# 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 30th 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 and 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.

## Creating New Knowledge: Selected New Research Programs

During FY2010, MPC worked to identify opportunities for environmentally sustainable materials design and processing for infrastructure used in energy generation and storage, transportation, construction, and communications. Major proposals that culminated in awards include:

Donald Sadoway, John F. Elliott professor of materials chemistry, was awarded funding from Advanced Research Projects Agency–Energy ($6.9M over three years) by the Department of Energy (DOE) to conduct research on liquid metal grid-scale batteries. The project was described by DOE as a technology that "could revolutionize the way electricity is used and produced on the grid, enabling round-the-clock power from America's wind and solar power resources."

## 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. It 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. MPC collegium membership remained stable this year, despite continued economic challenges.

## 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. MPC's 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 becoming familiar 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 17-member industry consortium. Consortium members include: Advanced Micro Devices, Alcatel-Lucent, Analog Devices, Corning, Electronics and Telecommunications Research Institute, Fujitsu, Hewlett Packard, International Business Machines, Intel, Kotura, LioniX, National Semiconductor, Nippon Electronics Corporation, Optitec, Siemens, Silicon On Insulator Technologies, and XIO Photonics. The MPhC consortium features the communication technology roadmap (CTR) program and its industry-led technology working groups (TWGs). Leadership of the consortium is directed by the MIT staff and by one representative of each member company, forming the board of directors. Phase II of CTR's groundbreaking program was completed in 2009, culminating in the publishing of the second roadmap. Highlights of the CTR report can be found at http://mph-roadmap.mit.edu/. Organization of the roadmapping effort originally began with the formation of three TWGs: (1) cross-market applications, (2) complementary metal-oxide-semiconductor (Si) platform, and (3) integration, packaging, and interconnect. TWG activities helped to support the funding of three CTR fellows who work closely with each TWG, resulting in the authorship of white papers under the direction of industry-based TWG leaders. This effort has yielded a highly productive interaction between academia and industry, in order to formulate a roadmap for the future of the microphotonics industry. CTR Phase III is now well underway, with a growing membership and a new structure for engagement and deliverable work products. Shifting from a four-year, 200-page document, CTR III will publish shorter, more frequent white papers on a revolving timeline to better match the industry cadence of a typical product cycle.

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 fourth year of its electrically pumped silicon-based lasers for chip-scale research program, funded by MURI from AFOSR. AFOSR has approved funding its program extension phase, which will enable continued research beyond the fourth year.

MPC continues its support of two ongoing programs awarded by the Defense Advanced Research Projects Agency (DARPA) microsystems technology office to MPhC. 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.

Prior work on a one-year feasibility study funded by the Department of Defense on an ultradense photonic-electronic integration initiative involving MPhC, the Computer Science Artificial Intelligence Laboratory (CSAIL), and Sandia National Laboratories has led to a program awarded to professor Anant Agarwal of CSAIL by DARPA's information processing technology office/strategic technology office. The all-to-all-computing initiative had led to a critical mass of results under the ultraperformance nanophotonic intrachip communications program. The scope of this newly funded research program includes all original members of the feasibility study, and includes material and device research on integrated photonics circuits. For more information about these and other programs, please visit http://mphotonics.mit.edu/.

MPC completed its first year supporting $S^3$TEC, a DOE Office of Basic Energy Sciences sponsored EFRC, led by professor Gang Chen. The center is a multidisciplinary effort including leading researchers from Physics, Chemistry, Materials Science and Engineering (DMSE), Electrical Engineering and Computer Science (EECS), and Mechanical Engineering. The research focus of the center has application in the use of solar and other heat sources in conversion to electrical energy. The scientific research is based on three major areas: (1) the study and control of photons for solar thermoelectric and thermophotovoltaics, (2) understanding electron and phonon transport, and (3) high temperature reliability. The core activities of the center are focused on the investigation and development of thermoelectric materials, the collection and conversion of heat energy into electrical energy, and thermophotovoltaics for high-efficiency energy conversion of solar energy into electricity. Key to the energy conversion process is the ability to understand phonon transport processes in these materials combined with the design and fabrication of highly selective surfaces to serve as efficient photon emitters in the case of thermophotovoltaic systems. Investigation of the material systems requires use of unique and adapted characterization tools such as thermoreflectance and acoustic wave and phonon tomography at Oak Ridge National Laboratory (ORNL).

Based at MIT, the center includes partnerships with Boston College and ORNL and supports the research efforts of 12 principal investigators from multiple academic disciplines, and student and post-doctoral members assigned from their research teams. The center was officially launched in August for a five-year period based on meeting annual reporting requirements. The goals of this research center would enable highly efficient harvesting of heat energy from multiple high temperature processes such as power plants, chemical plants, and engines as in turbines and automobiles, in addition to realizing more efficient collection of the full solar energy spectrum into usable, sustainable green energy. Additional information about $S^3$TEC can be found at http://s3tec.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. MPC supports many ongoing research programs with faculty, including professor Christopher Schuh's research with Mitsubishi Materials Corporation. Recently completed research agreements include professor Lionel Kimerling's new programs with Chanel, and a separate multicenter program including faculty from CSAIL and the Research Laboratory of Electronics on integrated photonics with Advanced Phonotics Integrated Circuits Corporation.

## Advancing Materials Research at MIT

MPC functions as a liaison between the cutting-edge materials research being performed at MIT and other materials science, engineering, and processing interests within and outside 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 focus 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, seven visiting engineers, one visiting scholar, and 20 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, MPC's first priority is the 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. MPC measures 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.

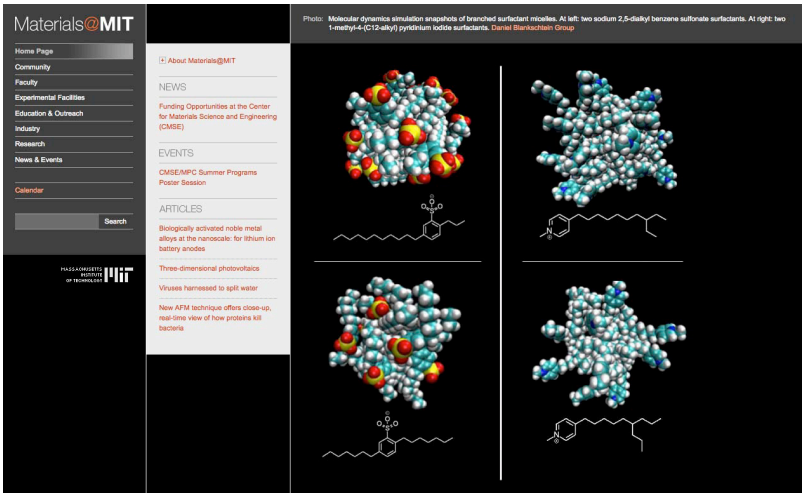
MPC places great importance on publication in pursuit of its outreach goals. The internet is its main mode of information distribution. The MPC website includes document sharing, data sharing, event registration, survey administration, a resource reservation system, and a method of connecting MPC web users with each other. Since its launch in August 2008, the new MPC website has received more than 43,679 visits, and 29,877 of those visits were from first-time visitors to the website. The visits come from 133 countries, the top five being the US, China, India, Japan, and Germany. The document management system used for file sharing has logged more than 11,864 file downloads from the materials user community.

Another important outreach mechanism is poster sessions. In FY2010, MPC sponsored or cosponsored two poster sessions: the summer internship poster session, in August, and the Materials Day research review poster session, in October. MPC also partnered with the Center for Materials Science and Engineering (CMSE) and DMSE to promote monthly seminar series featuring materials industry leaders. MPC also took part in the Photonic Integrated Circuits theory and practice tutorial series, which featured 10 webinars by a distinguished lecturer.

## 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 faced by outside visitors 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 the site as a campus-wide materials reporting resource. The website receives more than 11,170 visitors per year and more than 895 visitors per month, approximately 51 percent 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 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, materials news articles segment as well as worldwide materials news feeds and MIT Materials news feeds.*




*Screen capture of the Materials@MIT homepage.*

## Summer Research Internship Program

MPC does not limit its educational outreach to the MIT community. For 27 years, MPC has sponsored (now cosponsored with CMSE) a summer internship program for promising undergraduate researchers from other colleges and universities throughout the country. The nine-week MPC summer internship is a National Science Foundation (NSF) research experience for undergraduates 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.


*2009 Summer Scholars.*

The 2010 program involves 14 faculty and 14 students from schools including Cornell University, West Virginia University, the University of Minnesota–Twin Cities, the University of del Turabo (Puerto Rico), and North Carolina State University. Project areas include carbon nanotube (CNT) nanostructures, copolymers, colloidal nanoparticles, antimicrobial polymer coatings, super hydrophobic surfaces, thermoelectric analysis of alloys, thermopower waves in CNTs, superconducting nanowire, and implantable oxygen sensors.

For more information about the MPC/CMSE research experience for undergraduates 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, MPC invites the materials community to a celebration of all that has been accomplished over the past year. This celebration is called 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/postdoctoral associate poster session. The theme of the Materials Day 2009 symposium was "materials for energy," and the event looked back at the 30-year legacy of MPC and how a widening focus has come to define an interdisciplinary hub of activity at MIT today. Nine presentations were made over the course of the day from both MIT faculty and industry professionals, drawing a standing-room-only crowd of nearly 180 attendees.

Speakers included Dr. Daniel Cunningham, BP Solar (New Materials for PV [Photovoltaic] Modules: Cost, Performance and Reliability); Professor Chen (Nanostructured Heat Transfer and Energy Conversion Materials); Dr. Andrew Kim, Philips Lumileds (Progress and Challenges in Solid State Lighting); professor Marc Baldo, EECS (What's Exciting about Excitonics?); Professor Harry Tuller (Nanostructured Materials for Next Generation Fuel Cells); Professor Gerbrand (The Materials Genome: Accelerated and Large-Scale Materials Discovery in the Energy Field); Dr. Bart Riley, A123 Systems (A123 Systems Li-ion Batteries: From Nanotech to Reality); Sean Dalton, Highland Capital Partners (Creating and Funding Startups: A Venture Capital Perspective); and others.

The day ended with dinner and an address given by keynote speaker professor Roberto Rigobon, Sloan School of Management. His presentation, Financial Crisis, Energy, and World Sustainability, was well-received by the over 100 attendees. Approximately 107 registered guests from industry, government laboratories, MIT, and other universities attended the meeting; an additional 66 researchers and students from MIT joined throughout the day.

The poster session that immediately followed the panel presentations included over 70 posters presented by graduate students and postdoctoral associates from departments including Chemical Engineering, Chemistry, Civil and Environmental Engineering, EECS, 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:

> Stop-flow Lithography: A Platform for Novel Particle Synthesis
> Priyadarshi Panda, Chemical Engineering
> Advisor: Patrick Doyle

Luminescent Solar Concentrators
Carlijn Mulder, EECS
Advisor: Marc Baldo

"Backpack" Functionalized Living Immune Cells
Albert Swiston, DMSE
Advisors: Darrell Irvine, Robert Cohen, and Michael Rubner


*Materials Day 2009 Poster Session Winners, from left to right: Albert Swiston (DMSE), Priyadarshi Panda (CE), Dr. Ernest Littauer, Advisory Board Member, MPC. Carlijn Mulder (EECS), Mark Beals, Associate Director, MPC and Carl V. Thompson, Director, MPC.*

Materials Day 2010 is scheduled for October 13, 2010.

## Focus on Interdisciplinary Research Collaborations

During FY2010, MPC continued to focus on developing microphotonics 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 microphotonics, MPhC engenders research and development cross-fertilization, leading to innovation. The vision of MPhC is a future where the microphotonics 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: microphotonics devices for complementary metal-oxide-semiconductor integration, microphotonics 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 FY2010.

In August, Professor Chen, director of the Pappalardo Micro and Nano Engineering Laboratories, started conducting research with funds awarded by the DOE–EFRC

program. The program plans to supply $17.5M to fund S$^3$TEC at MIT. The center will be managed by MPC and the objective is to create novel solid-state materials for converting sunlight and heat into electricity.

"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."

For more information about the S$^3$TEC center go to http://s3tec.mit.edu/.

## International Partnerships with Industry and Government

### The Iberian Nanotechnology Laboratory–MIT Program

MPC, in collaboration with the Microsystems Technology Laboratory (MTL), has begun a major new research program with the Iberian Nanotechnology Laboratory (INL). 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 $35M (25M euros) of new sponsored research at MIT in its first five years.

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, the organizers of INL–MIT have selected a number of current MIT research projects, in MTL and 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.

### Singapore–MIT Alliance

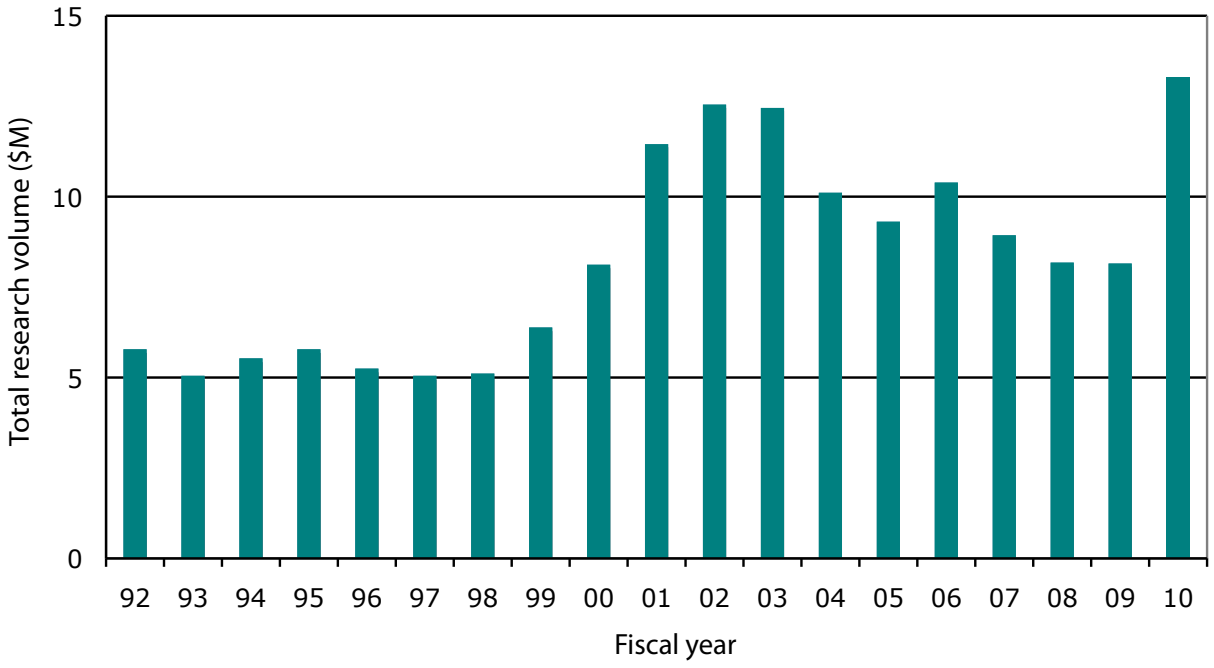
The Singapore–MIT Alliance (SMA) serves as an intellectual hub for interactions between MIT and global researchers in the areas of science and technology. The alliance allows faculty, researchers, and graduate students from MIT to collaborate with their counterparts from universities, polytechnics, research 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 Carl Thompson. Through the leadership of professor Eugene Fitzgerald, MPC faculty are currently developing plans for future programs with an energy focus.

## Research Volume

MPC, EFRC, and MPhC total expenditures were $15M in FY2010. The 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 $44.5M for FY2010.

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

**MPC Research Volume, FY1992–FY2010.**




## Outlook

MPC 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 Convergence Products 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 Kimerling's leadership, MPhC 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. Its focus on materials for energy includes Professor Chen's EFRC, sponsored by DOE, 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 SMA and will seek modes of continued collaboration with Singapore universities, national laboratories, and industry as the SMA program winds down. MPC also anticipates 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 alliance with CMSE to form an entity that promotes interdisciplinary research on materials at MIT. Through this alliance, and through expanded collaborations with other centers and laboratories, such as MTL, 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**
**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://mphotonics.mit.edu/.*

*More information about the Solid State Solar Thermal Energy Conversion Center can be found at http://s3tec.mit.edu/.*

*More information about the Crystal Physics and Electroceramics Laboratory can be found at http://electroceramics.scripts.mit.edu/.*