Microsystems Technology Laboratories

The Microsystems Technology Laboratories (MTL) conduct research and education with an intellectual core of semiconductor industry process and device technology and integrated circuits and systems design. MTL also leverages its infrastructure to foster new initiatives at the Institute and to support the general micro- and nanofabrication needs of MIT.

The MTL carries out graduate and undergraduate research activities in circuits and systems that are built using microsystems technology for applications such as wireless sensing networks and intelligent vision systems. Additionally, researchers are investigating the fabrication and study of small (i.e., micrometer to nanometer) structures and their use for the implementation of interesting integrated devices from nanometer-scale electronic devices to optical switches, displays, biosensors, and micropower generators. The MTL facilities include laboratory space for electronics testing and assembly, computation and communication, and microfabrication. The MTL microfabrication facilities include three clean rooms with a total of 6,500 sq ft: the state-of-the-art class-10 Integrated Circuits Laboratory, the flexible process environment Technology Research Laboratory, and the Exploratory Materials Laboratory. The equipment in MTL facilities has a replacement value far in excess of $60M. In AY2005, the MTL fabrication facilities were utilized by more than 400 students and staff. The laboratory manages a contract research volume of approximately $12M/year. Approximately $40M of contract research (primarily managed in other departments, labs, and centers) relied on the MTL facilities as an integral part of their research. The fabrication and computation facilities of MTL are maintained and operated by a full-time technical staff of 25 technicians and engineers.

Beyond the research programs, MTL supports several educational initiatives that leverage the research infrastructure of the labs. Chief among these is the undergraduate microfabrication laboratory, a lecture/laboratory course in which 120 students a year are afforded the opportunity to micro- and nanofabricate electronic, mechanical, and biochemical devices in the state-of-the-art MTL facilities. Additionally, we offer a project laboratory for team-based design of microfabricated structures. Lastly, via the iCampus initiative, Professor del Alamo is developing a series of web-based laboratory tools that permit testing of microfabricated structures.

MTL maintains a strong and vibrant interaction with industries that value not only the research output but also the students who are educated in state-of-the-art microsystems technology. The MTL facilities are supported in part by industry through the MIT Microsystems Industrial Group (MIG), whose current members include Advanced Micro Devices (AMD), Analog Devices, Applied Materials, Hewlett-Packard (HP), IBM, Intel Corporation, National Semiconductor, Novellus Systems, Samsung, and Texas Instruments. Four industry-funded centers are affiliated with the MTL, as noted below.

Highlights

The research activities of the MTL can be viewed online by exploring our annual report at the lab's website. MTL research spans an extraordinarily broad set of activities. If one were to identify a unifying theme associated with these projects, it would be the system-level interest in micro- and nanotechnology. The MTL represents a community that brings experimentalists skilled in materials and technology at the micro- and nanolevels together with circuits/systems researchers to realize visions for new systems that are enabled by the integration of these disciplines.

The circuits and systems group engaged in research in the areas of radio-frequency (RF) design, including receivers, modulators, and power devices. Wireless systems remained a major focus area in both the high-performance and ultralow-power domains. The high-performance wireless research was primarily directed toward gigabit LAN, whereas the low-power systems were primarily in support of wireless sensor networks. This was coupled to an extensive range of research on low-power design in general. Analog to digital conversion and mixed-signal circuit design continue to be major focus areas. Intelligent transportation systems and vision systems in support of these were studied. As part of a larger overall effort on interconnect issues, there was considerable work on circuit/systems issues in interconnect and the investigation of 3-D systems. Analysis tools for design of circuits and test devices to understand manufacturing issues provided core underpinning research for the entire circuits and systems area.

We explored a wide range of emerging technologies that are reported in detail in our annual report. Substrate engineering—the development of optimized silicon-based heterostructures—was a substantial activity, as was the exploration of novel means to achieve device isolation in integrated systems. Compound semiconductor systems such as InP/GaAs were explored for high-performance RF devices. Field emission structures were studied for a variety of applications in devices and displays, to name a few. In the areas of advanced fabrication technologies and materials, we saw exciting work on magnetics, metal interconnect materials, and environmentally benign processes. Lastly, we saw substantial and growing focus on new nonsilicon devices in organic and inorganic materials systems.

Photonic devices were studied for a wide range of applications. Quantum dots, photonic crystals, and display materials and devices were explored, as well as J-aggregates. Lasers in compound semiconductor materials and heterogeneous integration methods for merging such devices with silicon platforms were pursued. Integrated silicon photonics and silicon-compatible optical interconnect methods were developed. Microelectromechanical systems (MEMS) structures were merged with optics to achieve new functionality in optical systems.

In the area of MEMS, the primary focus areas are bio/chemical devices and systems, power devices, and a variety of enabling technologies. A large number of microfluidic devices are being developed for manipulation of cells, DNA, proteins, and other molecules. Microreactors are being designed that enable the synthesis of chemicals at a small scale, as well as microbioreactors that can be used in areas such as fermentation studies. Microchemical analysis systems such as portable gas analyzers are also studied.

In the area of portable power generation, we are exploring both fuel-burning and energy harvesting approaches. Primary focus of the energy harvesting approaches is to utilize piezoelectric materials for vibration harvesting. In the area of fuel-burning systems, we are exploring microturbines as well as fuel cells and thermophotovoltaics. Beyond these systems-focused projects, there is a wide-ranging set of projects looking into the applications of MEMS technologies for mechanical devices such as switches, tweezers, and nano-assembly. Finally, there are some core technology development efforts to understand better, model, and characterize MEMS materials and structures.

Molecular and nanoscale devices are a new and emerging area of work in the lab. Nanoscale assembly methods inspired by origami are studied, as well as nanoscale field ionizers. Nanodimensioned fluidic channels enable manipulation of chemicals and molecules that are nanoscale. Organic and quantum dot structures are explored for many electronic and photonic purposes. Carbon nanotubes have emerged as potentially exciting structures to explore for many different applications. The work in this area includes not only studying the material but developing means for fabrication and manipulation of the nanotubes. Magnetic nanoparticles hold great promise in advanced devices and are extensively explored. Self-assembly methods appear promising for creating ordered nanostructures, and these methods are being studied in detail. Quantum-effect devices are explored for a variety of applications, including quantum computing.

Beyond the detailed research activities summarized above, the laboratory focused its efforts in three areas: development of a new structure for our industrial engagements, undertaking major renovations and expansions of the existing infrastructure, and leading a campuswide initiative to create a vision for future facilities needs.

The industrial engagements of the lab to this point have been primarily structured around a major industrial consortium. To increase the attractiveness of this consortium, as well as to develop new models for interaction, the MTL rolled out a new program of interactions. Our highest level of engagement is an alliance level that engages the companies in a portfolio of sponsored research in a focused area. Currently we conduct these alliance relationships with HP and Samsung. We also have partnership relationships with companies that not only participate in our consortium but also contribute targeted support in individual areas. Intel, Texas Instruments, and National Semiconductor are partnership-level members. The Microsystems Industrial Group members provide core support and benefit from high-level interaction with the students and staff in the lab. Current MIG members include all alliance and partner members, as well as Analog Devices, AMD, Applied Materials, IBM, and Novellus. As noted above, the MTL has established relationships with four industrial centers at MIT in a manner that promotes positive interactions between the centers and the MTL. They are the Center for Integrated Circuits and Systems, the Center for Integrated Photonic Systems, MEMS @ MIT, and the Intelligent Transportation Research Center.

Major renovations in MTL were completed to expand laboratory space for faculty, including new members of the labs such as Professor Michael Perrott and Professor Joel Dawson. In addition, in the coming year we anticipate initiating a major overhaul of the cleanroom infrastructure in preparation for the addition of 2,000 sq ft of new cleanroom.

The MTL participated in a process this academic year that led to the recommendation to the senior leadership of MIT that a new building for micro/nanoresearch be created. We intend to continue participation in this initiative.

Future Plans

Our plans for the coming year follow directly from the activities of the previous year. A major push to grow participation in our industrial programs will be undertaken. Also, we hope in the next year to complete major infrastructure renovation to the cleanroom support equipment and to initiate the construction of new cleanroom space. We will continue our participation in defining the infrastructure needs for the next 10–20 years.

Martin A. Schmidt
Director
Professor of Electrical Engineering and Computer Science

More information about the Microsystems Technology Laboratories can be found online at http://www-mtl.mit.edu/.