

Materials Processing Center

The Materials Processing Center (MPC) was established as an interdisciplinary center within MIT's School of Engineering in response to a recognized national need to improve the materials processing knowledge base and streamline the process of translating materials research results into industrial innovations and applications. Following a science-to-systems approach, MPC assembles faculty resources and leverages existing knowledge to help companies and federal agencies address their challenges and create opportunities. MPC is now in its 29th year.

Mission

The mission of MPC is to provide an environment where students and professionals from industry, government, and academia collaborate to identify and address pivotal multidisciplinary issues in materials processing and manufacturing in a way that creates new knowledge, produces knowledgeable people, and promotes the exchange of knowledge in the service of our nation in the context of a global community.

Philosophy

MPC's philosophy focuses on an understanding of processing fundamentals to control internal structure, from the nanoscale to the macroscale, thereby optimizing a material's properties and performance. Center research covers a broad range of materials and processes via a number of common themes. Foremost among them is the control of materials structure, properties, and performance in an ecologically and economically sound manner.

Creating New Knowledge: Selected New Research Programs

During FY2009 MPC worked to identify opportunities for environmentally sustainable materials design and processing for infrastructure used in energy generation and storage, transportation, construction, and communications. The proposals submitted culminated in these awards:

Gang Chen, Warren and Towneley Rohsenow professor of mechanical engineering, was awarded funding (\$17.5 million over five years) for an Energy Frontier Research Center (EFRC) by the US Department of Energy. The objective of the Solid State Solar Thermal Energy Conversion Center (S³TEC) is to create novel solid-state materials for converting sunlight and heat into electricity.

Gerbrand Ceder, R.P. Simmons professor of materials science and engineering, was awarded an EFRC subaward (\$1.328M over five years) to spearhead the Northeastern Chemical Energy Storage Center. The center will implement a large-scale computational materials design program to understand and design novel materials for clean energy.

Harry Tuller, professor of ceramics and electronic materials, was awarded funding (\$2.64 million over three years) from the Single Investigator and Small Group Research (SISGR) program to start the Chemomechanics of Far-from-Equilibrium Interfaces project.

Professor Pablo Jarillo-Herrero was also awarded funding (\$1.77 million over three years) from the SISGR program for the Transport and Imaging of Mesoscopic Phenomena in Single and Bilayer Graphene project.

MPC Industry Collegium

The Industry Collegium of MPC creates a proactive forum where people from industry and MIT can work as partners in exploring and pursuing innovative materials processing research and development. MPC's Industry Collegium expands upon MIT's traditionally close liaison with industry by providing a direct link between materials science, engineering, and processing research at the university.

The collegium consists of domestic and international companies in a range of industries, from traditional structural materials to biomaterials. For member companies, the collegium provides broad access to MIT's materials community and one-on-one guided access to faculty, research staff, and students.

Collaboration with Industry

Fostering cooperative inquiry and experimentation in the cross-disciplinary area of materials science and engineering is the cornerstone of MPC. MPC strategy includes leveraging core federal research funding within the MIT materials community into expanded industrial-academic collaborations. Center research covers a broad range of materials and processes via a number of common themes. Foremost among them is the control of materials structure, properties, and performance in an ecologically and economically sound manner. Our philosophy focuses on understanding processing fundamentals to control internal structure, from the nanoscale to the macroscale, thereby optimizing a material's properties and performance.

MPC builds relationships with faculty by familiarizing itself with their current research projects, future interests, and resource needs; by bringing industries' materials and processing needs and interests to them; and by inviting them individually or in teams to collaborate with industry. MPC provides seed research program development funding to new faculty members and teams and assists with proposals, budgets, and the administration of research accounts. More than 50 faculty and senior research staff members have active research accounts in MPC. The faculty who have affiliation with MPC hail from nine departments in the Schools of Engineering; Science; and Humanities, Arts, and Social Sciences as well as the Sloan School of Management.

The Microphotonics Center (MPhC) is a subcenter of MPC and is supported by a 16-member industry consortium, whose members include Analog Devices, Corning, DuPont, ETRI, Fujifilm, Fujitsu, HP, IBM, Intel, Kotura, LioniX, National Semiconductor, NEC, Nortel, Siemens, and Soitec. The MPhC Consortium features the Communications Technology Roadmap (CTR) program and its industry-led Technology Working Groups (TWGs). The second phase of the CTR's groundbreaking program has now matured into the formation of three active TWGs: (1) cross-market applications; (2) CMOS (Si) platform; and (3) integration, packaging, and interconnect. TWG activities have helped to support the funding of three CTR fellows who work closely with each TWG, resulting in the authorship of white papers under the diligent direction of industry-based TWG

leaders. This effort has yielded a highly productive interaction between academics and industry in order to formulate a roadmap for the future of the microphotronics industry. So far, this initiative has involved 80 organizations from all over the world. The next roadmap document is scheduled for fall 2009. Highlights of the CTR report can be found at <http://mph-roadmap.mit.edu/>.

MPhC continues to assist in our nation's defense by working to advance emerging technologies that keep our armed forces at the forefront of military capability. The Air Force Office of Scientific Research (AFOSR) Multidisciplinary University Research Initiative (MURI) program in Silicon Lasers and Nanophotonics (in collaboration with seven other leading universities), completed the third year of its electrically pumped silicon-based lasers for chip-scale research program, funded by the MURI from the AFOSR. The AFOSR has approved funding its program extension phase, which will enable continued research beyond the third year.

Following completion of the Defense Advanced Research Projects Agency (DARPA) Electronic and Photonic Integrated Circuits (EPIC) program with BAE Systems and Alcatel-Lucent, two additional programs were awarded by the DARPA Microsystems Technology Office to MPhC in the past year. The first program, on athermal photonic circuits, is an effort to develop materials and photonic device design that is self-compensating for temperature variations leading to stable photonic device performance. The second awarded program is for a seedling effort using chalcogenide glass waveguides with ultralow loss properties of <0.002 dB/cm over a wide spectrum into the infrared range of 1.5 to 5.0 μm .

In addition, a one-year feasibility study funded by the Department of Defense helped to explore an ultradense photonic-electronic integration initiative involving MPhC, Computer Science and Artificial Intelligence Laboratory (CSAIL), and Sandia National Labs. This all-to-all-computing initiative had led to a critical mass of results under the ultraperformance nanophotonic intrachip communications program. A follow-on program has been funded by the DARPA Strategic Technology Office for continued research in this area involving CSAIL and MPhC. For more information about these and other programs, please visit <http://mphotronics.mit.edu/>.

Selected New Programs with Industry

MPC continues to support faculty research efforts with industry collaboration over a wide range of materials-science-based applications from metallurgical coatings for strength and corrosion resistance to integrated photonics, solar cells, and batteries. Recently completed research agreements include professor Chris Schuh with Mitsubishi Materials and professor Lionel Kimerling with Denso International.

Advancing Materials Research at MIT

MPC functions as a liaison between the cutting-edge materials research being performed here and other materials science, engineering, and processing interests within and outside of MIT. Interdisciplinary collaboration on research initiatives, graduate education, technology transfer, continuing education of industry personnel, and communication among industrial and governmental entities are MPC's priorities.

A major priority of MPC is outreach to new materials faculty and researchers at MIT as well as to the global materials community. MPC has more than seven visiting scientists, one visiting engineer, one visiting scholar, and 11 postdoctoral associates working within the center. The center is proactive in inviting faculty to participate in its research activities and educational programs, including developing new initiatives, symposia, seminars, and summer student internship projects.

Promoting Exchange of Knowledge

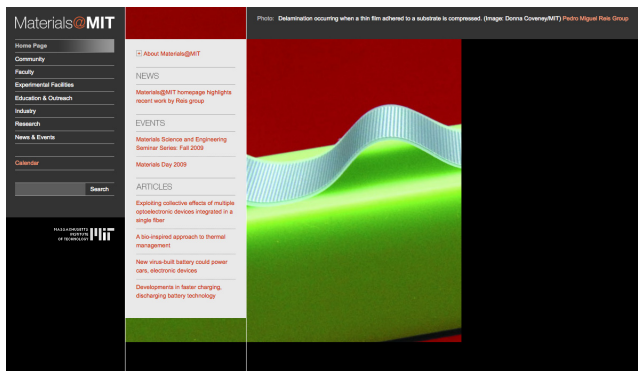
As part of the MIT community, the first priority of MPC is education of the next generation of materials processing research scientists, engineers, and leaders. To this end, MPC initiates programs to enhance the intellectual vitality of the materials processing community at MIT. We measure the value of these programs by the breadth of the materials arena they address, by the new and creative collaborations among faculty and students they catalyze, and by the degree of attention to the multidisciplinary nature of the materials science, engineering, and processing they generate.

MPC places great importance on publication in pursuit of its outreach goals. The internet is our main mode of information distribution. The MPC website includes document sharing, data sharing, event registration, survey administration, a resource reservation system, and a method of connecting MPC web users with each other. This year, the website was used as a tool to help put together several grant proposals. Since its launch on August 1, 2008, the new MPC website has received more than 20,700 visits, and 14,333 of those visits were from first-time visitors to the website. The visits come from 116 countries, the top five being the United States, China, India, Germany, and Japan. The document management system used for file sharing has logged more than 2,524 file downloads from the materials user community.

Another important outreach mechanism is poster sessions. In FY2009, MPC sponsored or cosponsored two poster sessions: the Summer Internship Poster Session (August 7) and the Materials Day Research Review Poster Session (October 15). MPC also partnered with the Center for Materials Science and Engineering (CMSE) and Department of Materials Science and Engineering (DMSE) to promote monthly seminar series featuring materials industry leaders.

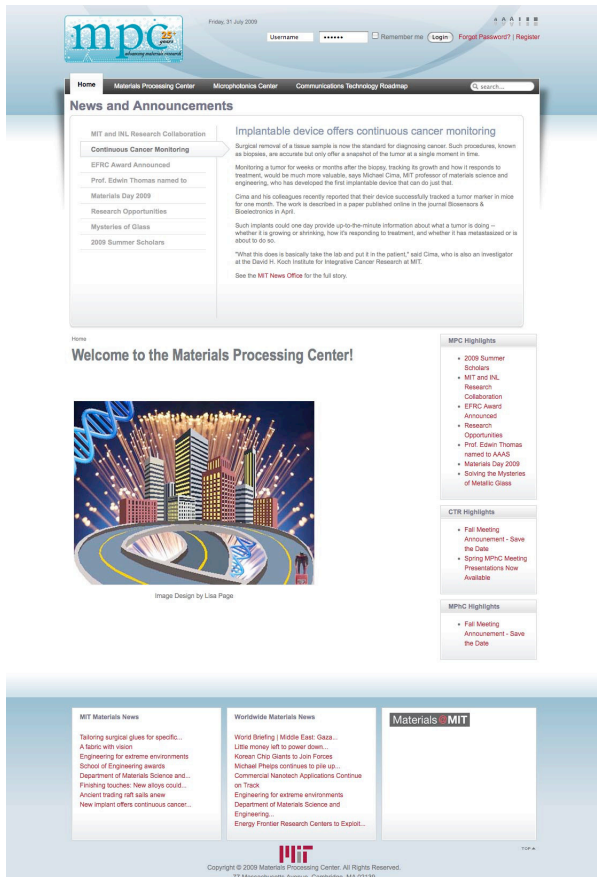
Materials@MIT Gateway

MPC continues to expand its collaborations with other materials-related centers across the campus to provide a common and guided gateway to the current maze of possibilities outside visitors face when approaching MIT with a materials interest. The [Materials@MIT](#) gateway web initiative (cosponsored by MPC, CMSE, and DMSE) actively encourages the participation of all campus organizations involved in materials research. This website has observed impressive international and local monthly traffic since its launch in FY2007. The increasing shift to online information transfer has catalyzed a more focused initiative utilizing this site as a campus-wide materials reporting resource. The website receives more than 18,000 visitors per year and more than 1,700 visitors per month, approximately 75% of which come from external web domains. Materials@MIT has become a highly successful portal for materials news and events within the MIT community. Faculties from several disciplines have availed



Screen capture of Materials@MIT homepage

themselves of the website's popularity, advertising well-received journal publications. The website has become a comprehensive repository of contact information for MIT start-up companies, MIT materials research centers, and shared experimental user facilities. A comprehensive listing of academic programs, K-12 outreach programs, and campus-wide research reports is available at this site in addition to a cross-departmental directory of faculty engaged in materials research.



Screen capture of MPC website homepage. Featured is a news and announcements segment, image from Course 3.003 Principles of Engineering Practice taught by professor Lionel C. Kimerling as well as worldwide materials news feeds and MIT materials news feeds.

Summer Research Internship Program

MPC does not limit its educational outreach to the MIT community. For 26 years, MPC has sponsored (now cosponsored with CMSE) a summer internship program for promising undergraduate researchers from other colleges and universities around the country. The MPC summer internship (a nine-week program from June 7 to August 8 of this year) is a National Science Foundation (NSF) Research Experience for Undergraduates (REU) that brings the best science and engineering undergraduates in the country to MIT for graduate-level materials research in the laboratories of participating faculty. The program culminates in a poster session held in Lobby 13, where students present their research to the MIT community.

The 2009 program involves 10 faculty and 10 bright, motivated students from schools including Columbia University, Penn State, University of Kansas, University of del Turabo (Puerto Rico), and St.



Summer scholars, 2008

John's University. Project areas include energy applications using multilayer assembly, development of conducting polymer actuators, nanostructure fabrication by using templated self-assembly, solar cells, and laser-assisted processing of sensor and actuator materials.

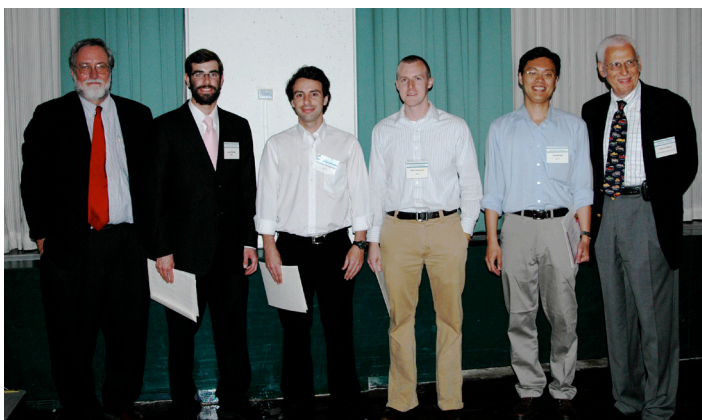
For more information about the MPC/CMSE REU summer internship in materials science, visit <http://mpc-web.mit.edu/>.

Materials Day

Sharing knowledge and insight with others in the materials science and engineering field can lead to new ideas, new collaborations, and new breakthroughs. Once a year, we invite the materials community to a celebration of all that has been accomplished over the past year. We call this celebration Materials Day, and it is used to honor and recognize important achievements and to talk about the future.

An autumn event, Materials Day highlights, in collaboration with CMSE, a daylong symposium on a featured topic, followed by a graduate student/postdoc poster session. The theme of the Materials Day 2008 symposium was "nanostructure to infrastructure to sustainability." The session chairs looked back at the 29-year legacy of MPC and how that widening focus has come to define an interdisciplinary hub of activity at MIT today. Professor Karl Berggren (Department of Electrical Engineering and Computer Science) chaired the session on nanostructures; professor Krystyn Van Vliet (DMSE) chaired the session on infrastructure; and professor Randolph Kirchain (DMSE) chaired the session on materials processing for sustainability.

Speakers included professor Edwin L. Thomas, department head and Morris Cohen professor, DMSE, "Top Down and Bottom Up Assembly of Nano and Micro Structures"; professor Darrel J. Irvine, DMSE, "Materials Design Across Multiple Length Scales to Interface with the Hierarchical/Structure of Biological Systems"; professor Brian L. Wardle, MIT Department of Aeronautics and Astronautics, "Literally Big Nano: Bulk Nanostructured Materials for Aerospace Applications"; professor Donald R Sadoway, DMSE, "Electrochemical Pathways for Sustainable Metals Production";



Materials Day 2008 Poster Session winners, from left to right, Carl V. Thompson, director, MPC; Fernando Vasconcellos; Kevin Krogman; Yu-Hua Kao; Dr. Ernest Littauer, Advisory Board member, MPC

professor Franz-Josef Ulm, MIT Department of Civil and Environmental Engineering, "What's the Matter with Concrete?"; professor Diran Apelian, Howmet professor of mechanical engineering, "Sustainable Development for the 21st Century: The Role of Materials Science and Engineering"; professor Jacqueline Isaacs, Northeastern University, Department of Mechanical and Industrial Engineering, "Responsible Nanomanufacturing:

Interdisciplinary Approaches to Sustainability"; Dr. Frank R. Field III, director of education, Technology and Policy Program, MIT "Sustainability of Materials Systems: Methods for Evaluating the Impact of Materials on Resource Efficiency"; and others.

Approximately 70 registered guests from industry, government laboratories, hospitals, MIT, and other universities attended the meeting; an additional 25–30 researchers and students from MIT joined throughout the day.

The poster session that immediately followed the panel presentations included 67 posters presented by graduate students/postdocs from departments including Chemical Engineering, Chemistry, Civil and Environmental Engineering, Electrical Engineering and Computer Science, Kavli Institute for Astrophysics and Space Research, DMSE, Mechanical Engineering, Nuclear Science and Engineering, and Physics. The posters are judged by a panel of representatives from industry as well as members from the MPC Advisory Board. Poster winners receive award certificates and \$500 prizes. The poster session winners were:

Ms. Nonglakk Meethong and Mr. Yu-Hua Kao, DMSE; faculty advisor, professor Yet-Ming Chiang; poster title, Nanoscale Olivine Compounds as High-Power Li-ion Battery Positive Electrodes for Transportation Applications; sponsors, United States Advanced Battery Consortium Project, Royal Thai Government Scholarship, and Taiwan Merit Scholarship.

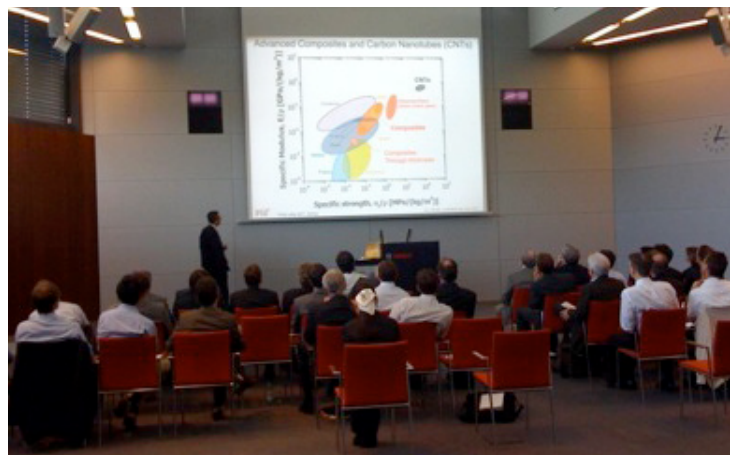
Mr. Fernando Vasconcellos and Mr. Albert Swiston, DMSE; faculty advisor, professor Michael Rubner; poster title, Functional Polyelectrolyte Multilayer Patches on Living Lymphocytes; sponsors, NSF CMSE, and CAPES, Brazil.

Mr. Kevin Krogman, Chemical Engineering; faculty advisor, professor Paula Hammond; poster title, Multifunctionalized Electrospun Materials for Toxic Chemical Protection; sponsor, Army Research Laboratory.

Materials Day 2009 is scheduled for October 7, 2009.

Materials Processing Center/Industrial Liaison Program Materials Workshop Stuttgart

MPC, in fulfillment of its mission to enable and facilitate outreach to the industrial community, organized a one-day workshop in Europe with the Industrial Liaison Program office at MIT to present and discuss the development and impact of nanostructure materials now and into the future. The meeting was hosted by Robert Bosch GmbH on June 2, 2009, at its research facility in Stuttgart, Germany, and featured presentations by five MIT faculty members including



Gerbrand Ceder, Richard P. Simmons professor of Materials Science and Engineering, MIT Department of Materials Science and Engineering, presenting "materials genome" project at MIT: Accelerated and Large-Scale Materials Discovery in the Energy Field

MPC director and DMSE professor Carl V. Thompson, DMSE professor Gerbrand Ceder, DMSE professor Francesco Stellacci, DMSE professor Harry Tuller, and Aeronautics and Astronautics professor Brian Wardle. More than 43 industry representatives registered and attended the event. Corporate participants included representatives from Robert Bosch, EADS, ThyssenKrupp, Metso, Shell Global Solutions, Draegerwerk AG, Daimler AG, Bayer Technology, E.ON Engineering, Sirius, Umicore Research, and Insamet.

The presentation team covered a wide range of subjects in the area of materials science and research but were all within a theme of "nanostructure to infrastructure" and focused on the impact of recent nanotechnology and computational advances on infrastructure-related materials development, including those for energy, aerospace, and resource remediation. Feedback received from the participants showed a general appreciation of organizing the event in their geographic region, making it much easier to participate in the event and looked forward to other opportunities for interaction.

Focus on Interdisciplinary Research Collaborations

During FY2008, MPC continued to focus on developing microphotronics projects through MPhC. MPhC conducts collaborative research focused on advancing basic science and emerging technology to enable the convergence of electronics and photonics. As a research community dedicated to optimizing interdisciplinary academic and industrial collaboration to advance basic science and precompetitive technology in areas relevant to applied microphotronics, MPhC engenders research and development cross-fertilization, leading to innovation. The vision of the MPhC is a future where the microphotronics platform enables enhanced information access, bandwidth, reliability, and complexity that extend the advance of silicon integrated circuit technology. This year, MPhC has focused on four research areas: microphotronics devices for CMOS integration, microphotronics systems, thin-film photovoltaic cells, and multiwavelength

detectors and sensors. MPhC research programs have continued to generate significant new intellectual property for their sponsors in FY2009.

In April 2009, the Department of Energy awarded two of its 46 multimillion-dollar EFRCs to MIT. The EFRC program plans to supply \$17.5 million to fund the S³TEC at MIT. The research center, which will be managed by MPC and directed by Gang Chen, the Warren and Townley Rohsenow professor of mechanical engineering and director of the Pappalardo Micro and Nano Engineering Laboratories, will start conducting research in August 2009. The center's objective is to create novel solid-state materials for converting sunlight and heat into electricity. MPC has already started working on creating the S³TEC website, which will be available after September 2009 and can be accessed at <http://s3tec.mit.edu/>.

"As global energy demand grows over this century, there is an urgent need to reduce our dependence on fossil fuels and imported oil and curtail greenhouse gas emissions," said US Secretary of Energy Steven Chu. "Meeting this challenge will require significant scientific advances. These centers will mobilize the enormous talents and skills of our nation's scientific workforce in pursuit of the breakthroughs that are essential to make alternative and renewable energy truly viable as large-scale replacements for fossil fuels."

International Partnerships with Industry and Government

The Iberian Nanotechnology Laboratory–MIT Program

MPC, in collaboration with the Microsystems Technology Laboratory, has begun a major new research program with the Iberian Nanotechnology Laboratory (INL), through the INL–MIT program. The two institutions will create MIT–INL, a new education and research enterprise focusing on nanotechnology. The collaboration will create 10 senior research positions for scientists, who will launch an aggressive new nanotechnology research agenda, and it will enable approximately \$35 million (25 million euros) of new sponsored research at MIT in its first five years. In May of this year, José Rivas, director-general of INL, and Subra Suresh, dean of the School of Engineering at MIT, formalized the agreement.

As described by INL council president Luis Magalhães, INL is the first nanotechnology laboratory in the world with international legal status and is designed to provide an environment that supports nanotechnology research in an open and flexible environment for researchers of any nationality to work together in world-leading projects. As part of the first step in the collaboration with MIT, the organizers of INL–MIT have selected a number of current MIT research projects, in the Microsystems Technology Laboratories and the MPC, to benefit from the INL structure. These projects include research on nanoparticles that can selectively adsorb water contaminants, autonomous microsystems that can move around water supplies and sense contaminants (while sustaining themselves on power scavenged from their environments), new materials for energy storage, revolutionary tools and technologies for monitoring our food supply, and others.

MIT–Tohoku University Workshop

The technical exchange and collaboration between MIT and Tohoku University about applications of carbon nanotubes (CNTs) was the main focus of this workshop. The workshop, scheduled on September 23–24, 2008, which included a full agenda and laboratory tours, gathered students from MIT and students from Tohoku University to discuss electronic characteristics of CNTs. The aim of Tohoku University research is to develop highly sensitive strain sensors using CNT-dispersed resin. Students focused on the analysis of electronic conduction of CNTs under strain based on quantum chemical molecular dynamics and the production of the sensors as an experiment.

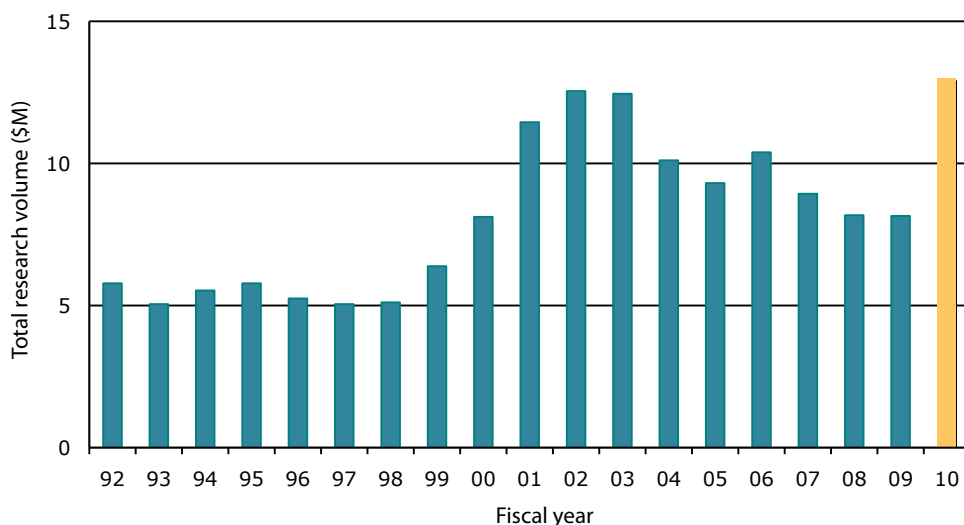
Singapore–MIT Alliance

The Singapore–MIT Alliance (SMA) serves as an intellectual hub for interactions between MIT and global researchers in the areas of science and technology. This alliance allows faculty, researchers, and graduate students from MIT to collaborate with their counterparts from universities, polytechnics, research institutes, and industry in Singapore and Asia. MPC faculty have been heavily involved in the program in advanced materials for micro- and nanomaterials, cochaired by MPC director, professor Carl V. Thompson. Through the leadership of professor Eugene A. Fitzgerald, MPC faculty are currently developing plans for future programs with an energy focus.

Research Volume

MPC and MPhC total expenditures were \$9 million in FY2009 (see Figure 6). Our five priority research areas are medical materials, photonics, energy, environment, and nanotechnology. Campus materials research volume across MPC, CMSE, Institute for Soldier Nanotechnologies, and DMSE reached nearly \$35.5 million for FY2009.

Figure 6. MPC research volume, FY1992–2009 and projected volume for FY2010.



MPC researchers are sponsored not only by a variety of companies but also by nearly every major federal research-sponsoring agency, including the NSF, the Department of Energy, the National Institutes of Health, Office of Naval Research, Department of Defense, and AFOSR.

Outlook

The center amplified its role in supporting a wide range of interdisciplinary research on materials through development of new services for faculty and new outreach activities. This support of the broad range of materials research at MIT is complemented by development of focused research activities in specific areas of key materials technology. Professor Michael Cima's Ceramic Processing Research Laboratory continues to support innovative, high-impact research in biotechnology, pioneering in the application of an engineering perspective to problems in health. Under professor Lionel Kimerling's leadership, the center has also come to be recognized for its leading research in microphotonic materials and systems. MPhC continues to drive a collaboration among industry leaders in creating a roadmap for development of microphotonics technology. This position of leadership is likely to be supported by a significantly expanded research funding base in the near future.

Over the past year, MPC has also targeted new areas of focused research, including materials for energy, computational materials, and infrastructure materials. Our focus on materials for energy is off to a great start with professor Gang Chen's ERFC, sponsored by the Department of Energy, and Professor Tuller's project on chemomechanics of far-from-equilibrium interfaces. In the coming years, these government-sponsored research programs will attract interest in collaboration and complementary research support by industry. Funding in the area of energy technology is also likely to continue to increase, given the US government's focus on this area of national need.

International collaborations are also a new focus for MPC. They have been boosted by the center's key role in the new INL-MIT program. MPC faculty have been deeply involved in the SMA and will seek modes of continued collaboration with Singapore universities, national laboratories, and industry as the SMA program winds down. We also anticipate expanded collaborations and research agreements with top universities in Europe and Asia.

Perhaps most importantly, MPC has begun a process that will lead to a formal merger with the CMSE to form an entity that promotes interdisciplinary research on materials at MIT. Through this merger, and through expanded collaborations with other centers and laboratories, such as the Microsystems Technology Laboratory, this new organization will be able to better serve MIT's broad and growing materials community, advocating for common needs for improved research infrastructure, and supporting rapid growth of new research activities of national and international importance.

Carl V. Thompson

Director

Professor of Materials Science and Engineering

Stavros Salapatas Professor of Materials Science and Engineering

More information about the Materials Processing Center can be found at <http://mpc-web.mit.edu/>.

More information about the Microphotonics Center can be found at <http://mphotronics.mit.edu/>.