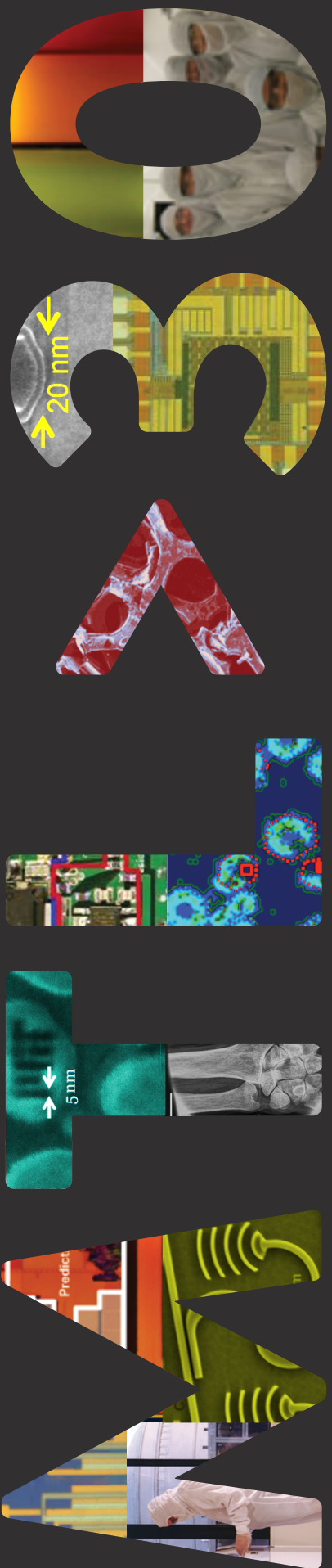
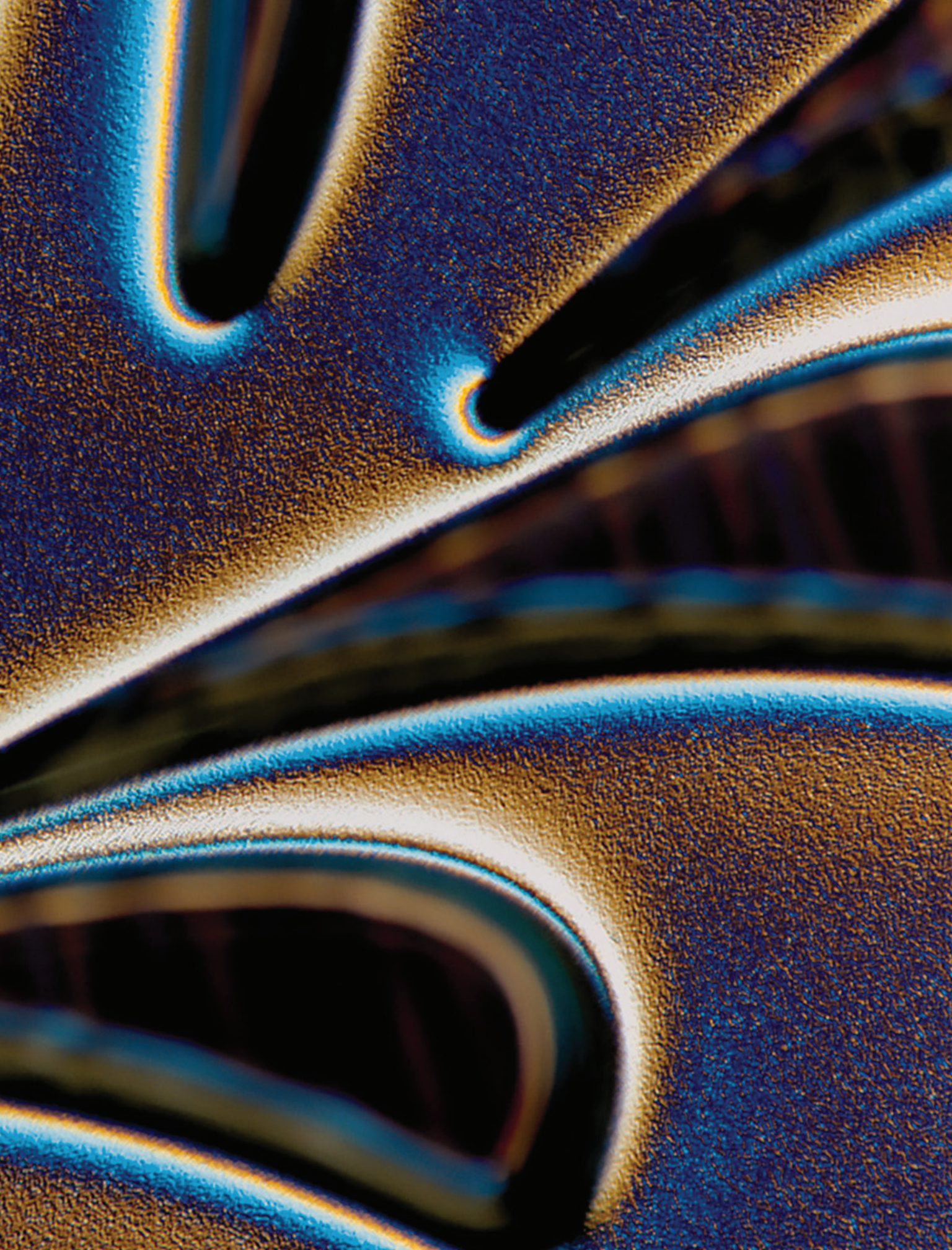
CELEBRATING 30 YEARS OF MICROSYSTEMS TECHNOLOGY AT MIT

October 29-30, 2014



Massachusetts Institute of Technology



Dear Symposium participants,

Thank you for joining us in the celebration of the 30th anniversary of the Microsystems Technology Laboratories of MIT. With this symposium, we want to celebrate the numerous accomplishments of the broad MTL community over the last 30 years and share our dreams about the great potential of micro- and nano- technologies for years to come. While we rejoice in past achievements, this symposium is mostly about the future, hence the ">" symbol in the name "MTL>30." Engineering and science of the very small continues to surprise and delight us. In addition, the nano world may very well hold the key to solving some of the world's most urgent challenges.

We hope you enjoy the program.

— **Charles G. Sodini,** *Clarence J. LeBel Professor, Department of Electrical Engineering and Computer Science, MIT*

— **Jesús A. del Alamo,** *MTL Director & Donner Professor, Department of Electrical Engineering and Computer Science, MIT*

Facing page: detail of microengine fabricated in MTL. Photo, Felice Frankel.

"I was fortunate to be the first junior faculty recruit in the resurgence of silicon microelectronics at MIT in the late 70's. I still remember vividly the afternoon that Paul Penfield walked into my office in Building 13 and told me "...you better sit down... we [MIT] have decided that we must build a state-of-art microelectronics lab and you will head the project." With the untiring help of many colleagues including my early MIT mentors and other senior faculty, and in particular the junior faculty that joined the effort since and went on to illustrious careers at MIT, MTL became a reality a few years after. But the MTL labs were not launched out of a vacuum. They came out of the microelectronics instruction lab in Building 13, that by the time I joined was already helping support a small number of research projects. Having cut their teeth in the challenges presented by running and expanding that lab, the early MTL transition technical staff and most notably Tony Colozzi, proved invaluable in the site selection, design and building of MTL as we know it today. Looking back 30+ years and contemplating the impact that MTL has had on our innovation-fostering education environment and on the careers of innumerable graduate and undergraduate students, it is with great pride that I extend my greetings to all on the occasion of this wonderful celebration."

DIMITRI ANTONIADIS (MTL Director, 1984–1989)

Program

WEDNESDAY, OCTOBER 29, 2014

CAMBRIDGE MARRIOTT HOTEL, KENDALL SQUARE, CAMBRIDGE, MA

6:00pm **Reception**

7:00pm **Dinner**

WELCOME
Jesús A. del Alamo, *MTL Director & Donner Professor, Department of Electrical Engineering and Computer Science, MIT*

8:00pm OPENING REMARKS
Charles G. Sodini, *Clarence J. LeBel Professor, Department of Electrical Engineering and Computer Science, MIT*

L. Rafael Reif, *President, MIT*

8:10pm DINNER SPEAKER
Robert Kahn, *Chairman, CEO & President, Corporation for National Research Initiatives*

The Role of Infrastructure in Microsystems Development from Single Chips to Trillions of Interconnected Devices and Other Things

Dr. Kahn will discuss the important role that infrastructure plays in microsystems development. He will focus primarily on networking and network-based infrastructure such as the MOSIS system that enables researchers to access shared VLSI fabrication runs at low cost and the MEMS and Nanotechnology Exchange that helps researchers to implement MEMS/nanotechnology devices and systems. Dr. Kahn will discuss the application of such technology to a broad range of emerging needs such as the so-called “Internet of Things” along with the need for a framework that supports interoperability of heterogeneous systems.

"This facility (MTL) is of great interest to industry, which includes a broad spectrum of the electronics industries and computer industries. That interest is as much for the manpower that it would permit us to train effectively as it is for the specific programs of research which will be undertaken. The industry recognizes that its productivity in the area of design and development of integrated circuits is of vital interest to both the economic and defense status of the United States. Both the manpower and idea components which can be contributed by the university are of great importance in this national context."

—Memo from R.B. Adler, March 10, 1981.

RICHARD ADLER (MTL Director, 1989–1990)

THURSDAY, OCTOBER 30, 2014

6TH FLOOR, MEDIA LAB, BLDG. E14, MIT

8:30am **Opening Remarks**
Jesús A. del Alamo, *MTL Director & Donner Professor, Department of Electrical Engineering and Computer Science, MIT*

8:35am **Martin A. Schmidt,** *Provost, MIT*

8:40am **Paul Gray,** *Professor Emeritus & President Emeritus, MIT*

8:45am **Paul Penfield,** *Professor Emeritus, Department of Electrical Engineering and Computer Science, MIT*

8:55am **Dimitri Antoniadis,** *Ray & Maria Stata Professor, Department of Electrical Engineering and Computer Science, MIT (via video)*

Keynote Session

SESSION CHAIR: **Charles G. Sodini,** *Clarence J. LeBel Professor, Department of Electrical Engineering and Computer Science, MIT*

9:00am KEYNOTE 1
Ahmad Bahai, *Chief Technology Officer, Texas Instruments*
Pervasive Solid State Electronics—Promises & Challenges

Astonishing progress in silicon devices and circuits and highly reliable mass manufacturing techniques have prompted unprecedented revolutions in electronics for the last 4 decades to the extent that electronics is increasingly permeating our life. While there is a lot more to be gained from silicon, clearly no exponential trend is forever. Therefore, a slower and possibly linear improvement in silicon performance will face a growing challenge to keep up with exponential demands. What does it mean for the future of ever-growing solid state electronics, or are there other exponents at work? A daunting challenge worth spending a talk on!

"As I reflect on my time in MTL, what stands out most is the lab's remarkable culture of collegiality and collaboration. The great discoveries that have emerged from MTL's centers and programs are a direct product of the value the lab places on interaction and community. When you share equipment, you share problems, strategies, ideas and ambitions—and you gain the insight and creativity of all the brilliant people around you.

In the Director role, I gained a perspective that continues to shape who I am as an administrator. I will always be grateful for the lessons I learned and the relationships I built during my years leading one of MIT's greatest treasures. I send my best wishes to those who have called MTL home, and I am thrilled to be able to participate in the celebration of this important milestone."

L. RAFAEL REIF (MTL Director, 1990–1999)

9:45am

KEYNOTE 2

Jack Sun, *Vice President of Research and Development & Chief Technology Officer, Taiwan Semiconductor Manufacturing Company*

Collaborative Semiconductor Innovation—The Next Frontiers

A holistic and energy-efficient 3Dx3D system scaling approach can provide most of the computation throughput and special functions required for emerging applications. It can extend semiconductor innovation into the next decade to enhance future lifestyles and drive the growth of the silicon-based nano-electronics industry. There are many new frontiers in 3D transistor, interconnect, specialty technology, 3D packaging, circuit design, system architecture, and applications with interesting opportunities and challenges ahead to be explored and conquered by a collaborative, synergistic, and symbiotic semiconductor ecosystem which unleashes innovation. Besides the internet of things (IoT), cloud computing, and big data analytics, we can imagine a bionic age emerging with digitally-enhanced or semiconductor-augmented vision, hearing, limbs, and many other capabilities, such as cognitive computing, universal translators, and brain wave interfaces/communications.

10:30am

BREAK

10:45am

Panel Discussion I: Education for the Future of Nanotechnology/ Nanosystems Students

MODERATOR: **Thomas H. Lee,** *Professor of Electrical Engineering, Stanford University*

This panel will feature some of our more established alumni to discuss their views on the most important features of their education at MTL and MIT that helped them with their career paths. Panelists have had careers in large, medium, and start-up companies—in microelectronics and other related fields—as well as academic careers. The panel will be asked to project to the future and comment on the role over the next 30 years of the modern research university, with advice for current students.

PANELISTS:

Mark Allen, *Alfred Fitler Moore Professor, University of Pennsylvania*
Kush Gulati, *Executive Director and General Manager of the Advanced IP Solutions Group, Maxim Integrated*
Vida Ilderem, *Vice President, Intel Labs, Intel*
Craig Keast, *Associate Head, MIT Lincoln Laboratory*
David White, *Senior R&D Group Director, Cadence*

12:15pm

Student/Postdoc Poster Presentations & Demonstrations (60-SECOND "ELEVATOR" PITCHES)

SESSION CHAIR: **Vicky Diadiuk,** *Associate Director, Microsystems Technology Laboratories, MIT*

“Congratulations to all that contributed to creating and sustaining the remarkable community that is the Microsystems Technology Laboratories. I believe the success of MTL can be traced to the strong sense of community fostered by common interests and a commitment to shared and open resources. In addition, MTL has benefited from a very dedicated and accomplished staff, as well as deeply engaged industry representatives.

The blending of all this has produced remarkable impact in research, education, and talent development.”

MARTIN A. SCHMIDT (MTL Director, 1999–2006)

12:45pm **Lunch & Student/Postdoc Poster Session & Live Demonstrations**

1:45pm **Awards**

1:50pm **_MIT.nano:_ A Sneak Preview**

Vladimir Bulović, *Fariborz Maseeh Professor and Associate Dean for Innovation, School of Engineering, MIT*

In the spring of 2014, MIT announced the launch of MIT.nano, ***a new innovation space*** for exploration, education, prototyping, and translation of new nano/micro-scale ideas and technologies into the world. This new facility will be constructed in the heart of MIT campus (next to the great Dome) to house a comprehensive set of tools for nanoscale research. It will annually support technical endeavors of over 2000 researchers in a broad set of fields including energy, health, life sciences, materials, quantum sciences, electronics, photonics and manufacturing. MIT.nano will enable MIT researchers and our collaborators to address many urgent challenges that are beyond the range of existing technologies. The new building signifies the centrality of nanoscience, nanotechnology and nanomanufacturing for the needs of the 21st century, and will be a key innovation hub for the campus.

2:15pm **Panel Discussion II: Vision for the Future of Nanotechnology**

MODERATOR: **Karen K. Gleason,** *Associate Provost, MIT*

Nanotechnology includes fields as diverse as surface science, organic chemistry, semiconductor physics, nanofabrication, mechanical engineering and many others. At the nanoscale, new physics, new materials and new technologies lead to new devices, such as quantum memories based on electron spin, graphene sensors or nanocrystalline solar cells. This panel will feature five of our younger MTL core faculty with diverse backgrounds but sharing a common passion for the possibilities of nanotechnology. They will briefly introduce their particular research program and point to the exciting future of nanotechnology.

PANELISTS:

Dirk Englund, *Jamieson Career Development Assistant Professor, Department of Electrical Engineering and Computer Science, MIT*

Pablo Jarillo-Herrero, *Mitsui Career Development Associate Professor, Department of Physics, MIT*

William Tisdale, *Charles & Hilda Roddey Career Development Assistant Professor, Department of Chemical Engineering, MIT*

Kripa Varanasi, *Associate Professor, Department of Mechanical Engineering, MIT*

Michael Watts, *Associate Professor, Department of Electrical Engineering and Computer Science, MIT*

"The Microsystems Technology Laboratories has a rich collaboration and sharing culture, and I am very lucky to be a part of this community. As a Director of MTL, I saw the lab focus to not only cover innovations in materials, devices and circuits, but also expand to include integrated systems. We are very fortunate to have a dedicated group of semiconductor and system companies supporting the educational and research mission of MIT. I am excited to be a part of MTL's future as it defines and impacts the next generation of truly inter-disciplinary research problems while engaging researchers across MIT, industry and other institutions."

ANANTHA CHANDRAKASAN (MTL Director, 2006–2011)

3:30pm **BREAK**

3:45pm **Panel Discussion III: Vision for the Future of Nanosystems Applications**

MODERATOR: **Anantha Chandrakasan,** *Keithley Professor and Department Head, Department of Electrical Engineering and Computer Science, MIT*

The application space for nanosystems will expand far beyond the current information and communication products we see today. For example, resonators fabricated with micro/nano machining technology may be used to measure mass in an aqueous environment with a huge resolution improvement or to provide filtering of GHz signals with amazing quality factors. Medical devices capable of continuously monitoring physiological parameters can lead to real-time clinical decision-making, monitoring of disease progression, and titration of therapy. Power generation and conversion by exploiting the unique properties of nitride semiconductors is on the horizon. This panel will feature five of our younger MTL core faculty from around MIT. They will briefly introduce their particular research program and paint a picture of the possibilities that nanosystems might bring to the world during their careers.

PANELISTS:

Ruonan Han, *Assistant Professor, Department of Electrical Engineering and Computer Science, MIT*

Thomas Heldt, *Hermann L.F. von Helmholtz Career Development Professor, Institute for Medical Engineering and Science and Department of Electrical Engineering and Computer Science, MIT*

Scott Manalis, *Andrew (1956) and Erna Viterbi Professor, Department of Biological Engineering, MIT*

Tomás Palacios, *Associate Professor, Department of Electrical Engineering and Computer Science, MIT*

Dana Weinstein, *Associate Professor, Department of Electrical Engineering and Computer Science, MIT*

5:00pm **Closing Remarks**

Jesús del Alamo, *MTL Director & Donner Professor, Department of Electrical Engineering and Computer Science, MIT*

"I marvel at the breathtaking pace of MTL's technical discoveries, and reflect fondly on the years during which I had the opportunity to lead the Labs. The MTL Innovation Factory aggregates MIT's dreamers, thinkers, and makers, sparking innovation through unexpected encounters at the crossing of the disciplines. Our inclusive culture and abundant productivity are the magnet for our external partners, whose real-world experience, in turn, hones the focus of our research and innovation missions. Together, this broad community is MTL's core strength, with collective achievements that aptly reflect the essence of MIT's drive: *Mens et Manus* (Mind and Hand) in service to the world."

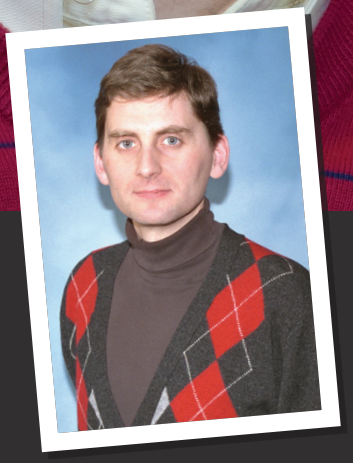
VLADIMIR BULOVIĆ (MTL Director, 2011–2013)

Student/Postdoc Posters & Demos

Anirban Basu *Luis Fernando Velásquez-García* **+DEMO**	**A Portable X-ray Generator Using a High-Current Field Emission Cathode and a Reflection Anode for Absorption Imaging of low-Z materials**
Andres Canales *Polina Anikeeva* **+DEMO**	**Thermal Drawing of Minimally Invasive Neural Probes**
Winston Chern *Judy Hoyt*	**Strained-Si/Strained-Ge Heterostructure Bilayer TFETs**
Hugh Churchill *Pablo Jarillo-Herrero*	**Transport and Optoelectronics with Two-Dimensional Semiconductors**
Matthew D'Asaro *Jeffrey Lang* **+DEMO**	**Stretchable Pressure and Shear Sensitive Skin**
Maggie Delano *Charles Sodini* **+DEMO**	**A Portable Bioimpedance Spectroscopy Measurement System for Congestive Heart Failure (CHF) Management**
Wenjing Fang *Jing Kong*	**Asymmetric Growth of Graphene on Copper Enclosure with Layer Control by Chemical Vapor Deposition**
Dan Hanks *Evelyn Wang*	**Evaporation from Nanopores for High Heat Flux Thermal Management**
Wei-Chun Hsu *Gang Chen* **+DEMO**	**Ultrathin Crystalline Silicon Solar Cells Enabled by Light-Trapping Nanostructures**
Nathan Ickes *Anantha Chandrakasan*	**Self-powered Long-range Wireless Microsensors for Industrial Applications**

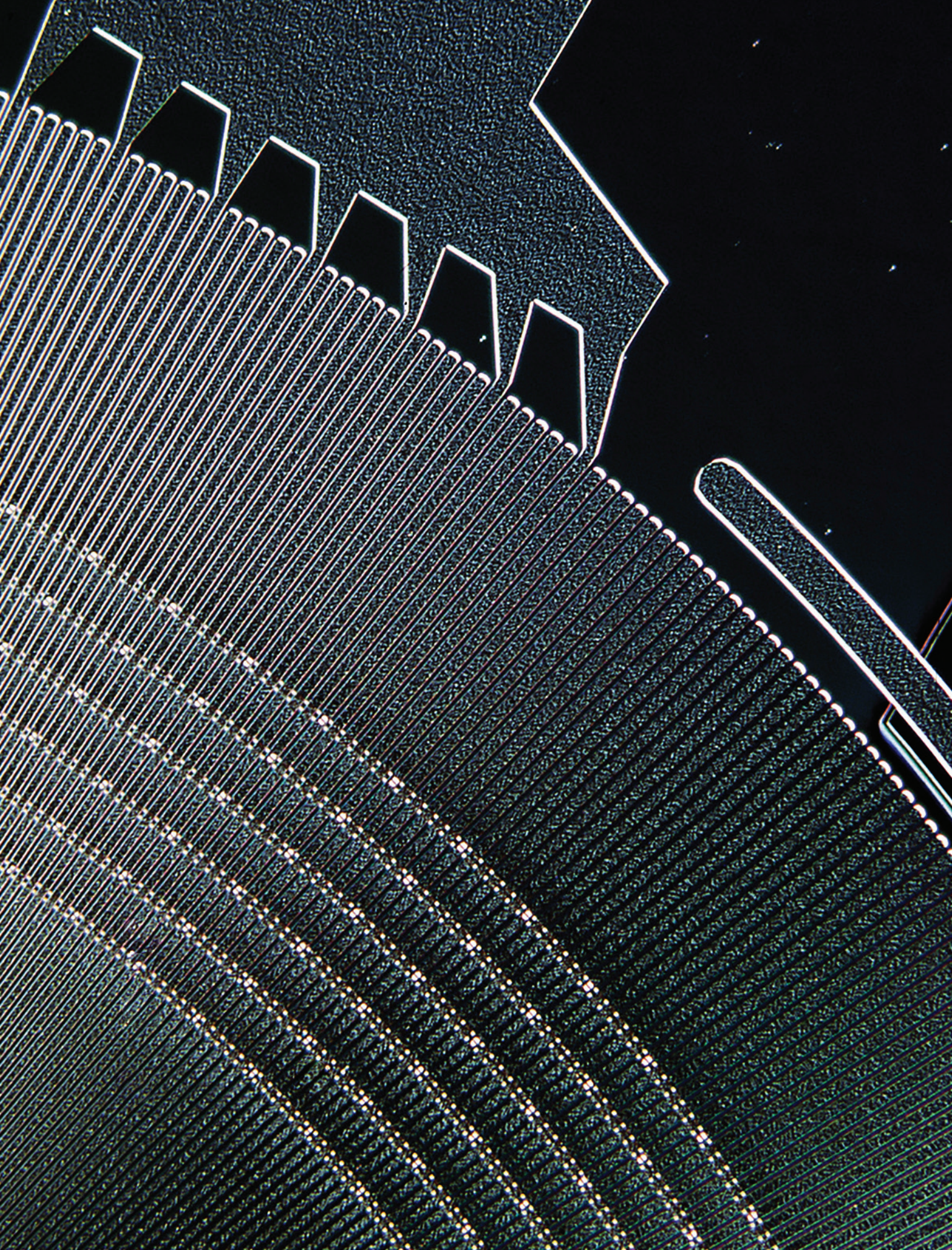
"It is a source of great pride for me to find myself at the helm of the Microsystems Technology Laboratories at this momentous occasion of its 30th anniversary. It's been 30 years of remarkable accomplishments and countless satisfactions. It's been 30 years in which we have all marveled at how the small things that we are so passionate about have proven to have such a big impact on our lives. With MIT.nano just peeking over the horizon, the future of micro- and nano-scale science and technology research will continue to shine bright at MIT for years to come.

To all that have traveled with us in this remarkable journey, Happy 30th Anniversary!"



JESÚS DEL ALAMO (MTL Director, 2013–Present)

Eric Jones *Silvija Gradečak*	**Quantifying Stress and Strain in Individual III-V Semiconducting Nano-Heterostructures**
Jeong-Gil Kim *George Barbastathis*	**Double Cone Nanostructures for Ultimate Anti-reflectivity of Encapsulated Solar Cells**
Seungbum Lim *David J. Perreault*	**High Frequency Power Conversion Architecture for Grid Interface**
Jianqiang Lin *Jesús del Alamo* *& Dimitri Antoniadis*	**Nanometer-scale InGaAs Transistors for Future Logic Applications**
Vitor Manfrinato *Karl Berggren*	**Determining the Resolution Limits of Electron-Beam Lithography**
Sang Hoon Nam *Nicholas Xuanlai Fang*	**Broadband Light Absorption Enhancement of Ultrathin Titanium Oxide Film on Metallic Reflector for Solar Energy Devices**
Farnaz Niroui *Vladimir Bulović*	**Tunneling Nanoelectromechanical Switches Based on Molecular Thin Films**
Sabino Pietrangelo *Harry Lee* **+DEMO**	**An Electronically Steered, Wearable Transcranial Doppler Ultrasound System**
Ujwal Radhakrishna *Dimitri Antoniadis*	**Virtual-Source Model for GaN HEMTs: The Link Between Device Physics and GaN Circuit Design**
Jorg Scholvin *Clifton G. Fonstad* *& Ed Boyden* **+DEMO**	**High-Density Electrode Arrays for Neural Recording**



Katie Smyth *Sang-Gook Kim*	**Piezoelectric Micro Ultrasonic Transducers for Medical Imaging**
Amr Suleiman *Vivienne Sze*	**Energy-Efficient Hardware for Object Detection**
Xiaoxue Wang *Karen Gleason*	**Volatile Organic Compounds (VOCs) Sensors Based on Oxidative Chemical Vapor Deposition (OCVD)**
Mark Weidman *William Tisdale*	**Well-ordered Quantum Dot Solids with Functional Ligands**
Li Yu *Duane Boning*	**Understanding Variation in Semiconductor Processes, Devices, and Circuits**
Hangbo Zhao *John Hart*	**Strain-Engineered Manufacturing of Freeform Carbon Nanotube Microstructures**
Sungjae Ha & Lili Yu *Tomás Palacios* *& Anantha Chandrakasan*	**2D-Electronics for Sensor Applications**

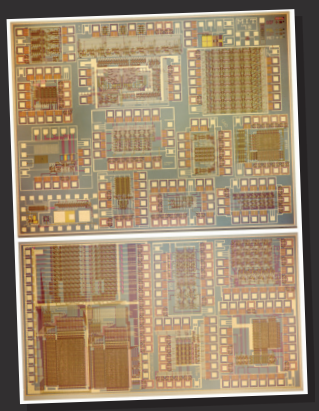
Facing page: Detail of electrostatic generator fabricated in MTL as part of the microgengine project. Photo, Felice Frankel.

MTL TIMELINE

1960
- *Semiconductor Electronics Education Committee* (SEEC) established

1968
- *Integrated Microelectronics Laboratory* ("Microlab") opens in Bldg. 13

1977
- *Submicron Structures Laboratory* (SSL) established in Bldg. 13, rechristened *NanoStructures Laboratory* (NSL) in 1994



MIT 1978 Multi-project chip set.

1978
- First offering of *Introduction to VLSI Systems*, a multi-project chip design course

1979
- *MIT VLSI Seminar* launched (renamed MTL Seminar in 2007)

1980
- MIT announces plans for establishing MTL (originally termed *LSI Fabrication Facility*)

1982
- *Microsystems Industrial Group* launched
- Weekly lunch meeting ("microlunch") of microsystems faculty starts; it continues to this day

1983
- Bldg. 39 renovations start

1984
- MTL opens, reporting to Department of Electrical Engineering and Computer Science; initial set of labs is *Integrated Circuits Laboratory* (ICL), *Technology Research Laboratory* (TRL), and SSL

1986
- Building 39 dedicated as *Gordon Stanley Brown Building*

From left to right: Joel Moses, David Saxon, Gordon Brown, Jean Brown, Paul Gray, and Gerry Wilson at the dedication of Building 39 in 1986.

1989 • Full CMOS process qualification of ICL achieved

1990

1991 • *Process Technology Committee* established

1994 • MTL and NSL spawn *Space Nanotechnology Laboratory* in Bldg. 37

1995 • MTL reporting moves to School of Engineering

1998 • *Center for Integrated Circuits and Systems* established

1999 • Bldg. 13 Microlab moves to Bldg. 39 and becomes *Exploratory Materials Laboratory* (EML)

2000

2000 • *Class 1 Committee* report on MTL fab operations issued

2001 • 4" to 6" wafer diameter conversion completed

2002 • *Microsystems Affiliate Program* for industrial users established, renamed *Fabrication Facilities Access Program* in 2004

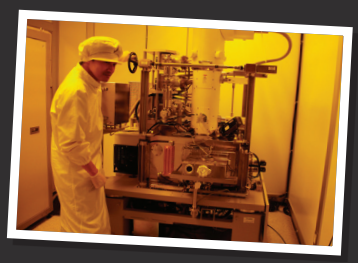
2003 • *CORAL fab management system* rolled out

Process engineer at a wafer cleaning station in TRL. Photo, Hutchins Photography, Inc.

2010

2010 • CORAL expanded with cost recovery and user interface modules

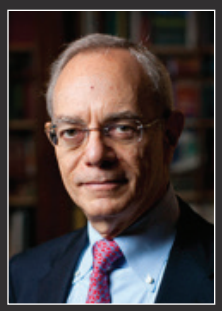
2012 • *Electron Beam Lithography Facility* (EBL) established in Bldg. 24; managed jointly with the Research Laboratory of Electronics



Elionix engineer at work in EBL.

2014 • *MIT.nano* announced

Architectural rendering of MIT.nano in the heart of the MIT campus.



L. Rafael Reif

President, MIT

Rafael Reif has served as the 17th President of MIT since July 2012. In his inaugural speech, Dr. Reif outlined the threats and opportunities presented by the sudden rise of credible, low-cost online learning alternatives and challenged MIT to use the campus as a lab to explore the future of higher education. While fostering the rapid growth of MIT's non-profit online learning platform edX—which engaged more than 2.2 million learners from 196 countries in its first two years—he also launched an Institute-wide Task Force on the Future of MIT Education, which in September 2014 issued its final report.

In keeping with MIT's role as a wellspring of innovation, Dr. Reif was asked by the White House to co-chair the steering committee of the national Advanced Manufacturing Partnership (AMP 2.0). In October 2013, to enhance MIT's own innovation ecosystem and foster education, research and policy, he launched the MIT Innovation Initiative. In that same spirit, in the spring of 2014 MIT began work on "MIT.nano," a major new facility at the heart of campus that will accelerate research and innovation at the nanoscale. In May 2014, Dr. Reif also launched an environmental initiative to drive progress towards solutions around the environment, climate, and how to construct a sustainable human society. A major component of the initiative will be the new Abdul Latif Jameel World Water and Food Security Laboratory.

In his previous role as MIT's provost (2005-2012), Dr. Reif helped create and implement the strategy that allowed MIT to weather the global financial crisis, drove the growth of MIT's global strategy, promoted a major faculty-led effort to address challenges around race and diversity, helped launch the Institute for Medical Engineering and Sciences, and spearheaded the development of the Institute's online learning initiatives, *MITx* and *edX*. For his work in developing MITx, he received the 2012 Tribeca Disruptive Innovation Award.

A member of the MIT faculty since 1980, Dr. Reif has served as director of MIT's Microsystems Technology Laboratories and as department head of Electrical Engineering and Computer Science. In 2004, he was named the Fariborz Maseeh Professor of Emerging Technology, a title he held until he was selected as president.

An elected member of the American Academy of Arts and Sciences, and a fellow of the Institute of Electrical and Electronics Engineers (IEEE), Dr. Reif is the inventor or co-inventor on 15 patents, has edited or co-edited five books and has supervised 38 doctoral theses.

He received the degree of Ingeniero Eléctrico from Universidad de Carabobo, Valencia, Venezuela, and his doctorate in electrical engineering from Stanford University.

Robert Kahn

Chairman, CEO & President, Corporation for National Research Initiatives (CNRI)

Robert E. Kahn is Chairman, CEO and President of the Corporation for National Research Initiatives (CNRI), which he founded in 1986 after a thirteen-year term at the U.S. Defense Advanced Research Projects Agency (DARPA). CNRI was created as a not-for-profit organization to provide leadership and funding for research and development of the National Information Infrastructure.

After receiving a B.E.E. from the City College of New York in 1960, Dr. Kahn earned M.A. and Ph.D. degrees from Princeton University in 1962 and 1964 respectively. He worked on the Technical Staff at Bell Laboratories and then became an Assistant Professor of Electrical Engineering at MIT. He took a leave of absence from MIT to join Bolt, Beranek and Newman, where he was responsible for the system design of the ARPANET, the first packet-switched network. In 1972 he moved to DARPA and subsequently became Director of DARPA's Information Processing Techniques Office (IPTO). While Director of IPTO he initiated the United States government's billion dollar Strategic Computing Program, the largest computer research and development program ever undertaken by the federal government. Dr. Kahn conceived the idea of open-architecture networking. He is a co-inventor of the TCP/IP protocols and was responsible for originating DARPA's Internet Program.

In his recent work, Dr. Kahn has been developing the concept of digital object architecture. This notion is providing a framework for interoperability of heterogeneous information systems and is being used in many applications such as the Digital Object Identifier (DOI). He is a co-inventor of Knowbot programs, which are mobile software agents in the network environment.

Dr. Kahn is an honored member of many scientific societies and advisory committees, including the National Academy of Engineering, IEEE, AAAI, and ACM. He is currently a member of the State Department's Advisory Committee on International Communications and Information.

He is a recipient of many awards, a few of which include the Marconi Society Award, the ACM SIGCOMM Award, the IEEE Koji Kobayashi Computer and Communications Award, the IEEE Alexander Graham Bell Medal, the IEEE Third Millennium Medal, and the ACM Software Systems Award. He has received the Presidential Medal of Freedom and twice received the Secretary of Defense Civilian Service Award. He is a recipient of the National Medal of Technology, the Charles Stark Draper Prize, the Prince of Asturias Award, the Japan Prize, and the Queen Elizabeth Prize for Engineering. He has received honorary degrees from a number of leading universities.

Ahmad Bahai

Chief Technology Officer, Texas Instruments

Dr. Ahmad Bahai is the Chief Technology Officer for Texas Instruments. Before this, he was the Chief Technology Officer at National Semiconductor. He is also a consulting professor at Stanford University and an IEEE Fellow. Previously, he was the technical manager of the communication and mixed-signal processing research group at Bell Laboratories until 1997 and Professor-In-Residence at University of California, Berkeley. He later co-founded Algorex, an IC and system design company for communication and acoustic applications, which was acquired by National.

Dr. Bahai co-invented the multi-carrier spread spectrum theory, which is being used in many modern communication systems, such as 4G and power line communication. He authored the first textbook on orthogonal frequency-division multiplexing (OFDM) in 1999 and served as the associate editor of IEEE journals for five years. He also served in the ISSCC technical steering committee until 2011. Dr. Bahai has served as a technology advisor for many major energy initiatives in Europe and China, the industrial advisory board of University of California, and was a visiting professor at Cheng Du University in China.

He has more than 80 IEEE/IEE publications and 35 patents on systems and circuits. He received his Master of Science degree from Imperial College, University of London and Ph.D. from University of California at Berkeley, all in electrical engineering.

Jack Sun

Vice President of Research and Development & Chief Technology Officer, Taiwan Semiconductor Manufacturing Company

Dr. Jack Sun has served as TSMC's Vice President of Research and Development since June of 2006 and as Chief Technology Officer since November 2009. During his career at TSMC, he has led the successful expansion and acceleration of the logic and Mixed-signal/RF technology roadmap at TSMC. He has driven the advanced technology R&D initiatives from the 0.18-micron node to today's leading edge 20nm process and beyond.

Prior to joining TSMC, Dr. Sun held a number of senior management and engineering positions at IBM Research and the IBM Semiconductor Research and Development Center for 14 years. He led many successful R&D projects that set world records and shaped industry trends in CMOS, SOI, low-power CMOS, low temperature CMOS, bipolar, and SiGe heterojunction bipolar transistors (HBTs).

Dr. Sun received his B.S. degree from National Taiwan University, and M.S. and Ph.D. degree from the University of Illinois, all in electrical engineering. He is an IEEE Fellow in recognition of his significant contributions to CMOS technology. He has over 200 papers, 11 US patents, and several ROC patents.

Mark Allen

Alfred Fitler Moore Professor, University of Pennsylvania

Mark G. Allen received the B.A. degree in Chemistry, the B.S.E. degree in ChemE, and the B.S.E. degree in E.E. from U. Penn, and the S.M. and Ph.D. (1989) degrees from MIT. From 1989 to 2013 he was Regents' Professor at the School of Electrical and Computer Engineering of the Georgia Institute of Technology, where he also held the positions of Senior Vice Provost for Research and Innovation and Director of the Institute for Electronics and Nanotechnology. In 2013, he moved back to U. Penn. Prof. Allen has been co-chair of a number of conferences and will co-chair the 2016 Solid State Sensor Conference. He was editor-in-chief (2009-2013) of the *Journal of Micromechanics and Microengineering*, and is a Fellow of the IEEE. Prof. Allen is the co-founder of several spinoff companies, including CardioMEMS and Axion Biosystems.

Dimitri Antoniadis

Ray & Maria Stata Professor, Department of Electrical Engineering and Computer Science, MIT

Prof. Antoniadis received his B.S. in physics from the National University of Athens in 1970 and his Ph.D. in E.E. from Stanford University in 1976. In 1978, he joined the faculty at MIT where he co-founded and was the first director of MTL. He later directed the SRC MIT Center of Excellence for Microsystems Technology and more recently the Multi-University Focus Research Center for Materials Structures and Devices. He, along with his students and colleagues, have made many pioneering contributions to Si, SOI, and Si/SiGe technologies and he is author and co-author of more than 400 technical articles. Prof. Antoniadis is a member of the National Academy of Engineering, a Life Fellow of the IEEE and recipient of several awards.

Vladimir Bulović

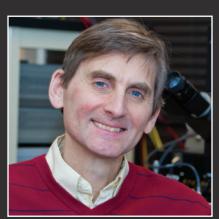
Fariborz Maseeh Professor and Associate Dean for Innovation, School of Engineering, MIT

Vladimir Bulović holds the Fariborz Maseeh Chair in Emerging Technology and is the MIT School of Engineering's Associate Dean for Innovation. He co-directs the MIT Innovation Initiative and is the faculty leading the design and construction of MIT's new nano-fabrication, nano-characterization, and prototyping facility: MIT.nano. He also co-directs the Eni-MIT Solar Frontiers Center, one of MIT's largest sponsored research programs. Prof. Bulović leads the Organic and Nanostructured Electronics Laboratory (ONE Lab), which he developed as a unique open nanotechnology facility. He is a founder of QD Vision, Kateeva and Ubiquitous Energy, and is a recipient of numerous research and teaching awards, including the Margaret MacVicar Faculty Fellowship, MIT's highest teaching honor.

Anantha Chandrakasan

Keithley Professor and Department Head, Department of Electrical Engineering and Computer Science, MIT

Anantha P. Chandrakasan received the B.S., M.S., and Ph.D. degrees in EECS from U.C. Berkeley in 1989, 1990, and 1994. Since 1994, he has been with the EECS department at MIT. He was Director of MTL from 2006 to 2011 and the head of EECS since July 2011. His research interests include micro-power digital and mixed-signal integrated circuit design, wireless microsensor system design, portable multimedia devices, energy efficient radios and emerging technologies. Dr. Chandrakasan is a recipient of a number of industry awards and co-author of a number of texts and many academic publications. He has served as program chair and committee chair for a number of conferences and scientific societies and was an Associate Editor for the *IEEE Journal of Solid-State Circuits* from 1998 to 2001. He is presently Conference Chair of ISSCC.



Jesús A. del Alamo

MTL Director & Donner Professor, Department of Electrical Engineering and Computer Science, MIT

Prof. del Alamo holds degrees from Polytechnic University of Madrid (1980), and Stanford University (M.S. EE, 1983 and Ph.D. EE, 1985). Over the years, Prof. del Alamo has carried out research on electronic devices in a variety of material systems, including Si and SiGe, GaAs, InAlAs/InGaAs and GaN. His current research interests focus on the physics, technology, modeling and reliability of new III-V compound semiconductor field-effect transistors. In addition, Prof. del Alamo is investigating the technology and pedagogy of online laboratories for science and engineering education (the iLab Project). From 1991 to 1996, Prof. del Alamo was a National Science Foundation Presidential Young Investigator. In 1999 he was elected a corresponding member of the Royal Spanish Academy of Engineering. In 2005, he was elected a Fellow of the IEEE.

Vicky Diadiuk

Associate Director, Microsystems Technology Laboratories, MIT

Dr. Vicky Diadiuk received the B.S. and Sc.D. degrees in Physics from MIT in 1972 and 1978. Her theses were in the field of Josephson and Nb-based superconducting junctions. Starting in 1978 she was a member of the research staff at MIT Lincoln Laboratory, where she worked on optoelectronic devices in III-V semiconductors and on diode lasers for optical communications, including external cavity-coupled laser and lenslet arrays. In 1996 she joined MTL, where she is in charge of managing the micro/nanofabrication laboratories. She is the Chair of MTL's Process Technology Committee. Dr. Diadiuk holds several US patents and is co-author of numerous publications. She has served on a variety of Conference Committees and University Technical Advisory Boards.

Dirk Englund

Jamieson Career Development Assistant Professor, Department of Electrical Engineering and Computer Science, MIT

Dirk Englund received his B.S. in Physics from Caltech in 2002. Following a year at TU Eindhoven as a Fulbright Fellow, he earned his M.S. in EE and Ph.D. in Applied Physics at Stanford in 2008. He was a postdoctoral fellow at Harvard University until 2010, when he became assistant professor of EE and applied physics at Columbia University. He moved to MIT in 2013 as assistant professor in EECS and a member of RLE and MTL. His research focuses on quantum technologies based on semiconductor and optical systems. Recent recognitions include the 2012 DARPA Young Faculty Award, the 2012 IBM Faculty Award, the 2011 Presidential Early Career Award for Scientists and Engineers, the 2011 Sloan Research Fellowship in Physics, the 2008 Intelligence Community (IC) Postdoctoral Fellowship, and the 2012 IEEE-HKN Outstanding Young Professional Award.

Karen K. Gleason

Associate Provost, MIT

Prof. Karen K. Gleason received her Ph.D. from U.C. Berkeley and her B.S. and M.S. degrees from MIT, where she also won All-American honors in swimming. She joined the Chemical Engineering (ChemE) faculty at MIT in 1987 and has served as executive officer of ChemE, associate director for the Institute of Soldier Nanotechnologies, and associate dean of Engineering for Research. Prof. Gleason's research focuses on the near room-temperature synthesis of ultrathin, conformal organic films by chemical vapor deposition (CVD) and she has authored more than 250 publications and holds 18 issued US patents. Prof. Gleason is a fellow of the American Institute of Chemical Engineering and has been given a number of awards for her work. In 2001, Prof. Gleason co-founded GVD Corporation, based on commercialized technology from her lab.

Paul Gray

Professor Emeritus & President Emeritus, MIT

Prof. Gray received his B.S. (1954), S.M. (1955), and Sc.D. (1960), in EE from MIT. He joined the EE faculty in 1960. He was associate dean for student affairs, 1965-1967, associate provost, 1969-1970, dean of the School of Engineering, 1970-1971, and chancellor, 1971-1980. He was the fourteenth president of MIT, 1980-1990, and chairman of the MIT Corporation, 1990-1997. After his retirement from the chairmanship, he resumed his teaching and advising activities. Among the programs at MIT that he helped to establish are the Undergraduate Research Opportunities Program (UROP), the Leaders for Manufacturing Program, and the affiliation with the Whitehead Institute for Biomedical Research. His public service includes four years on the White House Science Council.

Kush Gulati

Executive Director and General Manager of the Advanced IP Solutions Group, Maxim Integrated

Kush Gulati has over two decades of experience in the areas of high performance analog circuit design. In 2007 he co-founded Cambridge Analog Technologies, Inc., a company focused on a revolutionary ultra-low-power circuit technology, which was acquired by Maxim Integrated in 2011. He received the Ph.D. degree in EECS with a minor in business from MIT, M.S. degree in electrical and computer engineering from Vanderbilt University, and the B.S. degree in electronics and communication engineering from Delhi Institute of Technology, India. Dr. Gulati has numerous publications and patents in the area of circuit design. He is an active mentor and investor in start-ups in the semiconductor and hardware fields.

Ruonan Han

Assistant Professor, Department of Electrical Engineering and Computer Science, MIT

Ruonan Han received his Ph.D. degree in electrical and computer engineering from Cornell University in 2014. Prior to that, he received his B.Sc. degree in microelectronics from Fudan University in 2007 and M.Sc. degree in electrical engineering from the University of Florida in 2009. His research at MIT explores device, circuit and system technologies to bridge the terahertz gap between microwave and infrared regimes. He is the recipient of the ECE Director's Best Thesis Research Award and the Innovation Award from Cornell University, the Solid-State Circuits Society (SSCS) Pre-Doctoral Achievement Award, and the Microwave Theory Techniques Society (MTT-S) Graduate Fellowship Award from IEEE, as well as the Best Student Paper Award from IEEE Radio-Frequency Integrated Circuits Symposium (RFIC).

Thomas Heldt

Hermann L.F. von Helmholtz Career Development Professor, Institute for Medical Engineering and Science & Department of Electrical Engineering and Computer Science, MIT

Thomas Heldt joined the EECS Department in July 2013 and was also appointed to MIT's Institute for Medical Engineering and Science. Dr. Heldt studied physics at Johannes Gutenberg University, Germany, at Yale University, and at MIT. In 2004, he received the Ph.D. degree in medical physics from MIT's Division of Health Sciences and Technology and remained at MIT for his postdoctoral training. Dr. Heldt's research interests focus on signal processing, mathematical modeling, and model identification to support real-time clinical decision making, monitoring of disease progression, and titration of therapy, primarily in neurocritical and neonatal critical care. His research is conducted in close collaboration with colleagues at MIT and clinicians from Boston-area hospitals.

Vida Ilderem

Vice President, Intel Labs

Vida Ilderem is Vice President of Intel Labs and director of Integrated Computing Research (ICR) at Intel Corporation. ICR explores the evolution of computing with a focus on new emerging platforms. Research vectors include breakthrough technology innovations for seamless connectivity, highly integrated small form factors, sensor and actuators, and enablement of the Internet of Things and wearables. Prior to joining Intel in 2009, Dr. Ilderem served as vice president of Systems and Technology Research at Motorola's Applied Research and Technology Center. Dr. Ilderem holds a doctorate degree in electrical engineering from Massachusetts Institute of Technology. She has 27 issued patents.

Pablo Jarillo-Herrero

Mitsui Career Development Associate Professor, Department of Physics, MIT

Pablo Jarillo-Herrero joined MIT as an assistant professor of physics in January 2008. He received his M.Sc. in physics from the University of Valencia, Spain, in 1999. He then spent two years at the University of California in San Diego, where he received a second M.Sc. degree before attending Delft University of Technology in The Netherlands, where he earned his Ph.D. in 2005. He then moved to Columbia University, where he worked as a NanoResearch Initiative Fellow. His awards include the Spanish Royal Society Young Investigator Award (2007), NSF Career Award (2008), Alfred P. Sloan Fellowship (2009), David and Lucile Packard Fellowship (2009), IUPAP Young Scientist Prize (2010), DOE Early Career Award (2011), Presidential Early Career Award (2012), and ONR Young Investigator Award (2013).

Craig L. Keast

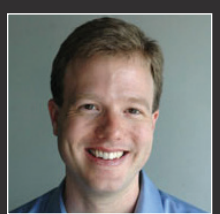
Associate Head, MIT Lincoln Laboratory

Dr. Keast began his career at MIT Lincoln Laboratory in 1981. From 1988 to 1992, as a Kodak Fellow, he pursued his graduate studies as part of MTL at MIT. He returned to Lincoln Laboratory as a member of the technical staff working on deeply scaled device development. In 1994, he became the Director of Operations for Lincoln's Microelectronics Laboratory and in 1996 he also became the Leader of the Advanced Silicon Technology Group. In 2009, he assumed his current position and was appointed a member of the Lincoln Laboratory Steering Committee which helps set strategic directions for the Laboratory. His division performs multidisciplinary work leveraging solid-state electronic and electro-optical technologies, innovative chemistry, materials science, advanced radio-frequency technology, and quantum information science. Dr. Keast holds a B.A. degree from Hamilton College, and S.M. E.E. and Ph.D. degrees in EECS from MIT.

Thomas H. Lee

Professor of Electrical Engineering, Stanford University

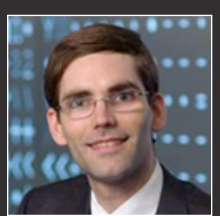
Dr. Lee received the S.B., S.M. and Sc.D. degrees in EE from MIT in 1983, 1985, and 1990, respectively, where his thesis described the world's first CMOS radio. He joined Analog Devices in 1990 and Rambus in 1992. Since 1994, he has been a professor of Electrical Engineering at Stanford where his research focus has been on telecom integrated circuits built in conventional silicon technologies, particularly CMOS. He is a Packard Fellow and has served as director of MTO at DARPA. Dr. Lee has authored a number of texts and papers, holds over 60 U.S. patents and cofounded several companies. In early April of 2011 he was awarded the Ho-Am Prize in Engineering (colloquially known as the "Korean Nobel"). He has over 100 oscilloscopes and thousands of vacuum tubes; no one, including himself, quite knows why.



Scott Manalis

Andrew (1956) and Erna Viterbi Professor, Department of Biological Engineering, MIT

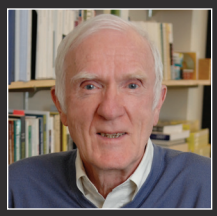
Scott Manalis is a professor of biological and mechanical engineering at MIT and has been a faculty member at MIT since 1999. He is also a member of the Koch Institute for Integrative Cancer Research at MIT. Dr. Manalis was the recipient of the Presidential Early Career Award for Scientists and Engineers (PECASE) from the Department of Defense. He has also been selected by *Technology Review* magazine as one of the 100 innovators under the age of 35. Dr. Manalis received his B.S. degree in physics from U.C. Santa Barbara in 1994 and his Ph.D. degree in applied physics from Stanford University in 1998.



Tomás Palacios

Associate Professor, Department of Electrical Engineering and Computer Science, MIT

Tomás Palacios is an Associate Professor in the Department of Electrical Engineering and Computer Science at MIT, where he leads the Advanced Semiconductor Materials and Devices Group. His research focuses on the combination of new semiconductor materials and device concepts to advance the fields of information technology, biosensors and energy conversion. His work has been recognized with multiple awards including the Presidential Early Career Award for Scientists and Engineers (PECASE), the IEEE George Smith Award, and numerous best paper awards. Prof. Palacios has authored more than 200 contributions to advanced semiconductor devices in international journals and conferences (40 of them invited), three book chapters and 15 patents. He is the founding director of the MIT Center for Graphene Devices and 2D Systems (MIT-CG), and the MIT GaN Energy Initiative.



Paul Penfield, Jr.

Professor Emeritus, Department of Electrical Engineering and Computer Science, MIT

Prof. Penfield received the B.A. degree in physics from Amherst College in 1955, and the Sc.D. degree in EE from MIT in 1960. He joined the MIT EECS faculty in 1960, serving as associate head from 1974 to 1978 and department head from 1989 to 1999. His technical interests have included solid-state microwave devices and circuits, noise and thermodynamics, electrodynamics of moving media, and computer-aided design. Prof. Penfield is a Fellow of IEEE and received from IEEE the Centennial Medal in 1984, the Circuits and Systems Society Darlington Prize Paper Award in 1985, and the Golden Jubilee Award in 1999. He is a member of the National Academy of Engineering, the American Physical Society, the Audio Engineering Society, and the Association for Computing Machinery. He is the author of numerous books and articles.

Martin Schmidt

Provost, MIT

In February 2014, Prof. Schmidt was appointed Provost of MIT. Beginning in 2008, he served as associate provost and since January 2012, he also assumed responsibilities for "all things industry" as the senior administrative officer responsible for MIT's industrial interactions. He has been a faculty member in EECS since 1988, and from 1999 to 2006 he served as the director of MTL. His teaching and research is in the areas of micro and nanofabrication of sensors, actuators and electronic devices, and MEMS. He is the co-author of more than 80 journal publications and 120 peer-reviewed conference proceedings, an inventor on more than 30 issued U.S. patents and involved with six start-up companies. Prof. Schmidt received his B.S. degree from Rensselaer Polytechnic Institute in 1981 and his S.M. and Ph.D. degrees from MIT in 1983 and 1988.

Charles G. Sodini

Clarence J. LeBel Professor, Department of Electrical Engineering and Computer Science, MIT

Charles G. Sodini received the B.S.E.E. degree from Purdue University in 1974 and the M.S.E.E. and the Ph.D. degrees from U.C. Berkeley in 1981 and 1982. Prof. Sodini was a member of the technical staff at HP Laboratories from 1974 to 1982 then joined the EECS faculty at MIT in 1983. His research interests are focused on low-power medical electronic systems for monitoring and imaging. Prof. Sodini was a co-founder of SMaL Camera Technologies and has served on a variety of IEEE Conference Committees, including IEDM where he was the 1989 General Chairman. He has served on the IEEE Electron Device Society Administrative Committee and was president of the IEEE Solid-State Circuits Society from 2002-2004.

William Tisdale

Charles & Hilda Roddey Career Development Assistant Professor, Department of Chemical Engineering, MIT

Dr. Tisdale joined the Department of Chemical Engineering in 2012, where his current work involves the study of movement of energy in nanostructured materials. Prior to joining the faculty, Dr. Tisdale was a postdoc in the Organic and Nanostructured Electronics Laboratory at MIT, where he studied exciton dynamics. He received his B.S. in Chemical Engineering from the University of Delaware in 2005 and his Ph.D. in Chemical Engineering in 2010 from the University of Minnesota, where he used ultrafast two-photon photoelectron spectroscopy and surface nonlinear optical techniques to probe the relaxation of charge carriers at semiconductor surfaces and QD interfaces. Dr. Tisdale is a recipient of the DOE Early Career Award, 3M Non-Tenured Faculty Award, and MIT's Everett Moore Baker Award for Excellence in Undergraduate Teaching.

Kripa Varanasi

Associate Professor, Department of Mechanical Engineering, MIT

Dr. Varanasi received his M.S. and Ph.D. degrees in MechE from MIT in 2002 and 2004, and his M.S. in EECS from MIT in 2002. Prior to joining MIT, Dr. Varanasi was a lead researcher and project leader at the GE Global Research Center. The primary focus of his research is in the development of nano-engineered surface, interface, and coating technologies that can dramatically enhance performance in energy, water, agriculture, transportation, medical, and consumer devices. Dr. Varanasi has received numerous awards for his work including the NSF Career and DARPA Young Faculty Awards. He co-founded LiquiGlide to commercialize super-slippery coatings, which was selected by *Time* and *Forbes* magazines as one of the best inventions of 2013.

Michael Watts

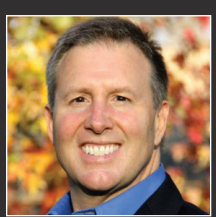
Associate Professor, Department of Electrical Engineering and Computer Science, MIT

Prof. Watts received his B.S. in Electrical Engineering from Tufts University in 1996. He then joined Draper Laboratory as a Member of Technical Staff. In 1999 he became a Draper Fellow and received his S.M. and Ph.D. degrees from MIT in 2001 and 2005, respectively. In 2005, he joined Sandia National Labs where he was a Principal Member of Technical Staff and led their silicon photonics development. In 2009, he received an R&D100 Award for work in ultralow power microphotonic modulators and switches. In 2010, he returned to MIT where he is an associate professor in the EECS department. Prof. Watts' research focuses on photonic microsystems for low-power communications, sensing, and microwave-photonics applications. Prof. Watts holds numerous patents and has authored or co-authored approximately 140 journal and conference publications and is a member of the Optical Society of America and the IEEE.

Dana Weinstein

Associate Professor, Department of Electrical Engineering and Computer Science, MIT

Dr. Weinstein joined the Department of Electrical Engineering and Computer Science at MIT in 2009. She received her B.A. in Physics and Astrophysics from U.C. Berkeley in 2004 and her Ph.D. in Applied Physics in 2009 from Cornell, working on multi-GHz MEMS. Dr. Weinstein is the recipient of the NSF CAREER Award, the DARPA Young Faculty Award, the Intel Early Career Award, and the IEEE IEDM Roger A. Haken Best Paper Award. Her current research focuses on hybrid MEMS-IC devices for low-power wireless communication, microprocessor clocking, and sensing applications. In particular, she is working to harness the benefits of acoustic vibrations to enhance the performance of next-generation electron devices. Her recent work on resonant body transistors, in which a field effect transistor (FET) is embedded inside a MEMS resonator, has yielded the highest frequency resonance measured in silicon to date.



David White

Senior R&D Group Director, Cadence

As a Senior R&D Group Director at Cadence, Dr. White manages the Cadence Virtuoso Electrically Aware Design (EAD) product suite for IC design and verification. His roles include product management as well as customer and partner development. He joined Cadence through the 2006 acquisition of Praesagus, an electronic design automation software company he co-founded in 2001. Prior to Praesagus, he was co-founder of InfoLenz, a software company developing personalization and recommendation systems for e-commerce, and NeuroDyne, a software company providing machine-learning solutions. He has served on the Advisory Board of the National Science Foundation and on the MIT-MIG Advisory Board at MIT. Dr. White has over 30 issued patents and numerous publications. He has an Sc.D. degree in EECS from MIT with a minor in management.

Acknowledgments

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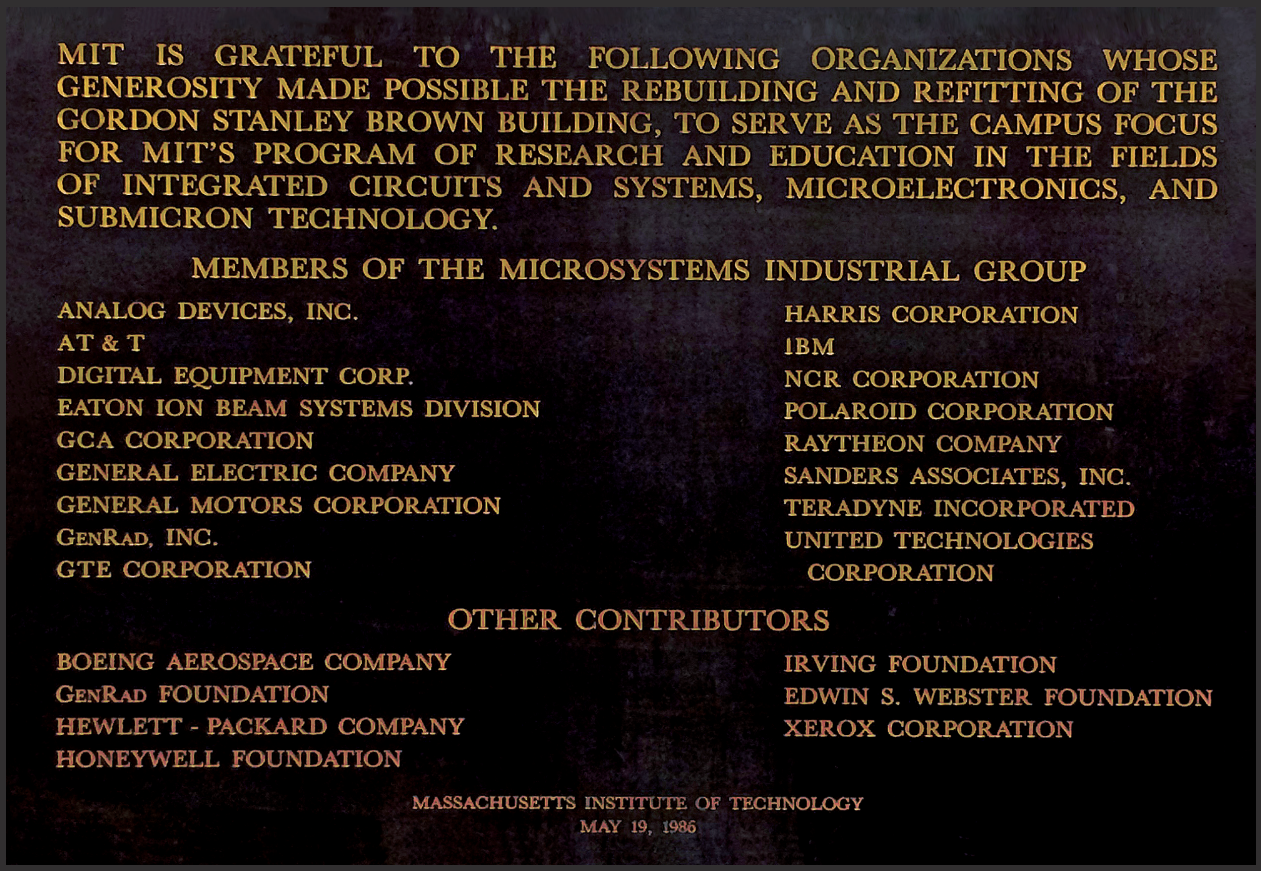
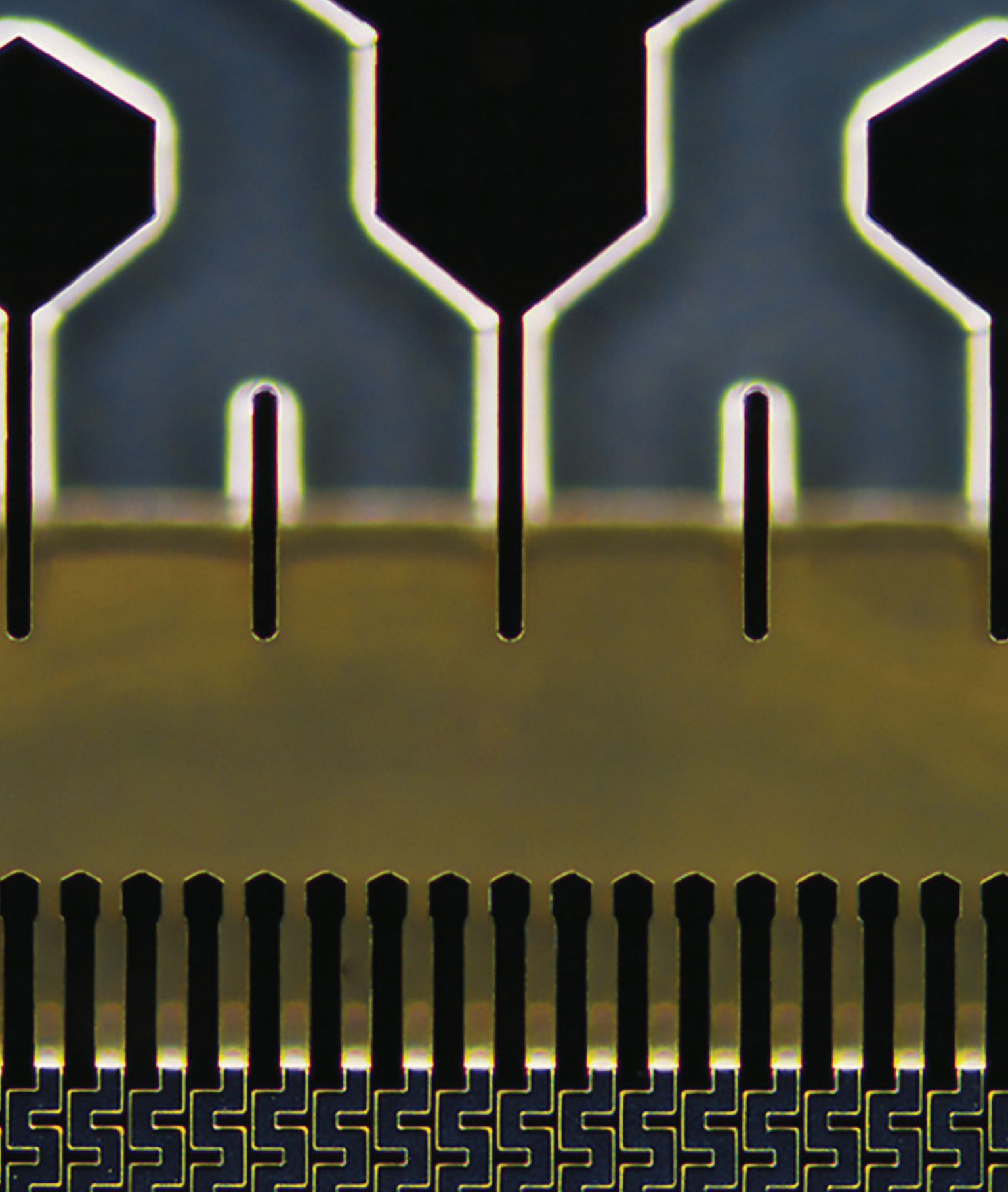


Above: Plaque in lobby of Building 39 commemorating the building's dedication in 1986.
Back cover: Microreactor fabricated in MTL. Photo, Felice Frankel.



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