Materials Processing Center/Microphotonics Center

This report discusses the FY2007 activities of the Materials Processing Center (MPC) and its major affiliate, the Microphotonics Center (MPhC). The MPC is an interdisciplinary center within MIT's School of Engineering; the MPhC is a center within the MPC. They share an overlapping staff in a common headquarters space. During FY2007, the staff numbered seven, led by the director, professor Lionel Kimerling (Department of Materials Science and Engineering).

About the Materials Processing Center

The MPC exists to create opportunities for industry and government to take advantage of the wealth of exciting materials science and engineering research taking place at MIT. From better batteries and stronger metals to integrated optical communication processors, materials science and engineering at MIT remains at the cutting edge.

As one of the leading research universities in the world, MIT is fertile ground for materials innovation. With a plethora of impressive ideas and breakthroughs, MIT routinely leads among US universities in patents granted. The sheer volume of new knowledge generated at MIT can be overwhelming. When a company or federal agency has an interest in materials innovation, the MPC acts as a guide to information, facilities, and researchers relevant to the particular needs of that organization.

One key advantage of the MPC is its structure as a "virtual center," without facilities, laboratory space, or equipment as such; its function is to bring people and resources together in an "intellectual space" to examine problems and pursue opportunities with a science-to-systems approach. With its finger on the pulse of all things materials related at MIT, the MPC is able to assemble faculty resources and leverage existing knowledge to help companies and federal agencies address their challenges and create opportunities.

The MPC/MPhC 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 MPC maintains relationships with the Center for Materials Science and Engineering (CMSE), the Department of Materials Science and Engineering (DMSE), the Institute for Soldier Nanotechnologies (ISN), the Industrial Liaison Program (ILP), the Research Laboratory of Electronics (RLE), the Materials Systems Laboratory (MSL), the Microsystems Technology Laboratory (MTL), the Media Lab, and the Computer Science and Artificial Intelligence Laboratory (CSAIL). The Materials@MIT gateway web initiative (cosponsored by MPC, CMSE, and DMSE) is actively encouraging the participation of all campus organizations involved in materials research. This website has observed impressive international and local monthly traffic since it was launched 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.

Over 25 Years of Service to the Institute

In October 2006, during the MPC's flagship Materials Day event, the center looked back on its legacy as an entrepreneurial entity, celebrating 26 years of vigorous research activities that have spawned academic–industry partnerships—ranging in geography from the local (Cambridge, MA) to the distant (Milano, Italy).

Established in 1980 with support under a NASA Center of Excellence grant, the MPC initiated with a metallurgy focus under the stewardship of its founding director, Professor Merton C. Flemings. With the arrival of the center's second director, Professor Kent Bowen, the MPC's vision widened to address the development of advanced ceramic materials during the 1980s. By the time of its fifth and current director, Professor Lionel C. Kimerling, the MPC's research activities have been organized into six industry sectors (electronics, transportation, primary materials, construction, energy, and biomaterials) and have expanded to include all four primary material fields (metals, ceramics, semiconductors, polymers) and spawn a sister center, the MPhC, to address the joint industry–academia effort to roadmap a major 21st century technology: semiconductor-based photonics.

In the course of its first 25 years of activity, the MPC has, in conjunction with the ILP and the Industry Collegium, pioneered the establishment of a foundation for interdisciplinary research collaborations and pedagogy at MIT.

About the Microphotonics Center

The primary focus of the MPhC is the interdisciplinary convergence of electronics and photonics. In addition to several traditional research programs with individual companies, recent MPhC accomplishments include two major federal programs, collaboration with CSAIL and Sandia National Laboratories, and a second phase of the MPhC Consortium's Communications Technology Roadmap.

Federal Programs

The MPhC proudly assists in our nation's defense by working to advance emerging technologies that keep our armed forces on the forefront of military capability. Two major Department of Defense (DoD) programs, the BAE Systems-led Defense Advanced Research Projects Agency (DARPA) Electronic and Photonic Integrated Circuits (EPIC) program (in collaboration with Lucent, Cornell University, and Columbia University) and 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), are currently under way through the MPhC.

In addition, a DoD-funded one-year feasibility study helped to explore an ultradense photonic-electronic integration initiative involving the MPhC, CSAIL, and Sandia National Laboratories. This all-to-all-computing (ATAC) initiative had led to a critical mass of results, under the Ultraperformance Nanophotonic Intrachip Communications program.

MPhC Consortium

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) tntegration, 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 to formulate a roadmap for the future of the microphotonics industry. So far, this initiative has involved 70 organizations from all over the world. Highlights of the CTR report can be found at http://mph-roadmap.mit.edu/about_ctr/report2005/.

About the MPC Industry Collegium

For the past quarter century, the MPC has acted as a hub for cooperation among the many MIT researchers exploring materials science issues from the perspectives of their individual academic specialties. The knowledge and experience of the MPC helps to open up the breadth of the MIT materials community to industry and government interests in materials science. The personal attention and guidance of the MPC can provide invaluable assistance to any enterprise seeking a solution to an issue or an opportunity in materials science, engineering, or processing.

When people from industry want to explore innovative materials processing research ongoing at MIT, the MPC Industry Collegium is an indispensable tool. Expanding on MIT's traditionally close ties with industry, the collegium provides a direct link between the MIT materials community and the short-, medium-, and long-term needs of its member companies.

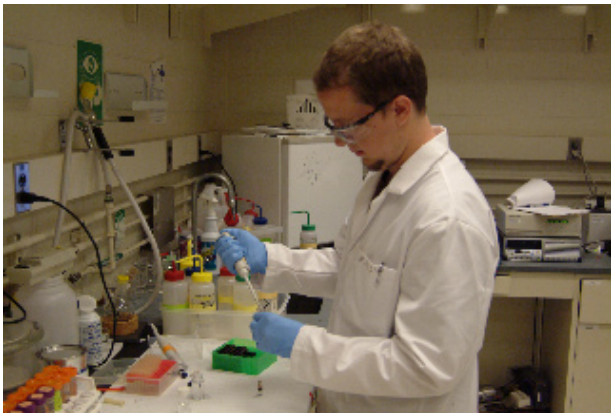
The collegium consists of domestic and international companies in a range of industries, from traditional structural materials to biomaterials. For member companies, the collegium provides both broad access to MIT's materials community and one-on-one guided access to faculty, research staff, and students. For more information about the Industry Collegium, please visit http://mpc-web.mit.edu/about_mpc/industryColl.php.

Advancing Materials Research at MIT

The 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 the MPC's priorities.

During the course of FY2007, the faculty involved with MPC have contributed a number of key discoveries and insights. Professor Christopher Schuh has demonstrated the synthesis of nickel-tungsten alloys whose structure can be controlled at the nanometer scale, imbibing the materials with properties superior to chromium platings. This work has led to the development of a Massachusetts-area start-up company, Xtalic. Professor

Michael Rubner's lab has developed a polymer thin film with superhydrophilic properties, making it possible to design fog-resistant coatings for optical lenses. Professor Michael Cima has been awarded, in collaboration with a number of MIT and Harvard University faculty, an MIT-Harvard Center of Cancer Nanotechnology Excellence grant of $20 million spread over a five-year period. Professor Xiao-Gang Wen has received a grant from the Foundational Questions Institute to study the fundamental relationship between quantum mechanics and gravity. Professor Silvija Gradecak has recently joined the DMSE faculty from Harvard and begun to develop nanowire heterostructures in collaboration with the laboratory of professor Eugene Fitzgerald. Such structures will enable the creation of ultra-low-threshold lasers in the visible and infra-red emission spectrum. The dynamic research environment at MIT fosters creativity and innovation, leading to inventions heretofore considered "the stuff of dreams." MIT researchers aim high; that drive and talent are available to assist not only other researchers around the world but also industry, our nation, and our planet. Behind the scenes, MPC is helping faculty to perform that research and helping to pair the science with its potential applications and sponsors.



MPC/CMSE Research Experiences for Undergraduates summer scholar Randy Carney (undergraduate at the Department of Chemistry, University of Arkansas) performs research in the laboratory of DMSE professor Franceso Stellacci during summer 2006.

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

Vertical Integration

The secret to MPC's success is taking the science and moving it with a vertically integrated team up to the systems level. Materials innovation and process innovation, already interdisciplinary since the field's inception, are at the center of an even broader interdisciplinary activity. There is a paucity of leaders who can comfortably and accurately plan "atoms-to-commerce" visions, developing system-level value that originates from atoms, molecules, and materials. The emergence of vertically integrated thinkers on the revenue side (i.e., some traditional sources of research financing in government and industry) needs to be encouraged and placed on a firmer pedagogical foundation.

As an organization dedicated to building community and interdisciplinary cooperation, the MPC must embrace these changes to create maximum opportunity for students and professors. This requires the MPC to continue to provide technology leadership and information consolidation to an even broader population. Traditionally, the MPC

has been an interface for industry to the MIT community. Today the MPC is becoming an interface for systems integrators (industrial and government) to gather information about bottom-up opportunities in general. This is a significant shift in role, and the MPC community has responded well. Recent programs have followed a new path in which the MPC is a consolidator of information and technology leadership not only across MIT but across other universities, equipment suppliers, materials suppliers, and outsourced research and development contract facilities.

MPC History and Mission

The MPC was established 25 years ago in response to a recognized national need to improve the knowledge base and streamline technology transfer in the field of materials science and engineering. Materials science traverses all the physical sciences. Materials processing, as the MPC defines it, covers a full range of types of materials and crosses traditional departmental and school boundaries.

The MPC mission is to provide an environment in which 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

- unites the MIT materials community,
- creates new knowledge,
- produces knowledgeable people, and
- promotes the exchange of knowledge in the service of our country and in the context of the global community.

Uniting the Materials Community

With dozens of faculty members and research staff doing materials research at MIT, multiple centers devoted to promoting or performing materials research, and hundreds of graduate and undergraduate students, the materials community at MIT is a vibrant, diverse group. We are united as a community in that we are all committed to advancing materials science, engineering, and processing. However, to grow as a community and truly leverage our collective intellectual resources, it is vital to connect with each other in more ways than simply through a broad common goal. The MPC creates opportunities for the materials community to come together—in research, in education, and in celebration.

MPC and CMSE administrators collaborating on the summer research internship. Left to right: MPC associate director George Kenney, MPC administrative officer Jonathan Bartels, CMSE director Michael Rubner.

The MPC interacts with materials-related centers on campus, such as CMSE, ISN, RLE,

MSL, MTL, the Media Lab, and CSAIL. The MPC maintains a close relationship with DMSE and works closely with the ILP, providing specific guidance to companies with materials-related needs.

Our ongoing strategy is to improve our position as an information resource for the campus community and portal for consortium/collegium member companies. With our program sponsors and research alliance partners, our key value continues to be our building of interdisciplinary faculty teams for tackling new areas of intellectual activity.

Materials@MIT Gateway Web Initiative

The MPC has partnered with CMSE and DMSE to launch the Materials@MIT gateway initiative. During FY2007, Materials@MIT has become an Internet gateway to the breadth of the materials research community at MIT. The website averages 4,000 visitors per month, approximately 75 percent of whom come from external web domains The website was launched in fall 2006, commemorating the 25th anniversary of the founding of the MPC, during Materials Day. Materials@MIT has become a highly successful portal to materials news and events within the MIT community. Faculties from several disciplines have taken advantage 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 are available at this site, in addition to a cross-departmental directory of faculty engaged in materials research. Some summarizing statistics that illustrate web activity at Materials@MIT are:

- The website averages 4,000 visitors per month.
- Approximately 75 percent of website visitors come from external web domains.
- Approximately 25 percent of website visitors come from educational domains.
- The most frequent international website visitors come from Germany, India, France, Japan, and Brazil.

The participation of any and every materials-related organization on campus will be welcomed and encouraged.

The second phase of website development is now being outlined, wherein the website will function as a proactive online resource for expanding the availability of faculty research reports in a more dynamic, centralized model—one that dispenses with the annual cycle of one activity report every 12 months. This new online model for faculty research reports will mark a definitive shift from MPC's traditional print publication, *Materials Research at MIT*, a research digest on MIT and MPC-affiliated faculty work in materials processing. The second website development phase for Materials@MIT is currently being pursued by the MPC, CMSE, and DMSE.

Creating New Knowledge

Focus on Interdisciplinary Research Collaborations

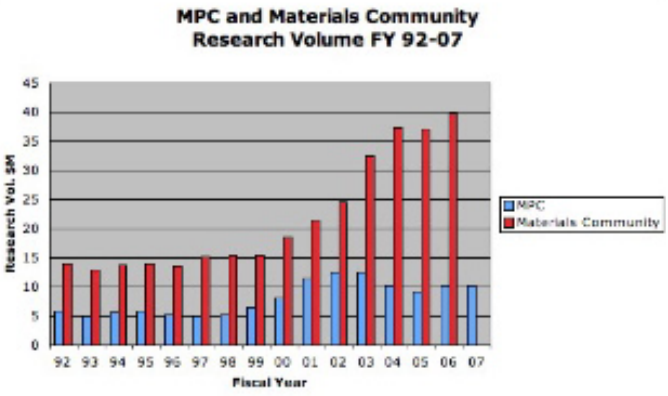
Fostering cooperative inquiry and experimentation in the cross-disciplinary area of materials science and engineering is the cornerstone of the MPC. The MPC strategy includes leveraging core federal research funding within the MIT materials community into expanded industrial–academic collaborations. 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 an understanding of processing fundamentals to control internal structure, from the nanoscale to the macroscale, thereby optimizing a material's properties and performance.

The 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. The MPC provides seed research program development funding to new faculty members and teams and assists with proposals, budgets, and the administration of research accounts. During FY2006, more than 50 faculty and senior research staff members had active accounts in the MPC. The faculty who have had some affiliation with the 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.

During FY2007, the MPC continued to focus on the development of microphotonics projects through the MPhC. The 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, the MPhC engenders research and development cross-fertilization leading to innovation. The vision of the MPhC is a future where the microphotonics platform enables enhanced information access, bandwidth, reliability, and complexity that extend the advance of silicon IC technology. The MPhC has several major research thrusts in addition to individual faculty members' research. MPhC research programs have continued to generate significant new intellectual property for their sponsors in FY2007.

Research Volume

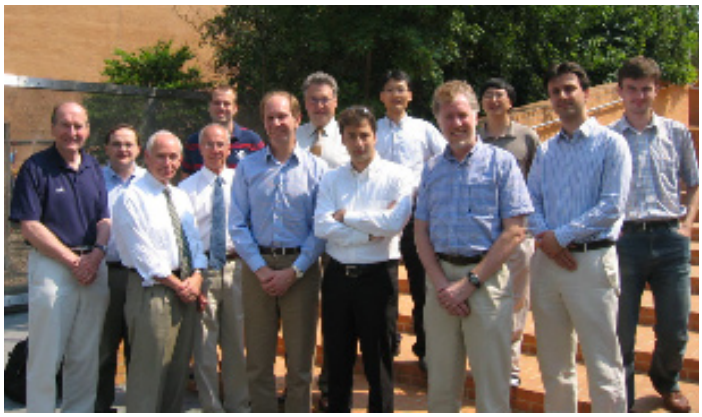
MPC and MPhC total research expenditures were $10.2 million in FY2007. In addition, the MPC supports a secondary research volume of nearly $400,000 to other centers. Our five priority research areas are medical materials,



MPC and materials community research volume, spanning fiscal years 1992–2007.

photonics, energy, environment, and nanotechnology. Campus materials research volume across the MPC, CMSE, ISN, and DMSE has steadily increased each year since 1999, reaching nearly $39.8 million for FY2006.

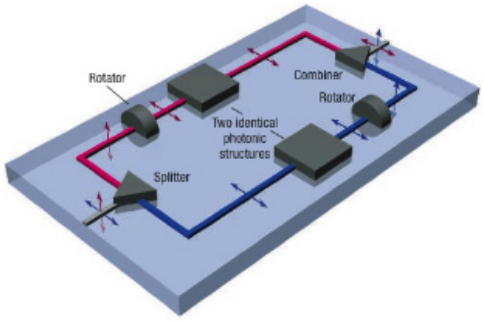
MPC researchers are sponsored not only by a variety of companies but also by nearly every major federal research-sponsoring agency, including the National Science Foundation (NSF), Department of Energy, National Institutes of Health, Office of Naval Research, DoD, and AFOSR.



Faculty and staff photo of collaborators in the Pirelli-MIT Alliance, which drew to a conclusion during FY2007. First row, left to right: Professor Henry I. Smith (EECS), Professor Franz Kaertner (EECS), Professor Lionel C. Kimerling (DMSE), Professor Erich P. Ippen (EECS), Dr. Marco Romagnoli (Pirelli), Dr. Luciano Socci (Pirelli), Dr. Jurgen Michel (DMSE), Milos Popovic, Anatoly Khilo. Second row, left to right: Dr. Peter Rakich, Mark Beals (MPhC associate director), J. Hyung (DMSE), Dr. Jifeng Liu (DMSE).

Industry Programs: Pirelli–MIT Alliance

During FY2007, a major five-year industrial partnership between the Pirelli Group and the MPhC came to its conclusion. Between spring 2002 and fall 2006, the Pirelli-MIT Alliance transferred close to $6.5 million to MIT faculty in an iteratively streamlined model—starting with eight faculty in 2002 and ending with three in 2006. This industrial alliance sought to develop novel devices, materials processes for them, and an integrated process flow that combined them onto a silicon platform to realize a reconfigurable optical add/drop multiplexer (ROADM). The project focused on developing a methodology to deal with optical fiber communications within a planar optical chip: the separation of an optical fiber's polarization states into two orthogonal modes for parallel signal processing. The resulting integrated circuit was experimentally demonstrated to function as a polarization transparent processor; the performance of this circuit was so successful that the Pirelli group is now moving into an active development phase with the program at their clean room production facility in Milano, Italy. The alliance concluded with a wrap-up meeting this July at MIT.



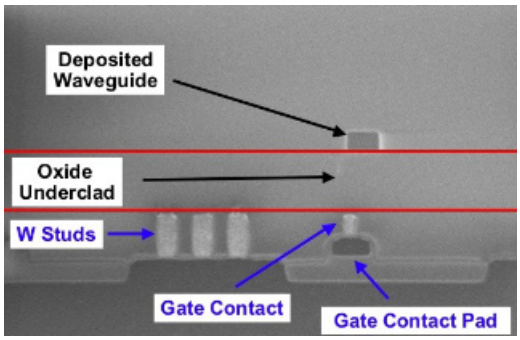
Schematic illustrating function of Pirelli-MIT Alliance ROADM. A mixed polarization signal from an optical fiber is split into its in-plane and out-of-plane polarization modes and routed along a foreground arm and a background arm. The out-of-plane mode is transformed into in-plane in the background arm. Identical signal processing functions are performed within both arms. At the end of the chip, the original in-plane mode is transformed into out-of-plane and combined with the signal from the background arm.

Federal Programs

DARPA EPIC Program

One of the largest federal programs of the MPhC is the Application-Specific (AS) EPIC, sponsored by DARPA, the central research and development organization for the DoD. This major, multiyear research contract (awarded in December 2004) is funding a collaboration led by BAE Systems (http://www.baesystems.com/), with MIT, Lucent Technologies, Applied Wave Research, Cornell University, and Columbia University.

The overall DARPA EPIC program supports research intended to produce novel approaches that "enable revolutionary advances in science, devices, and/or systems" in three areas: CMOS-compatible high-performance Si nanophotonic devices, AS-EPIC, and novel photonic devices. The MPhC's project is in the second area of interest—the fabrication and demonstration of AS-EPICs.



Cross-section scanning electron micrograph of an integrated optical filter (EPIC program), showing a deposited amorphous silicon waveguide above a device region containing electronic gate contacts.

On the cutting edge of integrated circuit research is the convergence of electronics and photonics, which incorporates electronic and photonic functionality on the same chip, using common CMOS processing methods. Now in its second phase, the principals in this program have designed, developed, and integrated tunable fourth-order optical filters, composed of silicon ring resonators, germanium-on-silicon modulators/diode photodetectors, and silicon waveguides with supporting electronic circuits. The entire circuit was fabricated within a 150-nm CMOS process flow, representing an unprecedented feat in materials integration. The phase-one circuit successfully performed as a broadband radio-frequency channelizer, demonstrating to DARPA a viable microphotonic product with size, weight, power, and performance metrics far superior to its current discrete electronic device alternative. The chips designed as part of this AS-EPIC program were fabricated at BAE System's Manassas facility.

For more information about the EPIC program, please visit http://mphotonics.mit.edu/about_mphc/EPIC.php.

MURI Silicon Lasers and Nanophotonics Program

The MIT MPhC has completed the first year of its electrically pumped silicon-based lasers for chip-scale research program, funded by MURI from AFOSR. The project is led by MIT's MPhC and includes collaborators from seven other leading research universities: Boston University, California Institute of Technology, Cornell University, Lehigh University, Stanford University, University of Delaware, and University of Rochester.

AFOSR, a component of the Air Force Research Laboratory, manages the Air Force's basic research program in support of Air Force goals of "control and maximum utilization of air and space." The MURI program, sponsored by the DoD, sponsors large-scale, multidisciplinary research projects that represent exceptional opportunities to contribute technology applicable to national defense. The awards provide support for research, graduate students, and laboratory instrumentation development.

The MURI program is being guided by two principal approaches in its current phase. In the first approach, researchers are integrating high-gain, electroluminescent materials into highly optical confinement structures based on the silicon platform. In the second approach, researchers are reengineering the electrical bandgap of a silicon-compatible material to enhance its light-emission efficiency. The impact of this program is underscored by the micrometer-scale dimension of these two on-chip laser approaches, making it conceivable eventually to integrate such light sources into the CMOS process flow that lies at the heart of the EPIC program. For the first time, this program is demonstrating the ability to integrate light-emitting materials into an optoelectronic circuit.

Various members of the MURI team during a discussion meeting. Faces available to view, left to right: Professor Harry Atwater (Caltech), Mark Beals (associate director, MPhC), Professor Dennis Prather.

For more information about the MURI, please visit http://mphotonics.mit.edu/about_mphc/MURI/MURI.php.

ATAC One-Year Feasibility Study

The DoD awarded a one-year grant to a collaboration composed of the MIT MPhC, CSAIL, and Sandia National Laboratories to perform a feasibility study on the viability of an ultradense photonic-electronic integrated circuit for computing application. Building on the impressive results demonstrated by the EPIC phase-one program, this ATAC one-year study yielded promising designs for multicore chip processors integrated with microphotonic devices. The designs have opened a new paradigm for computer core modeling that bypasses the conventional electronic restrictions on multicore structures.

Professor Anant Agarwal (CSAIL) explains the ATAC project to registered attendees at the fall 2007 microphotonics meeting.

Producing Knowledgeable People

As part of the MIT community, the first priority of the MPC is education of the next generation of materials processing research scientists, engineers, and leaders. To this end, the 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.

The MPC places great importance on publication in pursuit of its outreach goals. The Internet is our main mode of information distribution. The MPC supports interdisciplinary research teams with secure websites for data sharing, teleconferencing and videoconferencing facilities for meetings, and staff support for research project management.

The MPC website's weekly collection of materials research news stories continues successfully, highlighting the latest international breakthroughs in the field. Updated frequently, the MPC homepage features articles of interest to all materials science researchers, and the MPhC homepage features the subset of those articles relevant to the microphotonics community. The homepages feature only the most recent articles, but links to all the articles that have been featured so far remain available in an archive. A spotlight box has been added to the MPC homepage, placing increased emphasis on materials-related news items from within the MIT community. This spring, we spotlighted a DMSE class project: the construction of a fiber-based suspension bridge, in the ancient Mayan design, across an MIT dry moat. In addition, we have spotlighted the activities of the MIT Lemelson program InvenTeams, which tap high school students for participation in many materials-focused research projects.

Another important outreach mechanism is the poster session. In FY2007, the MPC sponsored or cosponsored two poster sessions: the Summer Internship Poster Session (August 10) and the Materials Day Research Review Poster Session (October 11). In addition, the Microphotonics Consortium has two annual meetings held in spring (May 18–19) and fall (September 10–11).

Summer Research Internship Program

The MPC does not limit its educational outreach to the MIT community. For 25 years, the 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 11 to August 10 of this year) is an 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 members. The program culminates in a poster session held in Lobby 13, where the students present their research to the MIT community.

The 2007 program involves 16 faculty members and 16 bright, motivated students from schools including Cornell, Rutgers, Princeton, Lehigh, Mary Baldwin College, and the University of Wyoming. This year, two of the attending students are undergraduate Siemens scholars sponsored in collaboration with the Siemens Foundation scholars. Project areas include quantum information processing, organic light-emitting diodes, nanoparticle synthesis, polyelectrolyte multilayers, high-temperature superconductors, and carbon nanotubes.

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, which is used to honor and recognize important achievements and talk about the future.

An autumn event, Materials Day features a daylong symposium on a featured topic, followed by a graduate student/postdoc poster session. The posters are judged by a panel of representatives from industry; poster winners receive certificates and $500 prizes.

The theme of the Materials Day 2006 symposium, was "Materials: Science to Systems. How We Made the Future—and What's Next?" The session chairs looked back at the 25-plus-year legacy of the MPC and how that widening focus has come to define an interdisciplinary hub of activity at MIT today. Speakers included Dr. Alan Taub, executive director of research and development for General Motors, "New Materials: The Real Enablers in the Reinvention of the Auto Industry"; Dr. Jerry Bautista, director of technology management, Intel Microprocessor Research Lab, "Materials Diversity for Fine Grained Hybrid Integration"; Professor Kent Bowen, Harvard Business School, "The Academic Research Engine and the Need to Manage, Science, Innovation, and Technology"; and MIT professor Michael Rubner, director of CMSE, "Leveraging Molecularly Assembled Multilayers into Commercial Applications," among others.

Materials Day 2006 featured ongoing research and results to date of these efforts via faculty presentations and an extensive poster session. The MPC normally awards three $500 prizes to the three best posters. This year, however, there was a four-way tie. The poster winners were as follows:

- "All-Nanoparticle Thin Film Coatings: A Versatile Means to Create All-in-One Coatings (Daeyon Lee; advisors, Robert Cohen and Michael Rubner)
- "Highly Wettability-Reversible Nanowire Paper" (Xiaogang Liu; advisor, Francesco Stellacci)
- "Multimaterials Integrated Fibers" (Fabien Sorin; advisor, Yoel Fink)
- "Design, Fabrication, and Testing of Multilayered Microfabricated Solid Oxide Fuel Cells" (Namiko Yamamoto; advisor, Brian Wardle)

To download the presentations from Materials Day 2006, please visit http://mpc-web.mit.edu/about_mpc/MatDay/MatDay06.php. Materials Day 2007 is scheduled for October 16, 2007.

Promoting the Exchange of Knowledge—Partnerships with Industry and Government

The MPC works to promote the exchange of knowledge in the service of our country and in the context of the global community. In addition to federal programs to bolster national defense through advancing technology through the MPhC, the MPC's events, programs, and publications help to foster knowledge transfer within the MIT materials community and to the outside world. The MPC has an active Industrial Advisory Board (IAB) composed of industry leaders from a spectrum of small to large companies. The IAB convenes yearly on the day after Materials Day. Last fall's meeting, held on October 12, 2006, was a departure from the typical IAB meeting's conventions. This time, the meeting focused upfront on industry feedback, adopting a format based on advisory board member comments, followed by associated responses from MIT faculty members. Dr. Ernest Littauer (retired, Lockheed Martin) commented on current energy needs and opportunities; professor Vladimir Bulovic (Department of Electrical Engineering and Computer Science) responded by highlighting the energy initiative at MIT. Dr. Hichem M'Saad (Applied Materials, Inc.) commented on materials processing requirements for the electronics industry; professor Eugene Fitzgerald (DMSE) responded by highlighting electronic materials research discoveries at MIT. Dr. Peter Bell (retired, Norton) commented on the investment of education at MIT; professors Edwin Thomas (DMSE) and Samuel Allen (DMSE) responded with presentations on materials education and graduate materials education, respectively, at MIT. Lastly, Dr. Thomas Blacklock (Novartis Pharmaceuticals Corporation) commented on current research opportunities for the pharmaceutical industry; professor Michael Cima (DMSE) responded with a presentation on the increasing role of materials in future medical applications. The meeting concluded with a broad discussion of the fluid boundary between academia and industry roles in defining standards for novel technologies such as pharmaceuticals and electronics.

In FY2007 the MPhC continued major research programs with industry affiliates. The MPhC also maintained its relationship with the sponsors of its major research programs; visiting industrial scientists affiliated with these programs are appointed through the MPC.

MPhC Consortium

The MPhC Consortium consisted in FY2007 of 12 member companies from the materials-to-systems technology supply chain of the computing, data communications, and telecommunications sectors.

The MPhC Consortium continued with the second phase of its Communication Technology Roadmap (CTR II) with expanded focus industry drivers for microphotonics adoption. The fall 2006 meeting, "Realizing Microphotonics Components and Systems" met with an attendance of approximately 80 industry members. The spring 2007 meeting, "High Volume Photonics: Drivers and Constraints for the Components-to-Consumer Supply Chain," met with attendance of 100 industry members, marking a 25 percent increase in membership activity. Industry-led TWGs, working in conjunction with three CTR research fellows, collated and reported findings on new industry sectors where the push for photonics-enabled technologies are now reaching critical impetus.

For more information about the MPhC Consortium, please visit http://mphotonics.mit.edu/about_mphc/consortium.php.

Communications Technology Roadmap II

The MPhC Consortium-based CTR II operated aggressively during FY2007, with its three industry-led TGWs executing a broad range of interviews with several industry sectors. The interview findings were collated and reviewed to identify emergent driving forces for microphotonics adoption. Two significant new markets were identified: the mobile phone and the automotive industry.

While the traditional understanding of microphotonics adoption has been as a solution to high-capacity bandwidth needs, TWG activity and membership forums at the fall and spring meetings have resolved a new understanding of emerging drivers: electromagnetic interference from densely spaced metal interconnects, ever-increasing demands for a reduction in device form factor, and lower electrical heat dissipation. Industry surveys undertaken by the TWGs have revealed that there is a broad awareness of these constraints and the enabling impact of a microphotonic solution. In particular, the mobile cell phone and automotive industry sectors are seriously exploring microphotonic interconnection options for future luxury end products. As for bandwidth demands, TWG surveys have revealed that within as little as five years, computation cluster server needs will reach a crossover point where high-volume demand for photonic interconnection will be effectively unavoidable. To address this near-term requirement, CTR researcher Erica Fuchs, working with professor Randolph Kirchain, has constructed the first cost model for a silicon photonics fabrication line; results show the production costs for such a facility to be comparable to its microelectronics counterpart.

CTR II is under the codirection of professors Randolph Kirchain (DMSE) and Lionel Kimerling.

Three TWGs are meeting regularly to focus on specific areas of interest. The CTR II TWGs are:

- Cross Market Applications: Characterizing Technical Requirements and Architectural Options, chaired by Alan Benner (IBM) and Tremont Miao (Analog Devices);
- Realizing a CMOS (Si) Platform, chaired by Michael Morse (Intel Corporation); and
- Integration, Packaging, and Interconnection, chaired by Louay Eldada (DuPont Photonics Technologies) and Richard Grzybowski (Corning).

For more information about the CTR program, visit http://mph-roadmap.mit.edu/.

Outlook

Interdisciplinary collaboration among the various fields of inquiry related to materials science, engineering, and processing is the prime focus of the MPC. Over the next few years, there are five key trends in materials science that will affect MPC. The first—interdisciplinary research teams with vertical integration to applications—is a wonderful confirmation of the idea, which MPC has always promoted, that strategically bringing together specialists from various academic specialties can produce a synergistic whole that is far more than the sum of its parts. Another key trend—vanishing academic department boundaries—has resulted in dual appointments for some new faculty. The interdepartmental faculty member is a great example of how the entire community is moving toward more interdisciplinary pursuits. A third key trend is a new type of triangular industry–government–university partnership, such as the EPIC program described earlier in this report. More intellectual property (IP) creation, a fourth key trend, is related to the collaboration we help arrange. Industry seeks IP from its sponsored research, so more collaboration means more IP creation. The application-rich nature of industry enables researchers to do what we do best—develop basic, fundamental results and then apply them when we get the opportunities. The last—but by no means least—key trend that will affect the MPC going forward is the fact that materials innovation is pervasive in our 21st century world. As more of the scientific community around the world begins to focus on materials science, engineering, and processing, we may look forward to a truly exponential increase in new ideas, materials, and applications.

Audience attendance at the fall 2007 microphotonics meeting. Foreground first row, left to right: Professor Randolph Kirchain (codirector, MPhC), Mindy Baughman (program coordinator, MPhC). Foreground second row: Mark Beals (associate director, MPhC).

The long-term strategic vision of the MPC must be to act as the intellectual leader in materials innovation and processing across the MIT community and the external community and interface with government and industrial systems integrators. The short-term plan is to continue building the relationship base to act as this central consolidator and leader in the materials community. In each sector of MPC research activity, system integrators must be identified and relationships established. This process in the

TWG leader Alan Benner (IBM) highlights findings from cross-market applications TWG during the fall 2007 microphotonics meeting.

defense sector is well under way, and the process has also started in the biomaterials/biotechnology area. With system integrator relationships growing, key community membership of individuals and resources outside the MIT community can also be folded into the MPC community.

A major challenge at MIT is the need for a better sense of community. The MPC has provided, for the past quarter century, a successful means of achieving a better sense of community within the School of Engineering and across the whole campus. Looking ahead, the MPC anticipates that the next quarter century will be even more exciting than the first, as collaborative initiatives with other materials research organizations on and off campus take shape and take flight.

Lionel C. Kimerling
Director
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/.