experimentally verified prior theoretical research by demonstrating that oblate ellipsoid nanoparticles are able to extinguish visible light normalized to nanoparticle size more efficiently than almost any other shape. High efficiencies were achieved, up to 100% over the entire visible range. Another important optical parameter is the optical scattering efficiency Q_{sca} (defined as the ratio of the scattering to geometric cross sections) of particles. Typically, this parameter is altered to achieve maximum opacity in thin layers without absorption by increasing the refractive index, an approach fundamentally limited by naturally available materials. IRG-I research, however, has shown that multilayer dielectric particles with a controlled radial structure and a high refractive-index contrast (without incorporating metals) can be used to control Q_{sca} solely through the internal architecture of core-shell particles.

This effort is establishing a wide-ranging, materials-agnostic fiber fabrication approach that can be used to create complex, multicomponent fibers with optical and electrical properties that allow development of unique fiber-based devices such as solar fabrics. The electronic and optical capabilities of these fibers can also be exploited as devices for stimulating and recording neuronal activity in humans to aid in the treatment of neurological disorders such as Parkinson's disease. The complex nanoparticles created in the fibers can be harvested for numerous other optical applications as well. On the fundamental side, this research offers a new paradigm for fluid-dynamic studies through the use of highly controlled environments for the observation of fluid instabilities involving multiple fluids co-flowing in hitherto unobtainable geometries and scales.

Faculty participants and department affiliations: Y. Fink, co-leader (Materials Science and Engineering [DMSE]); M. Soljacic, co-leader (Physics); J. Joannopoulos (Physics); S. Johnson (Mathematics); A. Abouraddy (University of Central Florida); and P. Anikeeva (DMSE).

IRG-II: Simple Engineered Biological Motifs for Complex Hydrogel Function

IRG-II researchers seek to understand the molecular mechanisms that govern the unique structure/property combinations of complex biological hydrogels and use this knowledge to create synthetic mimics with similar extraordinary properties. Using molecules engineered to contain a peptide sequence found in nucleoporins, this group has demonstrated that it is possible to use single amino acid substitutions to tune hydrophobic self-assembly in a manner that produces wide-ranging mechanical properties. In addition, they have found that modulating the charge profile surrounding hydrophobic domains significantly impacts the physical and functional properties of hydrogels, including the permeability of diffusing substrates. This work has therefore established that the environment surrounding hydrophobic domains is a critical design parameter by which to fine-tune self-assembly and molecular recognition of hydrophobic domains within soft materials. In an attempt to mimic the hydrogel within the nuclear pore and create selective sorting abilities that would be useful to extract substrates that are not related to nuclear pore passage, such as contaminants of food or water, the group has engineered curli fibers found in *E. coli* biofilms to display different peptides with negative, positive, and neutral charges on their surfaces. Since they are easily engineerable and low in cost, curli fibers are attractive as a platform scaffold for displaying peptides of interest and studying their resulting material properties.

This IRG also reports on the synthesis of a new class of bio-inspired smart polymer materials with dynamically tunable crosslink junctions. The crosslinks are formed from metal-coordinating moieties that can be tuned from very stable to easily disassociated crosslinks by simply changing the nature of the metal involved in coordination. This means that the assembly of the polymer into hydrogels and the resultant mechanical properties can be directly controlled via the kinetics of the network junctions.

In order to mimic the biological functions of aggrecan, the primary glycan-containing molecule of cartilage, members of this IRG have synthesized aggrecan bottlebrush mimics composed of a polypeptide backbone (L and D propargyl glutamates) modified with oligoethylene oxide side chains. Preliminary results indicate that the equilibrium swelling and hydration properties of these synthetic polypeptide systems depend strongly on the D or L isomer used to construct the chains and the resultant secondary structure. The mechanical properties of this series of gels have been investigated at the nanoscale via atomic force microscopy indentation and at the macroscale via rheological studies.

The fundamental knowledge and new materials developed within this IRG will lead to next-generation materials with potentially wide engineering implications, such as the design of self-healing filtration systems for water and food purification, new antimicrobial coatings for implants, or cartilage substitutes with high durability and lubrication capacity. New insights into the origin of the extraordinary properties of biological hydrogels are also expected with an understanding of the interplay among three common motifs found in these materials: repeat domains, reversible crosslinking, and glycosylation.

Faculty participants and department affiliations: K. Ribbeck, co-leader (Biological Engineering); P. Doyle, co-leader (Chemical Engineering); B. Olsen (Chemical Engineering); N. Holten-Andersen (DMSE); J. Johnson (Chemistry); A. Grodzinsky (Biological Engineering, Electrical Engineering and Computer Science [EECS], and Mechanical Engineering); P. Hammond (Chemical Engineering); and T. Lu (EECS/Biological Engineering).

IRG-III: Nanoionics at the Interface: Charge, Phonon, and Spin Transport

IRG-III research seeks to discover the coupling mechanisms between oxygen defects and the transport of phonons, spin, and charge at the interfaces of metal oxides. Using $SrTiO_3$ as an archetypal material for functional metal oxides, IRG-III researchers have established a theoretical framework for predicting the defect chemistry of $SrTiO_3$ with and without applied electric fields and predicting the polarization and electric enthalpy induced in a defect-free $SrTiO_3$ crystal with an applied electric field.

Resistance-based random access memories are promising alternatives to current flash technology, but the durability of these devices is uncertain given the limited understanding of the switching mechanism. Members of this group have utilized scanning tunneling microscopy to investigate the resistive switching behavior in TaO_x and $SrRuO_3$ films. Results show that the switching mechanism in $SrRuO_3$ is different from TaO_x and that oxygen defects play a vital role in $SrRuO_3$, providing new insights into the factors controlling switching. This group has also demonstrated that thermal conductivity can be controlled in oxide thin films by changing oxygen vacancy concentrations. The thermal conductivity of $SrCoO_x$ films as a function of phase and film thickness was changed by a factor of three by electrochemical pumping of oxygen into and out of the films, with the latter suggesting a ballistic phonon transport mechanism.

Nanocomposites composed of a magnetic phase (CFO [$CoFe_2O_4$]) together with another LSC ($La_{0.8}Sr_{0.2}CoO_3$) or BSCF ($Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_3$) phase have been used to explore the effects of hetero-interfaces on magnetism and oxygen reduction kinetics. It was demonstrated that the properties of the two phases are coupled due to a different strain state and crystal geometry, making it possible to use an external field (e.g., a magnetic field) to affect the properties of one phase and, indirectly, those of the other phase. This IRG also carried out a systematic characterization of the effects of voltage cycling in Co/GdO_x/gate structures. It was found that devices first switch to a low-resistance state as the gate voltage is increased and then switch back to a high-resistance state at Vg=8 V. This second resistive switching event was accompanied by abrupt changes in magnetic and optical properties, and reversible changes in optical reflectivity could be observed between 0 V and 3 V. The research of this IRG has transformative implications for energy and information technologies. By providing a better understanding of the central role that oxygen defects play in the electrical, optical, and magnetic properties of metal oxides at interfaces, this effort is expected to influence the next generation of emerging devices such as nanoionic and thermoelectric devices, fuel cells, and memristive and magnetoelectronic devices.

Faculty participants and department affiliations: C. Ross, co-leader (DMSE); B. Yildiz, co-leader (Nuclear Science and Engineering); G. Beach (DMSE); G. Chen (Mechanical Engineering); H. Tuller (DMSE); and K. Van Vliet (DMSE and Biological Engineering).

FY2015 Seed Research

- Seed 1: Chemically Modified Carbon Cathodes for High Capacity Li-O2 Batteries (Yogesh Surendranathm, Chemistry). This seed seeks to improve the long-term performance of Li-O_2 batteries by developing electrode surface treatments that inhibit the growth of insoluble Li_2O_2 precipitates.
- Seed 2: Interface Engineering of Silicon-Oxide Core-Shell Nanorods for High-Efficiency Water Splitting Photocatalysts (Alexie M. Kolpak, Mechanical Engineering). This seed utilizes computational methodologies to explore and optimize the photocatalytic water splitting properties of Si-TiO2 core-shell nanorods in solar energy conversion schemes.
- Seed 3: Single Crystal Study of Electronic Topology and Correlation (Joe Checkelsky, Physics). The aim of this seed is to grow single crystals of topological

materials with significant electronic correlation to explore new states of matter with novel magnetic and transport properties.

- Seed 4: Direct Deposition of Catalysts on Porous Metallic Foams for Efficient CO2 Electroreduction (Fikile R. Brushett, Chemical Engineering). This seed seeks to develop microporous metal foam electrodes with nanostructured electrocatalysts for use in high-performance CO2 conversion devices.

Research Results: 2008–2014 Grant

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

IRG-I members have been investigating important details concerning the chemistry of high-energy-density battery systems based on $Li\text{-}O_2$ and $Na\text{-}O_2$ with a recent emphasis on non-aqueous $Na\text{-}O_2$ batteries due to their higher energy efficiency (90%) relative to their $Li\text{-}O_2$ counterparts. Using high-surface-area carbon nanotube carpets in $Na\text{-}O_2$ cells, this group has found that NaO_2 forms two distinct size regimes during battery discharge: micron-sized cubes at high rates and faceted nanoparticles at lower rates. This result provides key insights into the kinetics and rate-limiting nature of the oxygen reduction reaction during discharge of the $Na\text{-}O_2$ cell.

This group also carried out fundamental studies of transition metal oxides for use as oxygen electrocatalysis. A key result was that epitaxial strain introduced by a lattice mismatch could be used to tune the activity of (001)-$LaCoO_3$ toward oxygen electrocatalysis in alkaline environments. Moderate tensile in-plane strain was found to increase oxygen reduction activity and evolution reactions relative to compressive strain. The cost and instability of noble-metal catalysts in batteries have further motivated the group to examine different types of inexpensive transition metal oxide catalysts. Through a virus-based templating approach, a variety of nanosized perovskite and spinel oxide materials with controlled size, shape, composition, structures, and morphologies were created and explored as electrocatalysts for rechargeable metal-air batteries. The battery performance of these new materials appears promising, as do the prospects for biomolecular directed synthesis to provide a selection platform for future energy storage electrocatalysts.

Faculty participants and department affiliations: G. Ceder, co-leader (DMSE); Y. Shao-Horn, co-leader (Mechanical Engineering); A. Belcher (DMSE and Biological Engineering); K. Hamad-Schifferli (Mechanical Engineering and Biological Engineering); D. Nocera (Chemistry); T. Van Voorhis (Chemistry); and C. Thompson (DMSE).

IRG-II: Mechanomutable Heteronanomaterials

IRG-II researchers continued investigations of new mechanomutable systems based on thin films of polyelectrolyte multilayers. A theory of active polymeric materials accounting for changes in material volume and properties due to actuation was employed to simulate indentation experiments. A dynamic decrease in cross-link density upon swelling, not seen in the conventional swelling theory of polymer networks, was observed and found to have a significant influence on mechanical properties. Such changes in mechanical properties demonstrate the potential for material design of mechanomutable coatings with applications in microscale and nanoscale devices.

The group also investigated how wrinkling instabilities induced in the interfacial layers of stratified composites could provide new energy absorption mechanisms critical to many engineering applications. A key result was that the composite material exhibits an enhanced energy dissipation that is repetitive, thereby providing a recoverable energy dissipation mechanism despite localized plasticity occurring in the system. In a modeling study of cross-linked single-wall carbon nanotube (SWCNT)/polymer hydrogels, the group found through simulations that single nanotubes or bundles of SWCNTs are formed during structural evolution, and the polymers highly entangle on the SWCNTs due to the crosslinking. This result has important implications for creating enhanced nanotube-reinforced polymers via manipulation of crosslinking density and nanotube dispersibility.

Faculty participants and department affiliations: R. Cohen, co-leader (Chemical Engineering); C. Ortiz, co-leader (DMSE); M. Boyce (Mechanical Engineering); M. Buehler (Civil and Environmental Engineering); P. Hammond (Chemical Engineering); K. Van Vliet (DMSE); and A. Balazs (University of Pittsburgh).

IRG-III: Multimaterial Multifunctional Nano-Structured Fibers

IRG-III researchers have developed an exciting new process for carrying out chemical reactions within a fiber preform as it is being formed into a fiber. This process is capable of generating new materials and achieving a different structure in the final fiber from that in the fiber preform. As an example, the group demonstrated that a meters-long crystalline silicon-core, silica-cladded fiber could be drawn from a preform that does not contain any elemental silicon. To accomplish this, an aluminum rod inserted into a macroscopic silica tube was thermally drawn. The aluminum atoms initially in the core reduce the silica to produce silicon atoms and aluminum oxide molecules. The silicon atoms diffuse into the core, forming a large phase-separated molten silicon domain that is drawn into the crystalline silicon core fiber. The ability to produce crystalline silicon core fiber from inexpensive aluminum and silica could pave the way for a simple and scalable method of incorporating silicon-based electronics and photonics into fibers.

The group has also further developed fiber-based neural probes for the detection and stimulation of neural signaling within the brain and spinal cord. In this case, a thermal fiber drawing process was utilized to produce flexible multifunctional fiber probes for optical stimulation, electrophysiological recording, and drug delivery in the brain of freely moving mice without any negative foreign body response. This unique combination of optical, electronic, and microfluidic capability represents a first of its kind fiber system. The IRG team has also applied fiber processing to produce, for the first time, highly flexible all-polymer probes for optical stimulation and neural recording in the spinal cord of mice. These integrated, compliant devices promise a new set of diagnostic tools for the neuroscience community. On the theoretical side, the group has developed a large-scale parallel Stokes solver that has been used to successfully model the capillary breakup process involved in fabricating nanoparticles within fibers.

Faculty participants and department affiliations: Y. Fink, co-leader (DMSE); M. Soljacic, co-leader (Physics); J. Joannopoulos (Physics); S. Johnson (Mathematics); E. Ippen (EECS); A. Abouraddy (University of Central Florida); and P. Anikeeva (DMSE).

Initiative-I: High Def Nanomaterials: New Routes to 3D Hierarchical Nanostructured Materials and Devices

Initiative-I researchers continued development a new platform technology composed of functionally active, patterned nanoporous scaffolds created from carbon nanotubes coated with layer-by-layer (LbL) assembled polymers and contained within microfluidic devices. Modeling efforts have provided additional insights into the factors controlling the coating process, resulting in the ability to coat individual nanotubes or shrink-wrap an entire nanotube forest with an external coating. A set of guidelines for how the geometry of the nanotube device elements controls the spatial location of the resultant LbL coating was established.

Faculty participants and department affiliations: B. Wardle (Aeronautics and Astronautics), R. Cohen (Chemical Engineering), M. Rubner (DMSE), and M. Toner (HST).

Initiative-II: Quantum Optoelectronics and Spintronics with Topological Insulator Nanoscale Devices

Initiative-II researchers have focused on introducing ferromagnetic order into a topological insulator (TI) system without compromising distinctive quantum coherent features. Hybrid heterostructures were engineered to create a ferromagnetic state on a TI surface by using a ferromagnetic insulator on an epitaxial Bi_2Se_3 layer. Magneto-optic techniques clearly demonstrated ferromagnetic order in the interface TI layers. Depth-sensitive polarized neutron reflectometry measurements further provided direct evidence that these heterostructures exhibit proximity-induced interfacial magnetization in approximately the top 2-nm layer of Bi_2Se_3.

Faculty participants and department affiliations: P. Jarillo-Herrero (Physics), N. Gedik (Physics), and J. Moodera (Francis Bitter Magnet Laboratory).

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, Electron Microscopy, X-ray Diffraction, and Nano Materials, staffed by a team of highly motivated professionals. During the year ending June 2015, 1,056 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 education 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 Materials Research Experience for Teachers (MRET) 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.

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 this academic year, about 180 undergraduate students used the facilities as part of their laboratory subjects.

SEF staff members offered a number of mini-courses during MIT's 2015 Independent Activities Period (IAP) to train students to operate SEF equipment and apply the latest techniques to their research problems. In January of 2015, a total of six courses were scheduled to be offered to the MIT community, but, due to extreme weather in New England, only four courses took place.

Materials Research Facilities Network

During FY2015, students and faculty from around the United States and the world came to MIT through an NSF Materials Research Facilities Network (MRFN) supplement to our MRSEC grant. This MRFN supplement enables students and faculty who do not have access to instruments such as those available at our SEFs to visit MIT so that they can learn about and use these types of instruments. A process has been established that involves the submission of a short proposal outlining the work to be done and how the results will impact the proposer's research program and, if relevant, educational activities. Groups typically stay from Sunday evening to Saturday morning, and SEF managers set aside blocks of time for training and assisting with running samples and training students. All participants register in the Coral lab management system and take the required safety courses to enter the SEFs.

Two professors from Puerto Rico (Maria Del C. Cotto Maldonado and Oliva Primera-Pedroza), a professor from Brazil (Marisa Beppu), and a professor from the University of Akron in Ohio (Dr. Nicole Zacharia) visited the SEFs to use the instruments and train students. Dr. Eugenia Ciocan (Bunker Hill Community College), who will participate in the 2015 MRET program in Professor Polina Anikeeva's lab starting in June 2015, will also be using MRFN funding to complete her research in the CMSE electron microscopy and X-ray facilities through the summer. In addition, Professor Ellie Fini from the North Carolina Agricultural and Technical State University continued to use MRFN funds to complete her work in the electron microscopy and X-ray facilities.

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), which connects MIT research to industry. These organizations combined have more than 200 member companies. Since the start of the new MRSEC grant, MRSEC faculty and/or their group members have engaged in nearly 60 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 Ajinomoto Co. Inc., Chevron Corporation, Eaton Corporation, Energizer-Schick/Energizer Personal Care, ExxonMobil, Honda R&D Co., Natura, Saudi Basic Industries Corporation, Sekisui Chemical Company Ltd., Shell, and Wuxi Sunshine Power. The CMSE director made presentations about MRSEC to Chevron, Dai Nippon Printing, Hitachi Chemical Co., Illinois Tool Works, Samsung Electronics, Shanghai Banzan Macromolecule Material Co., and Total S.A. In addition, MRSEC faculty and/or their group members from the NSF grant ending in this reporting period engaged in about 100 meetings with representatives from domestic and foreign companies including 3M, BOE Technology Group Co. Ltd., Chevron Corporation, The Coca-Cola Company, Dyson Ltd., ExxonMobil, Lockheed Martin, Mitsubishi Electric, Novartis, RUAG Aerospace AG, Saudi Basic Industries, Shell, and Siemens AG.

In October 2014, CMSE contributed to the showcase MIT materials event, the annual Materials Day at MIT program organized by MPC. Co-organizing the event's poster session enables CMSE to highlight MRSEC-funded research and connect this research directly to managers and researchers from industry and government laboratories. All MRSEC-supported researchers are encouraged to have their group members contribute posters to this event. The title of the 2014 Materials Day was "New Frontiers in Metals Processing." Professor Carl Thompson from CMSE/MPC provided introductory remarks and an overview of the program, and Professor Bilge Yildiz gave a presentation about her MRSEC research. The meeting was attended by nearly 130 registered guests from industry, government laboratories, hospitals, MIT, and other universities, as well as additional researchers and students from MIT who joined throughout the day on a walk-in basis. Representatives from more than 50 US and foreign companies, laboratories, and universities attended the event, including employees of LG Electronics, Lockheed Martin, Procter & Gamble, Raytheon, Samsung Research America, Suncor Energy, and the US Army Research Laboratory. The capstone poster event included posters from CMSE students and others from the MIT materials science community. This year, out of a total of 66 posters submitted, 31 were from students and postdocs of faculty supported by CMSE funding. The poster session was judged by a panel of members from MPC's Advisory Board, which includes research managers from industry.

MRSEC-supported faculty presented an overview of their CMSE research in three ILP-sponsored conferences: the 2014 MIT Research and Development Conference (F. Brushett, S. Leeb, and T. Lu), the 2015 MIT Brazil Challenge of Innovation Conference (B. Olsen), and the 2015 MIT China Conference in Wuxi (G. Chen and C. Ross). The Research and Development Conference was attended by nearly 325 guests as well as 340 individual representatives from companies including 3M, Accenture, BMW, Bose, Energizer, ExxonMobil, Fujifilm, GE, LG Electronics, Nestle, Novartis, Pepsi, Pfizer, Procter & Gamble, Raytheon, Samsung, and Siemens. Co-organized with Fundação CERTI and SENAI, the Brazil conference united 11 world-renowned MIT faculty members, including Professor Olsen of CMSE, with the 2015 Brazilian Congress on Industrial Innovation for two days of presentations and discussions on fostering innovation across industries. Held in São Paulo, the event drew more than 450 attendees and explored a diverse range of topics, from management and manufacturing to energy, materials, agriculture, and automation. It also provided a platform for building effective partnerships of mutual advantage with one of the world's fastest-growing economies. The MIT China Conference provided opportunities to engage 265 academics and global executives in driving national and global economic growth through innovation and entrepreneurship in advanced manufacturing, new materials, and energy solutions.

Additionally, independent of ILP, CMSE helped to sponsor the 89th American Chemical Society (ASC) Colloid and Surface Chemistry Symposium, a three-day event that took place in June on the Carnegie Mellon University campus. The symposium highlighted the latest scientific advances in colloid and surface science and its connection with a broad spectrum of scientific fields. Attended by 600 individuals from academia, industry, and national laboratories, including international participants from 20 countries, the symposium comprised over 500 oral and poster presentations, a poster session, two plenary lectures, and an instrument exhibition. CMSE's contribution to the event enabled ASC to keep registration fees below the marginal cost per attendee, thus allowing more students to attend.

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. It is estimated that total direct job creation by the most closely CMSE-related companies (OmniGuide, LumArray, Luminus Devices, QD Vision, Kateeva, and WiTricity) is about 400 jobs and growing.

MIT's Technology Licensing Office is kept aware of new discoveries emanating from CMSE research and helps researchers file patents and issue licenses. During this reporting period, 10 new patents related to MRSEC were issued, and seven new patent applications/provisional patents are pending.

The center's MRSEC-supported faculty enjoy a high level of outside collaboration. During this funding period, there were a total of 75 collaborations (40 of which were international): 2 industrial collaborations, 63 collaborations with outside academic researchers, and 10 collaborations with government laboratories and agencies (all MRSEC related). 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.

In addition to 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 several years, CMSE has collaborated with Roxbury Community College (RCC) and Bunker Hill Community College (BHCC), two minority-rich two-year colleges in Boston, to make research experiences available to their 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.

Precollege Education

Materials Research Experience for Teachers

For the past 16 years, CMSE has operated a successful MRET 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.

Relationships between CMSE and the MRET participants extend beyond the summer program. Over the years, these continued collaborations have enabled class visits to MIT, K–12 school presentations by MRSEC researchers, and student involvement in research. For instance, in December, 2014 MRET participant Michael Griffin arranged a visit to Mircea Dincă's lab as well as the electron microscopy and X-ray SEFs for 17 of his high school students. In addition, Professor Paul Kasili has scheduled a field trip to the X-ray SEF for two of his community college biology classes.

Feedback from recent participants in the MRET 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 MRET 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 13th time in the summer of 2014. STEP consists of a one-week workshop, "Dustbusting by Design," that focuses on increasing middle and high school teachers' content knowledge and providing them with experience in engineering design. The workshop correlates with the Massachusetts state science learning standards. Participants spent the first four days of the program in a machine shop on campus learning about the design challenges associated with the motor in a hand-held vacuum and then immersed themselves in the engineering design process as they constructed motors of their own design. The remainder of the week was devoted to presentations by CMSE researchers and a seminar on teaching the design process in K–12 classrooms. The lab portion of the program was simultaneously taught to 40 high school girls in the Women's Technology Program.

Participants in STEP received a small stipend and professional development points. They were recruited from local school districts, from former applicants to the MRET program, and through other MIT-based programs for educators. Four teachers participated in the 2014 STEP (two middle school science teachers and two high school teachers). Entrance and exit surveys were used to determine how well the workshop met the teachers' professional needs. All of the 2014 respondents indicated that the program met or exceeded their expectations. One noted that the workshop deepened his knowledge of force fields and torque, and another commented that "STEP incredibly impacted my learning and will impact my teaching."

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 12 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 2014 and will continue to do so in 2015.

Workshops and Public Events

MRSEC faculty and students contributed content to programs on campus and at local public events. On March 28, four graduate students presented energy-related demonstrations at "Science, Engineering, and Technology in the City," a full-day program of lectures, demonstrations, hands-on lab projects, and panel discussions attended by approximately 200 local high school girls. This program is organized by the Boston Area Girls STEM Collaborative, of which MRSEC is a member. Professor Steven Leeb leads several outreach efforts each year. In April, he presented a table-top activity at Winnbrook Elementary School's (Belmont, MA) Science Night for parents and students. About 200 students and parents attended the event. In June, for the seventh year, he provided instruction on engineering experiments to 40 students in the Research Science Institute (RSI). RSI, a well-established national six-week research program for outstanding high school students, is sponsored each year by the Center for Educational

Excellence and held on the MIT campus. MIT also hosts a group of science teachers for a week each June for the Science and Engineering Program for Teachers. This professional development program has been in place for 27 years and features faculty lectures on new frontiers in science and engineering research as well as hands-on workshops. During the 2015 program, Professor Caroline Ross presented a lecture, "Magnetic Materials and Applications," to the 30 participants, and Professor Angela Belcher spoke on "Giving New Life to Materials for Energy, the Environment and Medicine." In addition, Felice Frankel, a CMSE research scientist, presented "Picturing to Learn: How Images Can Teach Science and Engineering."

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 23 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. During the summer of 2014, 17 seventh- and eighth-grade students attended with their science teachers. Six of them were girls and six were members of underrepresented minority groups.

The students participated in hands-on activities presented by faculty, staff, graduate students, and undergraduates. The 2014 program included classes on ultraviolet light, simple DC motors, electric circuitry, polymers, and solar cells. In addition, a group of graduate students presented table-top demonstrations of energy projects related to their research. Participants also toured the MIT Museum and the Wright Brothers Wind Tunnel. In review discussions at the end of each week, the students were able to describe the material presented and explain what they saw. An indication that the program met the goal of demonstrating that science and engineering are fun is that all of the students who completed exit surveys responded that they would recommend the program to their friends.

Undergraduate Education

Undergraduate Research Opportunities Program

The center provides opportunities for MIT undergraduates to participate in MRSEC research through MIT's Undergraduate Research Opportunities Program (UROP). Participants in this program work on MRSEC research on a part-time basis during the academic year and full time during the summer. MRSEC typically supports three students each academic term and three during the summer. UROP students sometimes continue their research beyond one term. Also, MIT provides funding for a limited number of UROP participants, and some of them work on MRSEC research. During this reporting period, MRSEC directly supported four undergraduates. One of them was a woman and one was an underrepresented minority student. CMSE faculty report that an additional two students (one woman) working on their MRSEC research were supported by MIT directly or worked for academic credit.

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 180 applications for the summer of 2014, 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 14 students accepted into the program for the summer of 2014 included nine women and five students from underrepresented minority groups. Because the CMSE/MPC program is well established as a quality internship program on campus, other organizational units seek to fold their summer undergraduate researchers into the program. Last summer, the stipends of two students in the REU program were paid through an Energy Frontier Research Center funded by the US Department of Energy's Office of Basic Energy Sciences. These two students were selected from the pool of applicants to the REU program and participated fully in the program.

The nine-week summer internship program begins with a three-day symposium during which faculty present their research, describing the projects available for the interns. At the end of the three days, the interns select their projects for the summer. Throughout the summer, the interns, along with the REU students, participate in weekly mentoring meetings and seminars. They also present posters at the RET/REU poster event.

The students completed surveys at the end of the program. Of the 18 interns (REU and CCP) who responded, 17 indicated that they learned new research skills over the summer. All of them said that the program met or exceeded their expectations. In terms of the impact of the summer experience on their career plans, 13 indicated that it confirmed or clarified their plans, two expressed a stronger interest in pursuing graduate studies in materials science and engineering, two felt the program increased their confidence in applying to graduate school, and one responded that he was sure of his plans at the start of the program and that the summer did not affect them.

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 Program

CMSE's Community College Program (CCP) is another targeted REU program designed to enhance the diversity of undergraduate participants in MRSEC's research and education programs and to broaden participation among science and engineering professionals. CMSE partners with RCC and BHCC to provide their students with research opportunities and encourage them to pursue careers in science, engineering, and technology. CCP participants are selected by science faculty at their home institutions. Selection criteria include the students' academic background, statements of interest, and faculty references. A total of six students participated in 2014, all of whom were male and three of whom were minority students. CCP students spent nine weeks on campus conducting research in faculty-led groups and joined the other REU students for weekly meetings and seminars. These meetings featured research discussions and speakers on intellectual property, graduate school admissions, poster preparation, and hot topics in materials science and engineering. CCP participants presented their research at the RET/REU poster session.

Typically, community college students do not have opportunities to gain research experience at their home institutions. By participating in CCP, they learn research and technical lab skills that increase their confidence and prepare them to pursue bachelor's degrees and science and engineering careers. The MRSEC director and education officer meet separately with the CCP students as a group at least twice each summer to discuss their research and their career plans. In these meetings students have reported that, in addition to building their confidence in their ability to perform science and engineering activities, their experience at MIT broadens their knowledge of possible science and engineering careers and provides a more realistic picture of graduate work. Since the program's beginning, 28 (58%) of the participants have enrolled in four-year colleges. Of those, 16 have completed their bachelor's degrees. One went on to medical school, and three others are currently pursuing graduate degrees in science and engineering. Another is earning an MBA. Six CCP participants proceeded directly from community college to employment. Six students continue at community college, and the status of nine other participants is unknown.

MRSEC collaborates with Professor Polina Anikeeva to broaden the impact of its partnership with RCC and BHCC. With CMSE support and her NSF CAREER grant funds, she embarked on a multiyear plan to engage BHCC and RCC faculty and students in her lab's research, thus extending MRSEC's outreach to a wider group of community college students and faculty. One professor and one student from each institution spent the summer of 2014 doing research with Professor Anikeeva's group as participants in CMSE's CCP and MRET programs. The intention is for the RCC and BHCC faculty to integrate their research experience into their classroom teaching. CMSE provided the professors' and students' stipends.

Partnership with Universidad Metropolitana

In 2008, MRSEC formed a collaboration with Dr. Juan Arratia at the Universidad Metropolitana (UMET) to enhance the research experiences of students at the three Puerto Rican universities affiliated with the Ana G. Mendez University System (UMET, Universidad del Turabo, and Universidad del Este). Dr. Arratia refers students to the CMSE/MPC Summer Research Internship Program (REU). At least two intern positions a year are set aside for these students. A goal of the partnership is to recruit and retain Puerto Rican science, technology, and engineering graduates. Since its inception, 14 students have participated in the program, and an additional two students spent two weeks at CMSE working with graduate students to learn to use research instruments in the SEFs. Of the 16 students who have been involved in the program, two are still completing their undergraduate studies, another five are currently pursuing graduate degrees, and one has completed her PhD. Five others have completed their bachelor's degrees and are employed in engineering jobs, and the career status of the remaining three is unknown. In addition to their research at MIT, undergraduates who participate in the REU program contribute to UMET's outreach to high school students in the San Juan area.

Enhancing Diversity within Existing Programs

To increase minority participation in the REU program, CMSE directly advertises the program to minority-serving institutions. In the fall of 2014, approximately 400 letters with attached recruitment flyers were emailed to principal investigators at NSF-funded Centers of Research Excellence in Science and Technology, Historically Black College and University Research Infrastructure for Science and Engineering awardees, and Louis Stokes Alliances for Minority Participation. CMSE also recruited via the Institute for Broadening Participation's online directory of REU programs. The number of applications from women and minority students has gradually increased since the beginning of the grant. Applications received for the 2015 program showed an increase in minority applicants (20%) relative to last year (16%). Women consistently account for approximately one third of the applicants. To further increase diversity in the REU program, the center, as mentioned, runs collaborative programs with two local community colleges and the Universidad Metropolitana, all of which serve underrepresented minority students.

Recognizing the importance of diversity in the pipeline of future scientists and engineers, CMSE seeks to impact the classroom experience of minority students by strengthening the materials content knowledge of their science teachers. CMSE is committed to achieving approximately 50% participation by teachers from schools with significant enrollments (above 50%) of underrepresented students. Three of the seven participants in the 2014 MRET program taught at institutions that meet this requirement. In addition, CMSE directly engages local middle school students through its Science and Engineering Program for Middle School Students. Students who participated in this program in 2014 were drawn from two Cambridge public schools where approximately 50% of the registered students are from underrepresented groups. Participation over the course of the grant (2009–2014) averaged 36% female and 54% minority students.

Postdoctoral Mentoring

CMSE has developed a robust postdoctoral professional development program. Over the past year, 23 postdoctoral associates worked on MRSEC research, 18 of whom were paid directly by the center. CMSE launched its postdoc mentoring program in 2010 with a director-led meeting of CMSE postdocs to identify their professional development needs and topics they would like to see addressed. As a result, a postdoc advisory committee was formed to provide input to the director about activities and services that would be beneficial to professional development. In 2011, with input from this committee, CMSE inaugurated a seminar series that features annual professional development events jointly sponsored by CMSE and a partnering MIT academic department. All postdocs working with CMSE faculty are invited to participate in the seminars, whether or not they are supported by MRSEC. The initial seminar, held in January 2011 and co-hosted by DMSE, featured a panel discussion focusing on career paths and balancing professional and family lives. CMSE partnered with the Department of Chemical Engineering to present the second seminar in 2012. At this event, a panel of faculty presented advice on finding and securing faculty positions, including information on the search process, interviewing, and negotiating a startup package. A total of 75 postdocs attended these two events. On exit surveys, attendees offered positive feedback on the two seminars. Similar seminars in partnership with other academic departments will be scheduled in the future to address topics identified by the advisory committee.

In the past, MRSEC collaborated with materials-related academic departments to sponsor master classes, taught by CMSE research scientist and science image specialist Felice Frankel, that focused on the visual communication of science and engineering. The classes were designed to enhance postdocs' and graduate students' oral and visual presentation skills. Frankel has worked with scientists and engineers for many years and has published two books. Her book *Visual Strategies: A Practical Guide in Graphics for Scientists and Engineers* formed the foundation of the master classes, which consisted of a large-group lecture followed by small-group workshops. Frankel presented an abbreviated version of the program to the center's REU students in July 2014. The response to the workshops and master classes has been very positive, indicating a strong interest in the topic. Consequently, another class is planned for fall 2015. In addition, CMSE will co-sponsor a seminar in July 2015, "Submitting Images to *Nature* Magazine," that will consist of a discussion with *Nature*'s art director, Kelly Krause, led by Frankel. The event will be recorded for distribution online as part of the 0.111x Making Science and Engineering Pictures MITx course.

In addition to the seminar series, the MRSEC director has been meeting individually with postdocs to offer career development and job search advice. The Office of the Vice President for Research (VPR) oversees a robust program of mentoring and professional development activities for postdoctoral researchers that includes a seminar series, workshops, and a library of online resources. The office also supports the postdoc-led MIT Postdoctoral Association, which sponsors speakers, workshops, career fairs, writers' groups, and social events. The postdocs are informed of this broad range of opportunities through a listserv maintained by VPR.

Finally, as part of its postdoc mentoring plan, CMSE encourages postdocs to hone their science communication and presentation skills by teaching in the center's education programs. In addition to mentoring REU students, they regularly participate in CMSE's middle school, high school, and teacher 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, six administrative and seven SEF staff support the program. Administrative staff includes an education officer, facilities and safety coordinator, financial administrator, assistant to the director, assistant director, and director. SEF staff include one technical associate, four research specialists, a postdoctoral associate, and a project technician. The CMSE director reports to the dean of engineering, 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 currently has a faculty education program leader who marshals our educational outreach plans with our education officer and a faculty special projects coordinator who will work with MRET participants to develop hands-on teaching modules and related video content. The overall objective is to create a new pipeline of future engineers and scientists for fields vital to the future of the United States through the use of cutting-edge, hands-on learning exercises. For example, a collaboration with a local MRET teacher led to the development of an inexpensive ($50–$100) polymerase chain reaction machine that allows K–12 students to learn about DNA biotechnology.

CMSE Junior Faculty SEF Award

CMSE, recognizing the financial burden MIT junior faculty face in utilizing large experimental facilities for research needs, started a new award program in 2011 to assist these faculty members in accessing the CMSE shared experimental facilities. The faculty who were awarded funds during FY2014 found the program very helpful, and it was decided to continue the program into the future and extend each award for a two-year period, allowing more time for the junior faculty members to use this funding. Contingent on the availability of center discretionary funds (this program is supported by funds distributed to CMSE from technology licensing revenue) and the number of qualified applicants, CMSE will typically offer awards to five or more MIT assistant professors each year at a level as high as $5,000 for each award. Each award will last for two years and can be applied only to user fees in CMSE shared experimental facilities. These awards are restricted to faculty engaged in research activities related to aspects of materials science and engineering as practiced at CMSE. One- to two-page research proposals for the awards will continue to be solicited from junior faculty throughout the MIT materials community each year and reviewed by the center director, who will make awards based on the strength of the faculty proposal and the financial need justification. The award recipient in FY2015 was Assistant Professor Xuanhe Zhao of the Department of Mechanical Engineering

MRSEC-Driven Materials Community–Building Activities

CMSE, in collaboration with the Department of Materials Science and Engineering and the Materials Processing Center, continues to host a seminar series in materials science and engineering that started in 2005. The objectives of the series are to provide an opportunity for faculty, research staff, and students from the CMSE community 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 and the MRSEC program. Three seminars were held during the fall of 2014; speakers were Professor Thilo Rehren (University College London Qatar), Professor Shriram Ramanathan (Harvard University), and Professor Scott Misture (Alfred University).

CMSE participated in and co-sponsored a "Future Faculty Workshop" held in July 2014 at the MIT Endicott House. In the broader context of promoting diversity at the faculty level, these very successful two-day workshops, originated by Professors Tim Swager (MIT) and Rick McCullough (Harvard), seek to provide intensive mentorship to minority students and postdoctoral fellows interested in pursuing careers in academics in the areas of materials science, chemistry, and chemical engineering.

CMSE also hosts 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.

CMSE Committees and Boards

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. The following individuals now serve on the board: Dr. Leonard Buckley, director of the Science and Technology Division at the Institute for Defense Analyses; Dr. Edwin Chandross, a materials chemical consultant; Dr. James Misewich, associate laboratory director for basic energy sciences at the Brookhaven National Laboratory; Dr. Rama Bansil, a professor in the Department of Physics at Boston University; Dr. Sharon Glotzer, Stuart W. Churchill Collegiate Professor of Chemical Engineering at the University of Michigan; and Dr. Raymond Samuel, assistant dean of the School of Engineering and Technology at Hampton University and an associate professor in the Department of Chemical Engineering.

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