Microsystems Technology Laboratories

The mission of the Microsystems Technology Laboratories (MTL) is to foster world-class nanoscale research, education, and innovation. Nanoscale science and technology can help solve some of the world's greatest problems in energy, communications, water, health, information, and transportation. Researchers at MIT are engineering new materials, structures, devices, circuits, and systems using MTL's facilities and services to find new solutions to persistent problems. MTL's research program is highly interdisciplinary and encompasses integrated circuits, systems, electronic and photonic devices, microelectromechanical systems (MEMS), bio-microelectromechanical systems (bio-MEMS), molecular devices, nanotechnology, sensors, and actuators. MTL faculty members and the students and researchers in their laboratories are conducting breakthrough research in areas including nanoscale transistors, medical devices, microfluidics, organic lasers, and perovskite photovoltaics, among others. They are working on a scale from approximately one nanometer (nm) to approximately one meter.

At present, MTL's core faculty comprises 52 members from seven departments across the Schools of Engineering and Science. Although MTL's faculty members are principally drawn from the Departments of Electrical Engineering and Computer Science (EECS), Mechanical Engineering, and Materials Science and Engineering, there is growing interest and engagement from faculty in the Departments of Biological Engineering, Chemical Engineering, Chemistry, and Physics. In addition, because circuits, sensors, and devices are integral to a virtually unlimited range of applications, MTL has built collaborations and interactions with many other research laboratories and centers across the Institute, including the Research Laboratory of Electronics, the MIT Energy Initiative, the Institute for Medical Engineering and Sciences the Materials Processing Center, the Materials Research Laboratory, the Computer Science and Artificial Intelligence Laboratory, the Koch Institute for Integrative Cancer Research, and the Institute for Soldier Nanotechnology. MTL core faculty members serve the Institute and the global community in significant leadership positions. We are honored to note that MTL's core faculty members includes President Rafael Reif, Provost Martin Schmidt, School of Engineering Dean Anantha Chandrakasan, Mechanical Engineering Department Head Evelyn Wang, MIT.nano inaugural Director Vladimir Bulović, Mechanical Engineering Associate Department Head Rohit Karnik, EECS Associate Department Head Joel Voldman, Research Laboratory of Electronics Director Marc Baldo, and Materials Research Laboratory Co-Director Carl Thompson.

MTL has historically managed a set of shared experimental facilities in Buildings 39 and 24. These facilities currently house more than 150 fabrication and analytical tools and serve a community of about 400 students and postdoctoral associates from all areas of MIT. A significant milestone for MTL was the transfer of administrative management of these fabrication facilities to MIT.nano. The physical transfer of the fabrication equipment and tools into the newly renovated Building 12 has recently begun. During this transitional period, MTL's fabrication capabilities, including diffusion, lithography, deposition, etching, and packaging, will continue to be available to the entire MIT community and the world outside MIT.

MTL also manages an information technology infrastructure that supports state-of-the-art computer-aided design (CAD) tools for device, circuit, and system design and serves a community of about 230 students and postdocs from across MIT. MTL has fostered strong relationships with major semiconductor manufacturers, enhancing MTL's ability to make available to the MIT community some of the most advanced integrated circuit fabrication processes available in the world today. In all, 560 MIT students and postdoctoral associates from 27 different departments, laboratories, and centers carried out their research in MTL's facilities or used MTL's design services in the past fiscal year. In addition, many researchers from for-profit companies, government research laboratories, and domestic and international universities use MTL's facilities annually.

End of an Era: Fabrication Facilities Transfer to MIT.nano

On July 1, 2018, the MTL Fabrication Service Center administration was formally transferred to MIT.nano, including the appointments of all sponsored research and service staff who manage the facilities and tools, and all of the financial activity of the facilities. MTL leadership and staff have worked very closely with the MIT.nano team to coordinate this administrative transition and to prepare for the physical transfer of tools and equipment from MTL to MIT.nano.

Fiscal year 2019 was the first full fiscal year in which MIT.nano managed the Building 39 fabrication facilities The current MTL leadership continues to run the Building 39 fabrication facilities on a day-to-day basis, periodically checking with MIT.nano administration for business-as-usual matters and offering timely consultation on all new issues. This allows the MIT.nano administration to focus on bringing the new facilities of Building 12 into service.

Industry Engagement

MTL partners with industry through the Microsystems Industrial Group (MIG) consortium. The member companies within the consortium support MTL research and operations through a membership fee. Some consortium members may also provide access to the state-of-the-art semiconductor fabrication design tools and processes and make equipment donations. Members of the MIG's Industrial Advisory Board (IAB) help guide the vision of MTL.

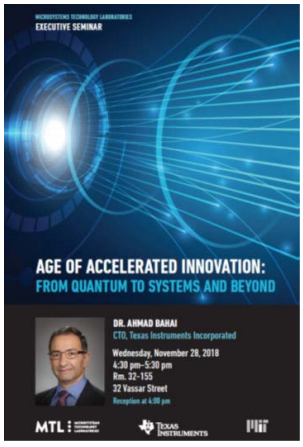
MTL hosted its annual Industrial Advisory Board meeting on January 31, 2019, with representatives from 10 MIG member companies in attendance. Selected members of the core faculty presented their current research, and the IAB representatives participated in a wide-ranging discussion of the current and future state of nanofabrication research at MIT. StartUP@MTL, introduced in FY2017, was again a highlight of the meeting, with the participation of seven MTL-related start-up companies whose senior leadership presented their technologies, future products, and business plans to the MIG members in attendance. MIG company representatives attending the meeting included Susan Feindt (Analog Devices), Chorn-Ping Chang (Applied Materials), Jordan Chesin (Charles Stark Draper Laboratory), Neil Condon (Edwards Vacuum), Vivek Dave (Harting), Yoshito Nejime (Hitachi), Dirk Pfeiffer (IBM), Nerissa Draeger (Lam Research Corporation), Tomo Tanaka (NEC Corporation), and Jim Wiesner (Texas Instruments).

January 2019 Industrial Advisory Board meeting (photo by Paul McGrath)

MIG member companies engage with MTL core faculty, students, and researchers in many ways, including online access to the MTL resume site, assistance with recruiting events on campus, exclusive access to MTL's annual research conference, faculty visits, and priority access to MTL resources. A unique benefit that member companies receive is the opportunity to have a scientist or engineer in residence on campus as an active participant in the research activities of an MTL-affiliated faculty member or research center. This past year, there were nine visitors from five MIG member companies:

- Sam Fuller (Analog Devices) with Charles Sodini
- Anthony Taylor (Edwards Vacuum) with Luis Velasquez-Garcia
- Vivek Dave (Harting) with Jesús del Alamo
- Tomohiro Tanaka (NEC) with Polina Anikeeva
- Dennis Buss (Texas Instruments) with Jesús del Alamo
- Josef Stein (Analog Devices) with Max Shulaker
- Maren Knop (Harting) with Jeffrey Lang
- Chiraag Juvekar (Analog Devices) with Anantha Chandrakasan
- Tom O'Dwyer (Analog Devices) with Charles Sodini

Among other significant activities with MIG companies, in September 2018, Lam Research organized a Lam Technical Symposium at Tsinghua University, in which Jesús del Alamo, Vladimir Bulović, and Max Shulaker participated.



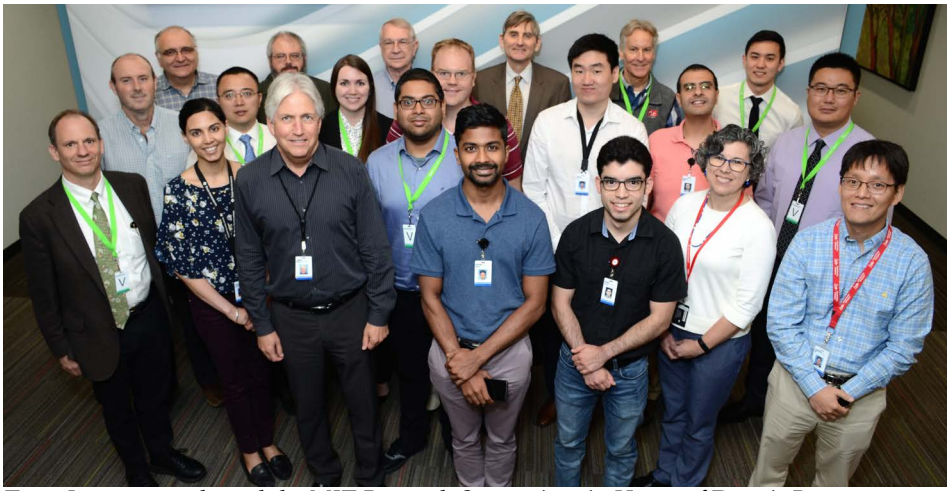
In October 2018, MTL hosted the annual Lam Research Day, which included a seminar by Richard Gottscho, Lam's executive vice president and corporate chief technology officer.

In November 2018, MTL held an MTL Executive Seminar led by Ahmad Bahai, who is both chief technology officer at Texas Instruments and director of corporate research at the company's Kilby Labs. More than 200 people attended.

Poster of Executive Seminar on Age of Accelerated Innovation: From Quantum to Systems and Beyond, presented by Ahmad Bahai, chief technology officer, Texas Instruments

In April 2019, Carlos Diaz of Taiwan Semiconductor Manufacturing made a presentation, "On the Essential Constituents for Future Logic Technologies," as part of the MTL Seminar Series.

In June 2019, Texas Instruments hosted the MIT Research Symposium in Honor of Dennis Buss. The symposium included MIT professors Ruonan Han, Jeffrey Lang, David Perreault, Song Han, Vivienne Sze, and Jesús del Alamo, along with students Cheng Wang, Intae Moon, Jessica Boles, Ethan Lee, Preetinder Garcha, and Utsav Banerjee. The symposium was a day of networking and events, with presentations by members of both Texas Instruments and MIT. It was held in honor of Dennis Buss, a long-time representative of Texas Instruments in MTL and a good friend of MTL and MIT. Buss passed away in 2018.



Texas Instruments hosted the MIT Research Symposium in Honor of Dennis Buss.

Throughout the year, industrial member company representatives from Analog Devices, Draper Laboratory, Edwards Vacuum, Harting, Hitachi, IBM, Lam Research, Texas Instruments, and Taiwan Semiconductor Manufacturing visited MTL to discuss specific research.

Research Centers

Four centers affiliated with MTL provide the opportunity for MIG member companies and other companies to become engaged in focused research initiatives. These are the Center for Integrated Circuits and Systems, the MIT/MTL Gallium Nitride Energy Initiative, the Medical Electronic Device Realization Center, and the MIT/MTL Center for Graphene Devices and 2D Systems.

The mission of the Center for Integrated Circuits and Systems (CICS) is to promote new research initiatives in circuit and system design as well as a tighter technical relationship between MIT's research and relevant industries. CICS investigates a wide range of circuits and systems, including wireless and wire line communications, high-speed and radio-frequency (RF) circuits, microsensor and actuator systems, imagers, digital and analog signal processing circuits, biomedical circuits, and power conversion circuits, among others. In FY2019, MTL supported CICS in hosting two Research Review events on campus. One was held in November 2018 and the other in May 2019 to honor the 20th anniversary of CICS.

The MIT/MTL Gallium Nitride (GaN) Energy Initiative is an interdepartmental program focused on advancing the science and engineering of gallium nitride–based materials and devices for energy applications. The GaN Energy Initiative provides a holistic approach to gallium nitride research for energy applications, and it coordinates work on growth, technology, novel devices, circuits and systems to take full advantage of the unique properties of GaN. Researchers in the GaN Energy Initiative are especially interested in developing new solutions for system-level applications in RF power amplification, mixed-signal electronics, energy processing, and power management, as well as advanced optoelectronics. Most of the work is done on GaN materials and devices that are compatible with silicon fabrication technologies, and in close collaboration with industrial partners to accelerate the insertion of these devices into systems. In October 2018, the GaN Energy Initiative held its annual review with support from MTL.

The vision of the MIT Medical Electronic Device Realization Center (MEDRC) is twofold: to revolutionize medical diagnostics and treatments by bringing health care directly to individuals, and to create enabling technology for a future information-driven health care system. This vision will, in turn, transform the medical electronic device industry. Specific areas that show promise are wearable or minimally invasive monitoring devices, medical imaging, portable laboratory instrumentation, and the data communication from these devices and instruments to health care providers and caregivers. MEDRC embodies the interdisciplinary focus of MTL's research through its close association with MIT's Institute for Medical Engineering and Science (IMES). MEDRC has been able to create strong connections with the medical device and microelectronics industry, venture-funded start-ups, and the Boston medical community. With the support of MTL and IMES, MEDRC serves as the catalyst for the deployment of medical devices that will reduce the cost of health care in both the developed and developing worlds. In AY2019, no MEDRC research conference took place, but the IMES Industrial Group, consisting of 30 industrial partners and MIT colleagues, gathered in May.

The MIT/MTL Center for Graphene Devices and 2D Systems (MIT-CG) brings together MIT researchers and industrial partners to advance the science and engineering of graphene and other two-dimensional materials. Specifically, the center explores advanced technologies and strategies that enable 2D materials, devices, and systems to provide discriminating or breakthrough capabilities for a variety of system applications, ranging from energy generation/storage, smart fabrics and materials to optoelectronics, RF communications, and sensing. In all these applications, MIT-CG supports the development of the science, technology, tools, and analysis needed to create a vision of the future of systems enabled by two-dimensional materials. In November 2018, the Graphene Center held its annual review with support from the Microsystems Technology Laboratories.

Research Highlights

A few of MTL's notable research results are highlighted below.

Professors Max Shulaker and Anantha Chandrakasan

Carbon nanotube (CNT) field-effect transistors (CNFETs) are a promising emerging technology for energy-efficient electronics. Despite this promise, carbon nanotubes are subject to substantial inherent imperfections. Every ensemble of CNTs includes some

percentage of metallic CNTs (m-CNTs). Metallic carbon nanotubes result in conductive shorts between CNFET source and drain, resulting in excessive leakage and degraded (potentially incorrect) circuit functionality. Several techniques have been developed to remove the majority of m-CNTs (no technique today removes all of them). While these techniques enabled the first digital CNFET circuits, it is still not possible to realize large-scale CNFET analog or mixed-signal CNFET circuits due to m-CNTs. While a digital logic gate can still function correctly in the presence of a small fraction of m-CNTs (but with degraded resilience to noise), a single m-CNT in an analog circuit can result in catastrophic failure (e.g., degrading amplifier gain resulting in the functional failure of circuit blocks). Shulaker and Chandrakasan's work demonstrates a circuit design technique called self-healing analog with resistive random-access memory (RRAM) and CNFETs (SHARC). The SHARC technique leverages the programmability of non-volatile resistive RAM to "self-heal" analog circuits automatically in the presence of metallic carbon nanotubes. Using SHARC, Shulaker and Chandrakasan experimentally demonstrated analog CNFET circuits that are robust to metallic carbon nanotubes, as well as the first mixed-signals CNFET subsystem (4-bit digital-to-analog converter and successive-approximation-register analog-to-digital converter). These are the largest reported complementary metal–oxide–semiconductor (CMOS) CNFET circuit demonstrations to date. This work was presented at the 2019 International Solid-State Circuits Conference.

Ruonan Han

Ruonan Han's group is investigating a chip-scale molecular clock, a miniature time-keeping device with high affordability. The device is based on the progress of recent research on high-precision terahertz (THz) rotational spectrometers, especially those using CMOS integrated circuit technologies. The clock probes the rotational modes of carbonyl sulfide (16O 12C 32S) molecule gas and then calibrates its megahertz output according to the measured terahertz transition frequency of OCS. In contrast to cesium or rubidium atomic clocks, the THz OCS clock has fully electronic operations and, hence, a significantly simplified implementation. In particular, it can be realized on a waveguide-attached CMOS chip, which minimizes the form factor and cost. Based on a lab-scale prototype with an Allan deviation in the 10^{-11} range, the Hangroup for the first time studied two critical metrics related to the long-term stability of THz OCS clocks: the clock sensitivities to temperature change of the OCS gas, and external magnetic field. The measured average temperature coefficient of the clock, without ovenized temperature stabilization and temperature compensation, is 9.5×10^{-11}/°C in the range of 28°C–70°C. Next, the measured clock shift in response to a 75-gauss external magnetic field was $< 4 \times 10^{-11}$, with a theoretical value near 10^{-13}. This group has also demonstrated the first CMOS prototype of the clock, which consumes only 66 milliwatts in direct current power and achieves an Allan deviation of 3.8×10^{-10} (τ = 1,000 s). These studies present the feasibility of a CMOS–based magnetic-shield- and heater-free clock with high energy efficiency and subparts-per-billion stability over a wide range of operating conditions. This work was published as an invited paper in *IEEE Transactions on Terahertz Science and Technology*.

Professor Luqiao Liu

Semimetallic iridate compound perovskite (SrIrO3) epitaxial films have been deposited by off-axis sputtering, exhibiting excellent crystalline quality as well as smooth surfaces. By performing second-harmonic Hall measurements on a series of SrIrO3/Co1-xTbx bilayers,

the investigators quantitatively determined the spin-to-charge interconversion efficiency of SrIrO3 and discovered a systematic temperature- and film-thickness-dependent evolution behavior. Notably, the measured interconversion efficiency reaches the remarkably large number of 1.1 at room temperature, which is significantly larger than the value of 5d transition metals, and comparable to the values reported in some topological material systems. These findings are further corroborated by ferromagnetic resonance-driven spin pumping studies in SrIrO3/Py bilayers, highlighting the significant opportunities offered by the iridate compounds in designing next-generation energy-efficient multifunctional spin Hall devices. This work was published in *Applied Physics Letters*.

Professor Jesús del Alamo

Professor Jesús del Alamo's group demonstrated for the first time thermal atomic layer etching (ALE) on indium-gallium-arsenide (InGaAs)–based III-V heterostructures. The group also reported the first transistors fabricated by the thermal ALE technique in any semiconductor system. They have further highlighted one unique advantage of thermal ALE: its integration with atomic layer deposition (ALD) in a single vacuum chamber. Using in situ ALE-ALD, the investigators fabricated the most aggressively scaled self-aligned InGaAs N-channel fin field-effect transistors (FinFETs) to date, featuring fin widths of less than 5 nm. The narrowest FinFET fabricated had record values for transconductance and subthreshold swings. The demonstrated transistors showed an average 60% conductance improvement over devices fabricated through conventional techniques. These results suggest that a very high-quality metal–oxide–semiconductor interface was obtained by the in situ ALE-ALD process. This research was presented at the 2018 International Electron Devices Meeting. The authors received the Best Student Paper Award (to be given at the 2019 International Electron Devices Meeting).

Professor Song Han

Model compression is a critical technique to efficiently deploy neural network models on mobile devices, which have limited computation resources and tight power budgets. Conventional model compression techniques rely on handcrafted heuristics and rule-based policies that require domain experts to explore the large design space, trading off among model size, speed, and accuracy, which is usually suboptimal and time-consuming. In this work, the authors proposed a model compression policy, AutoML for Model Compression, which leverages reinforcement learning. This learning-based compression policy outperforms the conventional rule-based compression policy by having a higher compression ratio, preserving accuracy better, and reducing human labor. Researchers achieved 2.7% better accuracy than the handcrafted model compression policy for the convolutional neural network model known as VGG-16 on the ImageNet database. The investigators have applied this automated, push-the-button compression pipeline to a MobileNet model and achieved 1.81 × speedup of measured inference latency on an Android phone and 1.43 × speedup on the Titan XP graphics processing unit, with only 0.1% loss of ImageNet Top-1 accuracy. This paper is available on ArXiv.

Program Highlights

In FY2019, MTL welcomed the fourth cohort of visiting faculty, postdoctoral associates, and students under the partnership MIT had established in 2015 with Tecnológico de Monterrey (the Monterrey Institute of Technology and Higher Education, Monterrey,

Mexico). Four visiting faculty members and two postdoctoral fellows were hosted by faculty members in six labs across MIT. The visiting researchers' interests ranged from enzyme-based biosensors for explosive detection to extreme bionics. The work of program participants resulted in several papers submitted for publication or for presentation in peer-reviewed journals and conferences. As part of this program, MTL hosted 41 students, postdocs, and faculty this year in seven separate one-week sessions of the MTL nanoLab hands-on course on nanotechnology.

MTL engages the community in a number of technical events and programs. In both fall and spring of each academic year, the laboratory hosts a seminar series spanning diverse technical areas. The seminars are organized by a committee chaired by Luis Velasquez-Heller, and all seminars are open to the public. MTL also hosts one doctoral dissertation seminar each semester featuring a recent MTL PhD graduate, as well as occasional executive seminars featuring senior leaders from the MIG member companies. In November 2018, Ahmad Bahai, chief technology officer and director of corporate research for Texas Instruments delivered an MTL executive seminar, "Age of Accelerated Innovation: From Quantum to Systems and Beyond." In December 2018, Sara Mouradian's dissertation, "Scalable Solid-State Quantum Information Processing," was selected for presentation at the doctoral dissertation seminar. Mouradian conducted her PhD research under the supervision of Dirk Englund in EECS. In May 2019, the doctoral dissertation seminar award winner was Taehong Kwon, who presented his dissertation, "Novel Micro/Nanofluidic System for Separation and Monitoring of Cells and Proteins in Perfusion." Taehong Kwon conducted his PhD research under the supervision of Jongyoon Han in EECS.

Sara Mouradian's dissertation, "Scalable Solid-state Quantum Information Processing," was selected for presentation at the doctoral dissertation seminar.

Every January, MTL holds the Microsystems Annual Research Conference (MARC), which is run by MTL graduate students. The 2019 MARC was co-chaired by graduate students Sirma Orguc and Alex Hanson. MARC is broadly attended by industry representatives, faculty members, students, and staff, as it provides a unique opportunity to learn about

research in the diverse areas encompassed by MTL while fostering interactions within the MTL community. The 2019 event was held in January. Approximately 180 students, postdocs, faculty, staff, and industry partners were in attendance this year, including 22 guests from MIG member companies and 27 organizers. MTL students, postdocs, and researchers presented more than 100 posters. The MARC agenda also featured a dinner keynote speech by Sophie Vandebroek, IBM's vice president of emerging technology partnerships, and a conference-opening technical keynote speech delivered by an MIT alumnus, Nevada Sanchez, cofounder of Butterfly Networks.

In May, MTL presented and moderated the Quest Workshop on Intelligent Hardware Technologies 10 Years Out, which featured faculty talks, a panel discussion, and a poster session. This full-day workshop explored novel long-term opportunities for artificial intelligence hardware research at MIT. Such opportunities are likely to emerge from a layered research ecosystem that includes new material science, novel algorithms, and more.

MIT Day at Tecnológico de Monterrey

MIT Day at Tecnológico de Monterrey was held on June 18. The event marked the fifth year of the partnership, which was celebrated with 14 presentations and several workshops. MIT participants were Director Jesús del Alamo, Professors Jeff Lang, Rafael Jaramillo, and Jose Pacheco, and students Chris Lang, Graham Leverick, Nigamaa Nayakanti, and Maria Bauza.

MIT Day at Tecnológico de Monterrey

Facilities Update

During the past year, MTL emphasized maintaining and extending the usefulness of existing fabrication tools in the Building 39 nanofabrication facilities, especially those that see heavy use and are expected to be moved to Building 12. Although those facilities are now the administrative responsibility of MIT.nano, MTL continues to provide

oversight for them. The nanofabrication facilities support the research activities of approximately 400 students and postdoctoral associates from inside and outside MIT. With approval from the Office of the Vice President for Research, MTL used equipment replacement funds for the years 2018–2020 to purchase two SAMCO systems, a plasma enhanced chemical vapor deposition (PECVD) system and a reactive ion etching (RIE) system, to replace the old Plasmatherm PECVD-RIE. These systems will serve as the cornerstone of the transfer of the fifth- floor nanofabrication facilities to Building 12. The new tools arrived in February 2019 and will be installed directly in Building 12 once the facilities in Building 12 are completed. After that, MIT.nano will oversee new equipment purchases and capabilities.

Outreach and Educational Activities

In support of MTL's mission to provide access to advanced fabrication technologies, MTL makes its facilities available to industry users through the Fabrication Facilities Access Program and to users from academia and government agencies through MTL's outreach program. In AY2019, MTL supported the activities of half a dozen different companies, including two start-ups founded by MTL alumni or faculty.

MTL supports MIT's educational mission by providing $3,000 of subsidized access to MTL's computational or fabrication facilities for any MIT undergraduate student. Three subjects are taught at MTL: 6.152J Micro/Nano Processing Technology, which introduces the theory and technology of micro/nanofabrication; 3.042 Materials Project Laboratory, which provides student project teams with the capability to design and fabricate a working prototype using materials processing technologies; and 6.07J Projects in Microscale Engineering, which is a project-based introduction to manipulating and characterizing cells and biological molecules using microfabricated tools for the life sciences.

MTL also actively engages in three School of Engineering initiatives: the Women's Technology Program, the Undergraduate Research Opportunities Program (UROP), and the Advanced Undergraduate Research Opportunities Program (SuperUROP).

Women's Technology Program

The Women's Technology Program (WTP) was created in 2002 to encourage high-school-aged young women with strong mathematical, scientific, and analytical abilities to pursue studies in engineering and computer science. The program provides these women with positive female role models, college-level computing and engineering experience, and an understanding of what engineers and scientists do and how they work. Participants in WTP-EECS have an opportunity during the summer for a hands-on experience in the microfabrication facilities of MTL. The program is under the guidance of a female graduate student whose research depends on using the MTL fabrication facilities. These young women go through the fabrication steps needed to transfer a group photograph onto a silicon wafer. Each student receives a wafer that displays the image of the group. Feedback from students has been very positive, and the wafers are a great reminder of their summer at MIT.

Undergraduate Research Opportunities Programs

SuperUROP and UROP engage MIT undergraduate students and promote direct interaction with faculty and industry sponsors, cultivate student creativity and professional development, and encourage students to consider the ethical and entrepreneurial aspects of their work. In FY2019, there were 18 undergraduate students in the program working in MTL. Eleven of these students were qualified to work in the MTL fabrication facilities as part of their project.

Core Faculty Appointments and Promotions

The following appointments and promotions involving MTL faculty took place in FY2019:

- Song Han joined MTL in July 2018. He is a graduate of Stanford University and was a postdoc at Google Brain. His research is in energy-efficient deep learning at the intersection of machine learning and computer architecture.
- Farnaz Niroui joined MTL in November 2018. She is a graduate of MIT and a postdoc at the University of California, Berkeley. She investigates unique physical phenomena and devices at the nanoscale.
- Rohit Karnik was appointed associate department head of education in the Department of Mechanical Engineering.
- Negar Reiskarimian joined MTL in July 2019. She is a graduate of Columbia University. Her research is in integrated circuits and systems, applied electromagnetics, and nanophotonics.
- Juejun (JJ) Hu joined MTL as core faculty and is an expert on integrated optics and photonics.

Awards and Honors

MTL faculty and students regularly receive recognition for their research contributions and accomplishments with numerous national and international awards. The awards and distinctions collected by MTL-affiliated faculty, staff, and students during the reporting period include the following:

- Judy Hoyt received the 2018 University Research Award for Excellence in Semiconductor Technology Research by the Semiconductor Industry Association and Semiconductor Research Corporation.
- Luqiao Liu was promoted to associate professor without tenure by the Departement of Electrical Engineering and Computer Science. He has also been selected as a 2018 US Air Force Young Investigator.
- Polina Anikeeva was awarded the 2018 Vilcek Prize for creative promise in medical science by the Vilcek Foundation.
- Timothy Swager received the 2018 Vannevar Bush Faculty Fellowship from the United States Department of Defense. The fellowship supports top-tier researchers at US universities.

- Pablo Jarillo-Herrero was elected a 2018 American Physical Society Fellow. He was also named Cecil and Ida Professor of Physics. His team's discovery of "magic-angle graphene"—graphene that behaves like a high-temperature superconductor—was selected by PhysicsWorld as Physics Breakthrough of the Year.
- David Perrault and his colleagues were awarded Second Prize Paper Award by *IEEE Transactions on Power Electronics* in September 2018.
- Song Han was selected as one of *MIT Technology Review*'s "35 Innovators Under 35" for his work in making the software that lets powerful artificial intelligence programs run more smoothly.
- Vivienne Sze won the MIT Edgerton Faculty Award and was recognized for technical innovation, educational excellence, and efforts to advance women and underrepresented minorities in her field.
- Jesús del Alamo was elected a fellow of the Materials Research Society for his extraordinary contributions to the physics, design, process technology, and reliability of III-V compound semiconductor transistors, and for his sustained commitment to knowledge dissemination among students and researchers.
- Dimitri Antoniadis and Anantha Chandrakasan were elected to the American Academy of Arts and Sciences for 2019.
- Eugene Fitzgerald was appointed chief executive officer and director of the Singapore-MIT Alliance for Research and Technology.
- Juejun Hu received an Early Career Achievement award in recognition of his original contributions to integrated optics and photonics through innovative material and device engineering.
- Lisa Kong was given the Outstanding Senior Thesis Award by the Department of Materials Science and Engineering. Kong's undergraduate thesis, "High-Resolution Transmission Electron Microscopy of III-V FinFETs," was reserached and written under the supervision of Professor Jesús del Alamo.
- Natalya Bailey and Adam Marblestone were included in "35 Innovators under 35" by *MIT Technology Review*. Bailey was named for a system to propel tiny satellites using electrical energy and Marblestone for writing the book on how to record every neuron in the brain.
- Brenda Garcia received the Outstanding Paper Award for her paper, "Near-room Temperature Direct Writing of Ultrathin Zinc Oxide Piezoelectric Films via Near-field Electrohydrodynamic Jetting for High-frequency Flexible Electronics," at the 20th International Conference on Solid-State Sensors, Actuators, and Microsystems. She came to MIT as a visiting scientist under the supervision of Luis Velasquez-Garcia under the aegis of the MIT–Tecnológico de Monterrey nanotechnology program.
- Yu-Hsin Chen, a graduate student in Vivienne Sze's group, received the 2019 Outstanding Dissertation Award from the Association for Computing Machinery's Special Interest Group on Computer Architecture, Institute

of Electrical and Electronics Engineers (IEEE) Computer Society, Technical Committee on Computer Architecture at ISCA 2019. The award recognizes excellent thesis research by doctoral candidates in the field of computer architecture. Chen was cited for his "contributions to efficient and flexible dataflows and architectures for deep learning acceleration." He also received a 2018 Jin-Au Kong Award for Best PhD Thesis in Electrical Engineering at MIT. Chen did his research in the Energy-Efficient Multimedia Systems Group. His thesis was co-advised by Professor Vivienne Sze and Professor Joel Emer.

- Amr Suleiman, a graduate student in Vivienne Sze's group, received the Best Student Paper Award at the 2019 IEEE Symposium on VLSI [Very-Large-Scale Integrated] Circuits for his paper, "Navion: A Fully Integrated Energy-Efficient Visual-Inertial Odometry Accelerator for Autonomous Navigation of Nano Droness." Award recipients are selected based on the quality of their written papers and the quality of their presentations at the symposium.
- Scott Tan was named in Forbes' "30 Under 30" for his work in developing an artificial synapse made of single-crystalline materials as part of an effort to develop neuromorphic computers. Joel Jean was also named in the Forbes "30 Under 30" list for his work on developing lightweight, flexible, and efficient solar panels based on metal-halide perovskites.

Administrative Update

MTL's staff is integral to the laboratories' infrastructure and to MTL's success. Two staff changes were announced during the reporting period. In October 2018, MTL hired Katrina Mounlavongsy as human resources administrator. MTL director Jesús del Alamo announced he will step down effective August 31, 2019.

Jesús A. del Alamo
Director
Donner Professor
Professor of Electrical Engineering