Report to the President year ended June 30, 2024,
Microsystems Technology Laboratories

Founded 40 years ago, MTL's mission is to address some of the world's most pressing challenges, including sustainability (in areas such as energy, water, and the electromagnetic spectrum), information and communication technologies, health, security, and transportation through research, education, and innovation in micro- and nanotechnologies. This requires a highly interdisciplinary approach that spans the discovery and engineering of new materials, structures, devices, integrated circuits (IC), and systems. A core pillar to many of these activities is MTL's effort on microelectronics research, which is more important than ever due to the growth of artificial intelligence, electrification of transportation, sensors to enable personalized healthcare, and the needs for a more resilient and efficient microelectronics supply chain.

Since December 2022, MTL has continued to build on its strong foundation of excellence under new leadership. The laboratory has successfully integrated with the Research Laboratory of Electronics (RLE) and completed the transfer of its microfabrication facilities to MIT.nano. These advancements have strengthened MTL's ability to support cutting-edge research and foster innovation across the MIT community.

As of 2024, MTL's core faculty comprises 67 members from seven departments across the Schools of Engineering, Science, and the Schwarzman College of Computing. While our faculty primarily come from the Departments of Electrical Engineering and Computer Science (EECS), Mechanical Engineering (MechE), Materials Science and Engineering (DMSE), and Physics, there is growing involvement from faculty in the Departments of Biological Engineering (BE), Chemical Engineering (ChemE), and Chemistry. The interdisciplinary nature of MTL's work has fostered strong collaborations with a wide range of research labs and centers at MIT, including RLE, the MIT Energy Initiative (MITEI), the Institute for Medical Engineering and Sciences (IMES), the Materials Research Laboratory (MRL), the Computer Science and Artificial Intelligence Laboratory (CSAIL), the Koch Institute for Integrative Cancer Research (KI), and the Institute for Soldier Nanotechnologies (ISN).

Historically, MTL managed shared experimental facilities in buildings 39 and 24, housing over 150 fabrication and analytical tools that served a community of approximately 400 students and postdocs. Following the completion of MIT.nano in the Lisa T. Su Building (Building 12), the administrative management of these facilities was transferred to MIT.nano at the end of FY19.

By 2024, the physical transfer of the fabrication environment, equipment, and tools to the new facilities has been fully completed, with ongoing efforts to decommission the old fabrication facility in Building 39 (Fab 39). Despite the transfer of these shared facilities, MTL continues to manage a robust information technology infrastructure supporting over 75 state-of-the-art computer-aided design (CAD) and analysis tools for device, circuit, and system design for ICs, PC boards, photonics, and MEMS. This CAD infrastructure serves a diverse MIT-wide community of more than 200 research students and postdocs, in addition to about 100 students enrolled in

EECS courses. MTL’s strong relationships with major semiconductor manufacturers continue to provide access to some of the most advanced commercial IC fabrication processes available today. Additionally, MTL supports the network infrastructure and maintains approximately 335 desktop and server machines for resident students, staff, and faculty.

Integration of MTL and RLE: Strategic Motivation and Achievements

As outlined in the 2023 President’s Report, the Microsystems Technology Laboratories (MTL) and the Research Laboratory of Electronics (RLE) embarked on an integration process in the summer of 2020. Traditionally, MTL has utilized a significant portion of the membership fees from its Microsystems Industrial Group (MIG) consortium to support research administrative services. However, these services are more effectively funded through a centralized allocation model. RLE serves as an exemplary model of this approach, with a longstanding tradition of delivering efficient and high-quality administrative services. The integration of MTL with RLE is a strategic move to preserve MTL’s resources, thereby strengthening the microelectronics community at MIT, while leveraging RLE’s best-in-class research administration capabilities.

It is essential to acknowledge that thriving intellectual communities like MTL require focused attention, which can be challenging to achieve within a larger allocation unit. The historical success of MTL underscores the value of a communal focus supported by discretionary resources that are reinvested within the community. Therefore, the integration of MTL and RLE was pursued with the following objectives:

- **Growth and Preservation of MTL's Intellectual Community**: Ensuring the continued development of MTL's intellectual community while maintaining its distinct identity and activities.
- **Enhanced Financial Resilience**: Diversifying and strengthening financial resources, including bolstering support for faculty startup packages.
- **Elimination of Legacy Barriers**: Facilitating the transfer of space to the combined RLE/MTL and decoupling space allocation from participation in intellectual communities.
- **Administrative Transition**: Moving MTL's administrative functions from MIG funding to RLE’s allocation model, ensuring sustainable support.
- **Continuation of Essential Services**: Preserving CAD/compute services, which have been integral to the MTL community for decades.
- **Leveraging Synergies**: Enhancing collaboration between MTL and the new quantum consortium within RLE’s Center for Quantum Engineering.

Progress and Achievements in Integration

As of August 2024, significant milestones have been achieved in the integration process, reflecting the successful completion of several key initiatives:

1. **Completion of Administrative Transition**: The transition of MTL's administrative functions to RLE's allocation model has been successfully completed. This shift has enabled MTL to preserve its discretionary funds, which are now being reinvested into faculty startup packages, infrastructure improvements, and other critical initiatives.

2. **Financial Integration**: The financial integration of MTL and RLE has progressed smoothly. Existing MTL contracts, originally supported by MIG funds, have been transitioned to RLE's allocation structure as they expired. All new research contracts are now fully managed under the RLE model, providing greater financial resilience and efficiency.

3. **Space and Resource Allocation**: The transfer of space to the combined RLE/MTL has been successfully executed, with a clear decoupling of space allocation from participation in intellectual communities. This has facilitated a more flexible and efficient use of resources across both laboratories.

4. **Continued Support for MTL's Intellectual Community**: MTL's intellectual community continues to thrive, with its distinct identity and activities preserved. The integration process has ensured that MTL remains a vibrant hub for microelectronics research, while benefiting from the robust administrative support provided by RLE.

5. **Sustained Essential Services**: Key services, such as CAD/compute support, have been maintained and integrated within the broader RLE infrastructure, ensuring uninterrupted service for the MTL community.

6. **Collaborative Synergies**: The integration has fostered enhanced collaboration between MTL and RLE's Center for Quantum Engineering, particularly within the new quantum consortium. This synergy is expected to lead to groundbreaking research opportunities and strengthen MIT's leadership in these emerging fields.

Conclusion and Future Outlook

The integration of MTL and RLE, initiated in 2020, has reached a critical juncture as we approach full completion. The phased approach has allowed for a seamless transition, preserving the unique strengths of both laboratories while creating new opportunities for growth and collaboration. The integration process will continue to be refined as necessary, with a focus on maintaining the distinct intellectual culture of MTL, optimizing financial resources, and leveraging the synergies between MTL and RLE to advance MIT's mission in microelectronics and beyond.

The success of this integration thus far sets a strong foundation for future endeavors, and we remain committed to supporting the ongoing needs of our faculty, students, and industry partners as we move forward.

Industry Engagements

Microsystems Industrial Group

MTL partners with industry through the Microsystems Industrial Group (MIG) consortium. The member companies within the MIG support MTL research and operations through a membership fee. Members of the MIG's Industrial Advisory Board (IAB) guide in shaping the vision of MTL.

MTL hosted its 2024 IAB meeting in person on Thursday, January 25, 2024, with representatives from 14 MIG member companies in attendance.

MIG company representatives attending the IAB meeting included: Mike DeLaus (Analog Devices), Mike Haverty (Applied Materials), David Carter (Draper), Fredrik Dahlgren and Joel Schleeh (Ericsson), Ted Letavic (GlobalFoundries), Hiroshi Suzuki and Junichi Tanaka (Hitachi High-Tech. Co.), Dirk Pfeiffer (IBM), Esther Jeng (Lam Research), John Callahan (Lockheed), Aki Sato and Johan Suzuki (MuRata), Sota Kagami (NEC), Ionet Radu (Soitec), Michael Perrott (Texas Instruments), and Gary Chen (TSMC).

In addition to the special connection that exists between MTL and its MIG companies, MTL is also committed to bringing into the MTL ecosystems those industry leaders that have demonstrated a strong multi-year commitment to supporting both MTL's research mission in microsystems and microelectronics, as well as its community and students. To formalize this, in 2023 MTL created the MTL Research Associates Group, with the companies Ericsson and Soitec as founding members of this group.

In March, MTL hosted the first virtual research forum with new member GlobalFoundries on March 11, with faculty presenting on research topics of mutual interest to partnership.
The first onsite GlobalFoundries Research Forum took place on Thursday, May 23 featuring an all-day presentation and information program with 45 staff and faculty participants from both MIT and GlobalFoundries.

Visitors

MTL has a longstanding tradition of fostering collaboration between industry and academia by hosting esteemed visitors who contribute to and strengthen our community. Recent examples include visits from research scientists from the Mongolian University of Science and Technology in July 2023, as well as key industry leaders from Hitachi, Samsung, NEC, Ericsson, Intel, and Lam Research throughout 2023 and 2024. These engagements not only enhance our research capabilities but also provide invaluable opportunities for knowledge exchange and partnership development.

Special Seminars

MTL actively engages the academic and industry community through a variety of technical events, including our renowned MTL Seminar Series, held each fall and spring. Organized by a dedicated committee chaired by Dr. Luis Velásquez-Garcia, these seminars cover a wide range of technical topics and are open to the public, fostering a culture of knowledge sharing and collaboration. In addition to the regular series, MTL also hosts special seminars featuring distinguished speakers. Notable events include Dr. Jinseong Heo from Samsung, hosted by Prof. Jeehwan Kim, and Junichi Tanaka and Michael Kwon from Hitachi, hosted by Prof. Tomas Palacios, as well as a special seminar with Dr. Ulrich Rohde.

Career Fair

MTL, MIT.nano, the Center for Quantum Engineering (CQE) and the AI Hardware Program held a joint Deep Tech Career Fair on September 21, 2023, at MIT. This Career Fair was organized, for the first time, along the Charles Vest Student Street in the Stata Building and was a great success with an estimated 200+ students. These students interacted with representatives from 15 MIG, MAP (MIT.nano's industrial consortium) QSEC (CQE's industrial consortium) and AI Hardware Program companies including Analog Devices, GlobalFoundries, Hitachi, Texas Instruments, and Lam Research from the Microsystems Industrial Group.

MARC

Held at the Omni Mount Washington Resort in New Hampshire on January 23-24, 2024, MARC gathered over 250 MIT students, faculty, staff, and industry partners to chart the future of microsystems and nanotechnology. Now in its 20th year, the student-run conference is organized by the Microsystems Technology Laboratories (MTL) and, since 2020, co-sponsored jointly with MIT.nano.

This year marks the 40th anniversary of MTL, which first opened at MIT in 1984. The anniversary was highlighted in the MARC 2024 conference theme: MTL@40 - Manufacturing Technology Leadership for the next 40 years.

The two-day conference was a reflection on what has been accomplished—both by MIT students who presented their latest research and by corporate partners who spoke about the growth they have seen in the microelectronics industry—as well as an opportunity to look to the future and the next set of discoveries.

In the opening keynote, Ted Letavic, corporate fellow and senior vice president of technology innovation at GlobalFoundries, spoke about his career in semiconductors and lessons he has learned over his 30 years in the industry. The following day, two panel discussions featured insights from company representatives who are part of the MTL Microsystems Industrial Group (MIG) and MIT.nano Member Advisory Panel (MAP). The first, titled "40 Years: Reflections on the Past and Visions for the Future," comprised leaders from Applied Materials, Ericsson, IBM, and Texas Instruments. A second panel that focused on the transition from academia to industry highlighted the journeys of panelists from Analog Devices, Lam Research, Soitec, and UpNano.

MARC2024 broke several records from previous years, including number of attendees and research abstracts. More than 130 student abstracts were presented, showing the breadth of research happening at MIT on microsystems, semiconductors, and nanotechnology.

MARC 2024 was held in conjunction with the QSEC Annual Research Conference, which took place on January 22 and 23, also at Bretton Woods. MIT students and faculty, as well as industry affiliates, were encouraged to attend both events and experience a breadth of research and engineering in materials, structures, devices, circuits, and systems.

More information about the MARC2024 event can be found here: https://www.mtl.mit.edu/news/student-led-event-brings-together-micro-and-nano-communities-across-academia-and-industry

Caption: More than 200 students, faculty, industry members and staff gathered for the 2024 Microsystems Annual Research Conference – a 2-day student-led conference highlighting the latest research in microsystems and nanotechnology.

Microsystems Annual Research Report

As with the Microsystems Annual Research Conference (MARC), the Microsystems Annual Research Report, started by MTL many years ago, has become a joint effort between MTL and MIT.nano in the recent years.

The 2024 MTL/MIT.nano joint Microsystems Annual Research Report represents a broad crosssection of the MIT community, with 37 faculty, 100+ students, postdoctoral associates, and research staff participating. The 180+ abstracts are organized in 11 topical areas including:

- 3DHI & Additive Manufacturing
- Circuits & Systems
- Electronic, Magnetic & Spintronic Devices
- Materials - Synthesis & Characterization
- Medical Devices & Biotechnology
- MEMS, Field-Emitter, Thermal, Fluidic Devices & Robotics
- Nanoscience & Nanotechnology
- Neuromorphic Devices & AI Hardware Accelerators
- Photonics and Optoelectronics
- Power Devices and Circuits
- Quantum Science and Engineering

MTL Research: Advancing Innovation Through Collaborative Centers

Research Overview

The Microsystems Technology Laboratories (MTL) at MIT is a hub of cutting-edge research, characterized by an extraordinary breadth of activities that center around microsystems. These systems leverage the unique attributes of micro-scale and nanoscale devices and circuits to address some of the most pressing challenges facing humanity today. MTL faculty are at the forefront of developing technologies that explore new materials and structures, innovative nanofabrication techniques, advanced devices, novel circuit concepts, groundbreaking system architectures, and algorithms to synthesize complex systems that push the boundaries of what is possible.

MTL's research spans a wide array of disciplines, including integrated circuits and systems, electronic and photonic devices, MEMS, bio-MEMS, molecular devices, nanotechnology, sensors, and actuators, among others. The materials investigated go beyond traditional silicon and germanium to include III-V compound semiconductors, nitride semiconductors, graphene, other 2D materials, polymers, glass, organics, and many more. A comprehensive selection of the projects currently under investigation is detailed in our Annual Research Report.

Research Centers and Initiatives

MTL's research is organized under a number of interdisciplinary Research Centers and Initiatives, where faculty with shared interests collaborate to explore novel concepts. These centers are supported by consortia of companies that pool resources to tackle the challenges and opportunities presented by new technologies. Each center is characterized by one or two annual symposia where research findings are presented and discussed. The following are key research centers under the MTL umbrella:

- **Center for Integrated Circuits and Systems (CICS)**: Spearheading research in circuits and systems design, CICS focuses on applications ranging from artificial intelligence and wireless communication to biomedicine and quantum information.
- **MIT-MTL Center for Graphene Devices and 2D Systems (MIT-CG)**: This center unites MIT researchers and industry partners to advance the science and engineering of graphene and other two-dimensional materials, targeting transformative applications in areas like energy storage, optoelectronics, and RF communications.
- **MIT-MTL Gallium Nitride (GaN) Energy Initiative**: Focused on developing and deploying energy-efficient GaN-based technologies, this initiative addresses the growing demand for advanced power electronics.
- **Medical Electronic Device Realization Center (MEDRC)**: Aiming to revolutionize medical diagnostics and treatments, MEDRC works to bring healthcare directly to individuals, laying the foundation for a future information-driven healthcare system.
- **AI Hardware Center**: Driving innovation at the intersection of academia and industry,

the MIT AI Hardware Center focuses on advancing next-generation AI hardware and software technologies, emphasizing energy-efficient systems for AI and quantum computing.

MTL Activities in the Context of the CHIPS and Science Act

The CHIPS and Science Act was signed into law by President Biden on August 9th, 2022, with the goal of strengthening the research, development and manufacturing of semiconductors and microelectronics in the US. MTL has been heavily involved in many programs related to the CHIPS Act including the following:

- Department of Defense's Microelectronics Commons. MTL, representing MIT, is a founding member of the Northeast Microelectronics Coallition (NEMC), one of the 8 Microelectronics Commons Hubs. In addition, Prof. Palacios represents MIT in NEMC's advisory board.
- In the context of NEMC, Applied Materials, a long time MIG company, provided more than $35M in new equipment to enhance the nanofabrication capabilities at MIT.nano.
- Thanks to NEMC, MTL received a grant to expand the Northeast Microelectronics Summer Internship Program (NMIP), which connects first-year and sophomore students with internships in microelectronics.
- MTL coordinated MIT's response to the Microelectronics Commons' 2024 Call for Proposals, and subsequent Call for Topics. Several projects were submitted for DOD consideration in February 2024 with strong MIT presence, and we expect awards to be announced in September 2024.
- MTL has worked closely with colleagues at Carnegie Mellon University and more than 100 other partners to put together a proposal for the NIST-sponsored US Manufacturing Institute on Digital Twin Technology for Microelectronics.

2024 Research Highlights

A few of MTL's notable research results are highlighted below, while the MTL website and Annual Report holds more comprehensive details on MTL activities, people, awards, and research accomplishments.

Prof. Duane Boning

Prof. Duane Boning's group focuses on machine learning methods to understand, model, and control variation in manufacturing and design, with an emphasis on IC and silicon photonic processes, devices, and circuits. A highlight of this year's research is his work to support design for manufacturability (DFM) and advanced process control (APC) in integrated circuits and silicon photonics. A key enabler in this work are Bayesian inference and Bayesian optimization (BO) machine learning approaches. A joint project with Samsung is exploring physics-informed modeling approaches for plasma etch BO. In applications to silicon photonics design, new automatic synthesis methods have been proposed to implement light processing (filters, routing) functions on programmable photonics fabrics. A collaboration with Analog Devices has resulted in new dynamic time warping approaches to better align sensor time series signals, with improved anomaly detection as a result. Finally, in collaboration with Prof. Carl Thompson, a novel machine learning approach using differential evolution has been proposed, showing how to identify multiple failure mechanisms from device reliability data.

Prof. Anantha Chandrakasan

Prof. Chandrakasan's research focuses on the advancement of ultra-low power wireless systems for the Internet of Things (IoT). A key project this year tackles the challenge of deploying wireless energy harvesting backscatter systems within licensed frequency bands to enhance energy efficiency and connectivity, eliminating the reliance on conventional batteries and high-power radios. This work addresses gaps in prior research, which either focused on improving rectifier sensitivity without integrating ultra-low power backscattering circuits or sacrificed sensitivity by increasing active communication power—leading to prolonged wake-up times at low power levels, a critical issue in applications such as rapid inventory counting in IoT-enabled warehouses.

In this project, a comprehensive backscattering integrated circuit (IC) was developed to operate in the 3.5GHz CBRS band, efficiently harvesting RF energy and initiating backscattering with less than a microwatt of available power. The innovation is rooted in its ultra-low power architecture, incorporating a current-starved ring oscillator with minimal line sensitivity and self-clocked signal encoding, which obviates the need for power-hungry low-dropout regulators (LDOs). Transient and backscattering measurements revealed the system's capability to maintain stable operation even at low power levels, achieving rapid energy storage within 18 seconds of wake-up, and backscattering encoded data, all within a compact $0.7cm^2$ footprint.
The system's superior performance in sensitivity, area efficiency, and suitability for low-power IoT applications positions it as a highly promising solution for next-generation batteryless IoT tags.

Prof. Jesús del Álamo

We have developed a back-end-of-the-line (BEOL) CMOS-compatible electronic platform based on an ultra-thin In_2O_3 amorphous channel fabricated by plasma-enhanced atomic-layer deposition. Enhancement-mode field-effect transistors (FET) with record transport characteristics in the ON regime at a reduced voltage have been demonstrated. We have found that channel width scaling enables a more positive threshold voltage coupled with a dramatic improvement in the current capability, both highly desirable attributes. We have further integrated ferroelectric (FE) memory functionality into the platform and show single FE domain switching in FE-FETs with highly-scaled active area. Ultrafast switching down to the 10 ns instrument limit, excellent retention over 1000 s, and outstanding write endurance of 10^7 cycles have been demonstrated. Using discrete domain switching as a sensitive probe, individual domain wake-up and fatigue have been observed. Our work reveals exciting physics in nanoscale BEOL devices with potential for future logic and memory applications.

Prof. Ruonan Han

RFID technologies are widely adopted in secure supply chain management for item tracking and goods integrity. While tag miniaturization and cost-effective, package-less fabrication promote ubiquitous tagging, and embedded security protocols enable tag authentication, they do not prevent anti-tampering attacks without the use of fragile packaging materials. For example, an attacker can detach a tag from a genuine item and attach it to a fake, leading the tag reader to mistakenly authenticate the counterfeit as genuine. To address this issue, Prof. Han's group, in collaboration with Prof. Chandrakasan's group, developed an anti-tampering tag that uses sub-THz waves to detect unique and hard-to-replicate fingerprints formed by metal particles in the adhesive. The tag chip, sized at 4.2 mm^2, is prototyped using the TSMC 65nm CMOS process. The tag contains minuscule slots that allow sub-THz waves to pass through and interact with microscopic metal particles mixed into the adhesive. The tag re-radiates the sub-THz signal from the reader through a slot, where it undergoes complex scattering based on the adhesive pattern below the chip before being sensed by another slot and backscattered to the reader. Having multiple slots in the chip creates more complex scattering information, serving as an analog fingerprint that is difficult to replicate. Any attempt to detach the tag destroys the pattern and the analog fingerprint, thereby enabling tamper detection. Using this hardware, the team demonstrated neural network-based authentication that effectively distinguishes tag responses, achieving 99% accuracy.

Prof. Song Han

Prof. Han's groundbreaking work on Activation-aware Weight Quantization (AWQ) is revolutionizing on-device large language model (LLM) inference. AWQ, which enables efficient 4-bit LLM quantization, significantly reduces the model size and accelerates performance, making it possible to deploy 13B LLMs on devices like a MacBook and Jetson Orin. This innovation addresses key challenges in on-device LLM deployment, such as reducing memory footprint while maintaining accuracy. AWQ's impact is evident with its selection as the Best Paper at MLSys'24 and its widespread adoption, evidenced by 6 million downloads on HuggingFace. Prof. Han's AWQ project not only brings LLMs closer to the edge but also ensures they run efficiently and securely without relying on cloud infrastructure. AWQ has been widely adopted by industry, including: Intel Neural Compressor, NVIDIA TensorRT-LLM, Amazon SageMaker, Google Vertex AI, AMD, vLLM, HuggingFace.

Prof. Luqiao Liu

Prof. Liu and his team have been focused on investigating new materials for useful memory and logic devices. Specifically, they have made the following major achievement: they discovered an efficient mechanism to electrically read out the magnetic state from an antiferromagnet – magnetic material with canceled magnetic moments from two competing spin lattices [Nature Communication, in press]. Traditionally it was believed that antiferromagnet cannot carry spin current due to their zero net moment, therefore will not exhibit finite magnetoresistance for useful magnetic reading operations. Liu's study reveals the important role of symmetry breaking in yielding a large antiferromagnetic tunneling magnetoresistance, which provides an efficient reading mechanism for magnetic memory and spin logic. This, in combination with the writing mechanism that they discovered earlier pave the avenue for useful antiferromagnetic spintronics.

Prof. Harry Lee

In collaboration with Prof. Charles Sodini, Prof. Lee's group has developed a new method to continuously evaluate hemodynamic function in critically ill patients. Treatment of circulatory shock in these patients requires management of blood pressure using invasive monitoring, but uncertainty remains as to optimal individual blood pressure targets. Critical closing pressure, which refers to the arterial pressure when blood flow stops, can provide a fundamental measure of vascular tone in response to disease and therapy, but it has not previously been possible to measure this parameter routinely in clinical care. Based on previous research on hemodynamics measurements and in collaboration with Massachusetts General Hospital, the Lee and Sodini groups introduced a new method to continuously measure critical closing pressure in the systemic circulation using readily available blood pressure monitors and then show that tissue perfusion pressure (TPP), defined as the difference between mean arterial pressure and critical closing pressure, provides unique information compared to other hemodynamic parameters. Using analyses of 5,988 admissions to a modern cardiac intensive care unit, and externally validated with 864 admissions to another institution, we show that TPP can predict the risk of mortality, length of hospital stay and peak blood lactate levels. These results indicate that TPP may provide an additional target for blood pressure optimization in patients with circulatory shock. This research provided a critical insight in the human circulatory system and gave rise to a new research project, extending it to the blood perfusion research to eyes, especially for glaucoma patients. This work is in collaboration with Profs Heldt and Sodini, and is funded by Analog Devices.

Prof. Tomás Palacios

The Palacios' group, in close collaboration with Prof. Jing Kong, demonstrated the first multi-channel highly-scaled MoS_2 transistor. This device and the detailed system-technology co-optimizatin (STCO) that it allowed are important steps to continue Moore's law and the relentless improvement of microelectronics beyond the 1-nm technology node. A key building block of this novel device is the low temperature growth of a single layer of MoS_2 over entire 8" Si wafers reported in 2023 (Nature Nanotech, 18(5):456-463, 2023). The group used multiple sequential growths tointegrate two different channels and gate dielectrics on top of each other in a CMOS compatible approach. This development allows to double the current drive of MoS_2 transistors with minimum increase in parasitic capacitances, , which minimizes delays and power consumption in future electronics.

Prof. Vivienne Sze

Professor Vivienne Sze works on energy-efficient computing systems for autonomous navigation, digital health, and embedded devices. Key advances include: 1) With Sertac Karaman, development of a memory-efficient method called GMMap to build a 3D map of the environment that can be used for autonomous navigation. 2). Compute-in-memory (CiM) accelerators can reduce data movement for AI tasks. With Joel Emer, they developed an open-source tool called CiMLoop to model diverse CiM systems and explore decisions across the CiM stack. The Sze group received the 2024 ISPASS Best Paper Award (May 2024) for the paper entitled "CiMLoop: A Flexible, Accurate, and Fast Compute-In-Memory Modeling Tool" at the IEEE International Symposium on Performance Analysis of Systems and Software (ISPASS).

MTL/MIT.nano Collaboration and Facilities Update

As of August 2024, the physical transfer of fabrication equipment to MIT.nano, located in the Lisa T. Su Building (Building 12), has been successfully completed. Equipment that was deemed unsuitable for the MIT.nano facility has been either sold or donated. The remaining machinery in Building 39, along with various peripheral components, is scheduled to be sold, traded in, donated, or scrapped in the coming months. This preparation is in anticipation of the future floor-by-floor remodeling of Building 39, as outlined in the 2017 Comprehensive Renovation and Space Planning (CRSP) Study. The remodeling will retain essential infrastructure, such as the deionized water plant, acid wastewater neutralization systems, and exhaust fans, which continue to serve private laboratories in Buildings 37, 38, and 39.

All users have now fully transitioned to the state-of-the-art fabrication facilities in Building 12, and all fabrication staff members are now based there. Fiscal responsibility for all fabrication operations has been formally transferred to MIT.nano. MTL's seven-year agreement with MIT.nano, established to provide financial support until 2023 by allocating $50,000 of the $150,000 MIG Membership fee received from each company, remains in effect on an interim basis. This arrangement will continue until a new agreement is formalized.

MTL Outreach and Educational Activities

SuperUROP and UROP Programs

The SuperUROP and UROP programs engage MIT undergraduate students and promotes direct interaction with faculty and industry sponsors, cultivates student creativity and professional development, and encourages students to consider the ethical and entrepreneurial aspects of their work. In FY24, there were 10 undergraduate students in the program working in MTL.

Northeast Microelectronics Internship Program

MTL in close collaboration with Mass Tech Collaborative under the Northeast Microelectronics Coalition (NEMC) HUB continues to support the, Northeast Microelectronics Summer Internship

Program (NMIP). This program received a grant from the NEMC hub under the CHIPS and Science Act to expand its outreach. The NMIP program aims to connect first-year and sophomore undergraduate students with summer internships in the microelectronics industry. Since its 2020 inception at MIT the program has connected with 500+ applicants from 63 educational institutions. The program works with 30+ partner companies. For Summer 2024, students interned at MACOM, IBM, MITRE, MIT-LL, Evolve Diamonds, Intel, SpaceX, MIT-LL, Draper, Finwave Semiconductors Inc., and Northrop Grumman Corp. The program is led by MTL project coordinator Preetha Kingsview along with Prof. Tomás Palacios serving as faculty director.

MTL Seminar Series

MTL engages the community in several technical events and programs throughout the year. In both fall and spring, the laboratory hosts a seminar series spanning diverse technical areas. The seminars are organized by a committee chaired by Dr. Luis Velásquez-Garcia, and all seminars are open to the public. In addition to these regular seminars, MTL hosts one Doctoral Dissertation Seminar (DDS) each semester featuring a speaker selected from recent MTL Ph.D. graduates, as well as occasional Executive Seminars featuring senior leaders from the MIG member companies. In December 2023, Dr. Rishabh Mittal's dissertation, " A 1-GHz Bandwidth CT Pipelined ADC with Reduced Sensitivity to Clock Jitter," was selected for DDS presentation. Dr. Mittal conducted his Ph.D. under the supervision of Prof. Hae-Seung Lee and Prof. Anantha P. Chandrakasan. In May 2022, the DDS award winner was Dr. Atharva Sahasrabudhe, who presented his dissertation, "Multifunctional Wireless Gut-Brain Neurotechnology." Dr. Sahasrabudhe conducted his Ph.D. under the supervision of Prof. Polina Anikeeva.

nanoLab with the Tecnológico de Monterrey

Since 2015, MTL's Dr. Luis Velasquez-Garcia has been hosting students, postdocs, and faculty from Tecnológico de Monterrey every year in six separate one-week sessions of the nanoLab hands-on course on nanotechnology; the nanoLab is part of the Monterrey Tec - MIT Nanotechnology Program. The nanoLab is divided in online lectures and hands-on laboratory work at the MIT.nano cleanroom; there is no occupation limit for the online classes, but there is an 8-person limit per session for the cleanroom laboratory. For the 2024 program, there have been 2 spring sessions with 113 attendants on-line and 16 attendants in the cleanroom, 2 summer sessions with 83 attendants online and 16 attendants in the cleanroom; 2 more sessions during the fall are scheduled with ~98 people attending the online sessions (~49 people per session, from historical trends) and 16 more people attending the cleanroom session (8 people per session). Given the large success of the nanoLab, Dr. Velasquez-Garcia is currently working on creating a second course on 3D-printed micro and nanosystems, and a third course on micro and nanofabrication fundamentals.

MTL Core Faculty Promotions, Awards, and Honors

MTL faculty, staff and students regularly receive recognition for their research contributions and accomplishments with numerous national and international awards. The following are some of these awards and distinctions during the reporting period:

- Moungi G. Bawendi receives The Nobel Prize in Chemistry 2023 “for the discovery and synthesis of quantum dots.”
- Jesus del Alamo and Yanjie Shao receive Intel’s 2023 Outstanding Researcher Award May 2024.
- Will Oliver named 2023 AAAS Fellow.
- Karl Berggren named 2024 MacVicar Faculty Fellow.
- Marc Baldo elected to the National Academy of Engineering 2024.
- Luca Daniel receives 2023 Bose Grants for daring new research.
- Yufeng Kevin Chen awarded the 2023 Bioinspiration & Biomimetics Steven Vogel Young Investigator Award.
- Joel Emer awarded the 2023 B. Ramakrishna Rau Award by the IEEE Computer Society.
- Dirk Englund elected a Fellow of the IEEE “for contributions to semiconductor quantum photonics and machine learning”.
- Farnaz Niroui, awarded the Junior Bose Award by the MIT School of Engineering.
- Kevin O’Brien awarded an Air Force Office of Scientific Research (AFOSR) Young Investigator Program (YIP) Award for 2024.
- Iwnetim Abate received the Young Scientist Investigator Award from ISSI 2024.
- Jing Kong named the Jerry Mcafee (1940) Professor In Engineering, effective July 1, 2024.
- YuFeng (Kevin) Chen promoted to Associate Professor Without Tenure, effective July 1, 2024.
- Farnaz Niroui promoted to Associate Professor Without Tenure, effective July 1, 2024.
- Dirk Englund promoted to Full Professor, effective July 1, 2024.
- Vivienne Sze promoted to Full Professor, effective July 1, 2024.
- Polina Ankeeva named head of the Department of Materials Science and Engineering effective July 1, 2024.
- Ruonan Han was presented the 2023 IEEE Solid-State Circuit Society New Frontier Award.

New Faculty

- Suraj Cheema joined the Department of Materials Science and Engineering, with a joint appointment in the Department of EECS, as an assistant professor in July 2024.
- Samantha Coday joined the Department of EECS as an assistant professor in July 2023.
- Joseph Casamento joined the Department of Materials Science and Engineering as Morris Cohen (1933) Career Development Chair, Assistant Professor.

- Roozbeh Jafari joined Lincoln Laboratory Biotechnology and Human Systems, and he is playing a key role to connect Lincoln Laboratory with LIDS and MTL, January 2024.

Other

- Tomás Palacios: "The SUPREME Center of the JUMP 2.0 Program" second Annual Review June 2024 (SUPREME microelectronics research center funded through the JUMP 2.0 consortium of the Semiconductor Research Corporation (SRC) and its partner); NMIP awarded $75,000 to expand the existing Northeast Microelectronics Summer Internship Program (NMIP) January 2024; Tomás Palacios joined IMB-CNM's Scientific Advisory Board - CSIC appointment
- Jelena Notaros group demonstrate first chip-based 3D printer June 2024
- Song Han - 1st Place Award, ACM Quantum Computing for Drug Discovery Contest and AWQ team received Best Paper Award of MLSys 2024; presented "EfficientViT: Multi-Scale Linear Attention for High-Resolution Dense Prediction" at Google 12/23; presented "AWQ: Activation-aware Weight Quantization for LLM Compression and Acceleration" at Apple 12/23; QuantumNAS team awarded 1st Place in ACM Quantum Computing for Drug Discovery Contest at ICCAD 2023
- Negar Reiskarimian and Soroush Araei received the Best Student Paper Award at IEEE Radio Frequency Circuits Symposium
- Duane Boning, Associate Director, MTL, received the EECS Burgess (1952) & Elizabeth Jamieson Award, named Vice Provost of International Activities (August 2024)
- Professors George Verghese, David Perreault, and John Kassakian publish the second edition of Principles of Power Electronics (Cambridge University Press) 32 years after the first edition
- Vladimir Bulović, Director, celebrated the 5-year anniversary of mit.nano

Respectfully submitted,

Tomás Palacios
Director, Microsystems Technology Laboratories