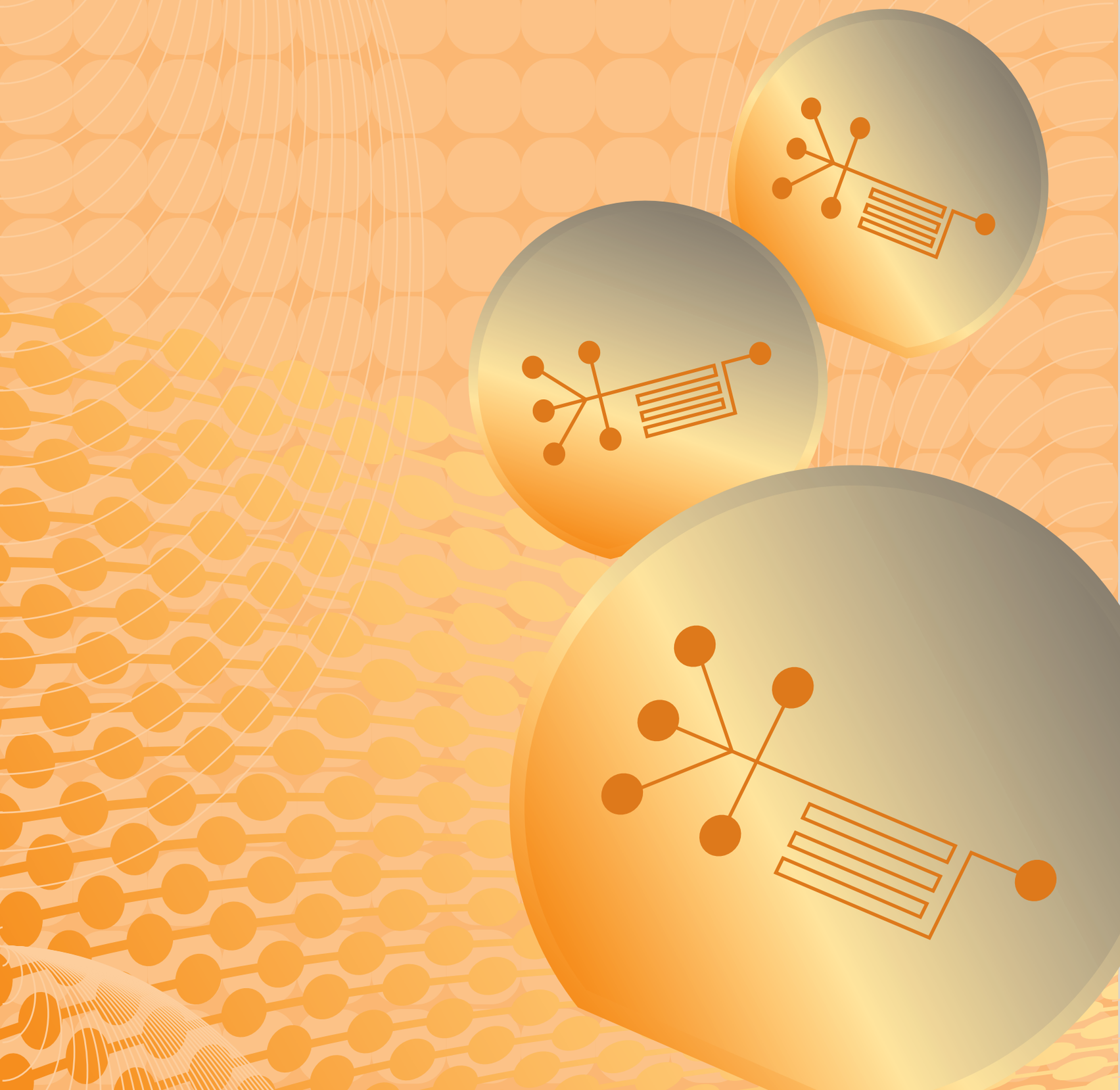
MTL MICRONOTES

the annual news magazine of the Microsystems Technology Laboratories • Fall 2007



MTL MICRONOTES

CONTENTS

Feature Story

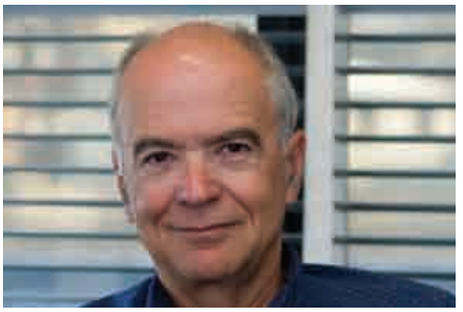
MARC HITS THE SPOT

Pages 10-15

Research

LOW POWER TO THE PEOPLE

Pages 16-17



Faculty

DIMITRI ANTONIADIS

Page 22

MTL MICRONOTES
VOLUME ONE, ISSUE ONE • FALL 2007

EDITOR-IN-CHIEF	Anantha Chandrakasan
ASSOCIATE EDITOR	Rhonda Maynard
DIRECTOR OF PUBLICATIONS	Mara Karapetian
ART DIRECTOR	Mara Karapetian
ALUMNI COORDINATOR	Debroah Hodges-Pabon
PHOTOGRAPHY	Paul McGrath
	Tony Rinaldo
	Gary Riggott

PSB 07-02-0308

NOTES FROM THE DIRECTOR

Welcome to the inaugural volume of the Microsystems Technology Laboratories (MTL) magazine, MTL Micronotes! The purpose of this annual magazine is to keep MTL alumni, members, industrial consortium and friends up-to-date with the exciting research activities, events, and news from MTL.

2007 proved to be another exciting year for MTL. During the past year our core faculty (30 members) engaged in a broad range of exciting research areas, including device fabrication, integrated circuits and systems, photonics, MEMS, and molecular- and nano-electronics. In addition, more than 110 affiliate members directly benefited from the fabrication and/or CAD infrastructure provided by MTL. Furthermore, over 500 researchers (primarily graduate students) conducted research at MTL, and our faculty, students and staff received several significant awards.

We had many exciting events during my first year as MTL's director. Our annual student research conference (MARC) was again a big success. Held annually in Waterville Valley, New Hampshire, MARC continues to be the flagship technical event of MTL. It is an opportunity for students to present recent research results to their peers, as well as to MTL faculty and industry representatives. And MARC is unique in that it is organized primarily by MTL graduate students, with the help of a steering committee made up of faculty and staff, making it an excellent opportunity for grad students to hone their leadership skills. Over 210 industry members, faculty, students and staff attended MARC 2007, making it one of the most successful conferences to date. You can read more about MARC on page 8.

In this issue, we also spotlight our weekly seminar series (page 6), which included the launch of our newly established biannual MTL Doctoral Dissertation Seminar. The seminars are open to the public, and streaming videos of all seminars are available on the MTL website via a special "members only" page. In addition to these regular seminars, we host the occasional Distinguished Seminar, as well, such as the February 2007 visit from Rich Templeton, CEO of Texas Instruments (co-sponsored by RLE and ILP). You can read about Rich Templeton's visit on page 7.

Of course, MTL couldn't operate without the generous contributions from our industrial consortium, the Microsystems Industrial Group (MIG). Research and operation is significantly subsidized by MIG, and I would like to take this opportunity to thank our MIG members for their continued financial support. The MIG donated equipment and provided directed fellowships, fabrication access to state-of-the-art technologies. I would like to welcome NEC and Cadence, our latest members of the MIG. Furthermore, I would like to thank the members of our Industrial Advisory Board (one member from each of our MIG companies), who provide significant assistance in shaping the vision of MTL.

In addition to financial support, MIG companies provide valuable opportunities for technical interactions with our faculty and students. In 2007, MTL graduate students visited three MIG companies – IBM, National Semiconductor, and Texas Instruments – as part of our newest initiative: MTL visit day to MIG member companies. During each visit, our graduate students presented leading-edge research results to the MIG companies and engaged members in detailed, focused technical discussions. We hope to continue expanding these events. See pages 26-28 for some photos from these events.

One final note: I encourage you to read our annual report, which will be available soon, for a more comprehensive look at MTL, including access to over 230 detailed research abstracts.

I hope you enjoy this issue. We are always eager to hear from you on ways to improve MTL, and we look forward to your continued active participation in the lab research and activities.

Sincerely,

ANANTHA P. CHANDRAKASAN
Director
Microsystems Technology Laboratories

MTL is an interdepartmental laboratory at MIT providing device fabrication and CAD infrastructure support to the entire campus. The lab has 30 core faculty members who are engaged in a broad range of exciting research including device fabrication, integrated circuits and systems, photonics, MEMS, molecular- and nano-electronics. In addition, more than 110 affiliate members directly benefit from the fabrication and/or CAD infrastructure provided by MTL. Over the past year, more than 500 researchers (primarily graduate students) have conducted research at MTL. Our faculty, students and staff have received several significant awards.

FABULOUS:
MTL FACILITIES UPDATE

by VICKY DIADIUK and SAMUEL CROOKS • MTL

MIT's Microsystems Technology Laboratories (MTL) was founded in the mid-1980s to provide modern microelectronics fabrication laboratories, including cleanrooms, design and testing facilities. MTL is as an Interdepartmental Laboratory (IDL) of the Institute, and the MTL Director reports to the Dean of the School of Engineering.

MTL's primary mission is to enable research and education in microelectronic/microfabrication technology through the support of an intellectual and physical environment required for such projects. The microfabrication, testing, and computational facilities of the MTL are open to the entire MIT community and researchers from other university or government laboratories, as well as limited industrial participation.

The facilities of the MTL consist primarily of fully-equipped cleanroom microfabrication laboratories and associated design, simulation, testing, and characterization infrastructure, as well as an extensive computer network. Researchers from many different MIT Departments, Labs, and Center utilize the MTL facilities, working on projects that include silicon and III-V electronics and photonics, carbon nanotubes, organic devices, and microelectromechanical systems (MEMS).

MTL has committed significant resources to the acquisition and maintenance of capital equipment. These capital improvements, upgrades, and purchases allow MTL to serve an increasingly diverse user base. In addition, many of the companies that are members of the Microsystems Industrial Group (MIG) donate capital equipment that is used in both the fab and computation facilities. MIG cash donations are also used to partially subsidize the cost of operating the fab and computation facilities.

Facilities

MTL's fabrication resources are managed and operated by a group of professional technical staff led by Dr. Vicky Diadiuk, MTL Associate Director for Operations, who reports to the MTL Director. Professor Judy Hoyt (EECS), MTL Associate Director, works closely with Dr. Diadiuk and the MTL staff to ensure that the facility meets the present and future needs of the growing community of researchers at MIT requiring fabrication capabilities. MTL's fabrication facilities are open to all MIT faculty and students, as well as users from other academic institutions and government agencies through the MTL Outreach Program. In addition, the Fabrication Facilities Access (FFA) program is designed to foster interaction with industry, by allowing their staff access to the MTL fabrication facilities.

Project Technician Dave Terry takes a peek in TRL. [Photo, Tony Rinaldo Photography]

All researchers planning to utilize the MTL fabrication facilities are required to successfully complete a safety and orientation course prior to their use of MTL facilities and must receive training from a research specialist for each piece of laboratory equipment they plan to operate. In addition they must submit a process description to the Process Technology Committee (PTC). The PTC, made up of faculty, students, and technical staff, reviews each process request to ensure that it does not compromise or contaminate any of the fabrication tools or other users' processes. A wide range of materials and substrates are accommodated in the fab, and the list grows as user needs evolve.

MTL also maintains a comprehensive Computation Infrastructure, providing a broad array of services to the community. Professor Jesús del Alamo (EECS), MTL Associate Director, has responsibility for this activity. Seamlessly connected to the Computation Infrastructure, is MTL's Common Object Representation for Advanced Laboratories (CORAL), with which the users of MTL's fabrication facilities interface with the fab tools to perform their processes (e.g., reserve time on machines in the fab). The user log is coupled to a sophisticated charging algorithm which calculates user fees on a monthly basis. CORAL was developed in collaboration with Stanford University and continues to evolve as the needs of MIT's microfabrication community require.

For information regarding MTL's technical operations and capabilities, contact Dr. Vicky Diadiuk, MTL Associate Director, Operations, telephone (617) 253-0731, e-mail diadiuk@mtl.mit.edu. For information regarding MTL programs and other general information, please contact Mr. Samuel Crooks, Associate Director, Administration, telephone (617) 253-3978, e-mail crooks@mtl.mit.edu. You may also wish to visit our web site at: http://mtlweb.mit.edu.

Pictured above from left to right: David White, Cadence; George Bourianoff, Intel Corporation; Peter Holloway, National Semiconductor; Anantha Chandrakasan, Microsystems Technology Laboratories; Brad Scharf, Analog Devices; David Williams, Novellus Systems; Takemitsu Kunio, NEC; Dennis Buss, Texas Instruments; David Kyser, Applied Materials; Paul Benning, Hewlett-Packard; Ghavam Shahidi, IBM. (Photo, Paul McGrath)

INDUSTRIAL ADVISORY BOARD

MIG MEMBERS TALK MTL • JANUARY 26, 2007

The MIG Industrial Advisory Board (IAB) is composed of members representing the MIG member companies, and who help to ensure that the research and education activities in the Microsystems Program are complementary to those conducted elsewhere and are relevant to industry's needs. IAB meets twice annually to review the overall operation of the laboratories, ongoing research projects, and future directions for microsystems research and education at MIT. IAB also serves as a sounding board for specific ideas. Individual members of IAB should encourage additional informal interactions between MIT personnel and the companies they represent.

TO READ BIOGRAPHIES OF ALL CURRENT MEMBERS, VISIT OUR WEBSITE:
http://mtlweb.mit.edu/mig/iab.html

MTL WELCOMES NEC TO ITS INDUSTRIAL GROUP

by CARL A. ACCARDO • Senior Advisor, MIT Industrial Liaison Program

The Microsystems Technology Laboratories (MTL) at the Massachusetts Institute of Technology and NEC Corporation announced on January 23, 2007 that NEC has joined the Microsystems Industrial Group (MIG), an exclusive ten member industry consortium. MIG was founded in the 1980s to support MTL infrastructure and provide direction to the Microsystems Technology Laboratories research and educational objectives in consultation with the faculty. NEC is the first Japanese company to join the group.

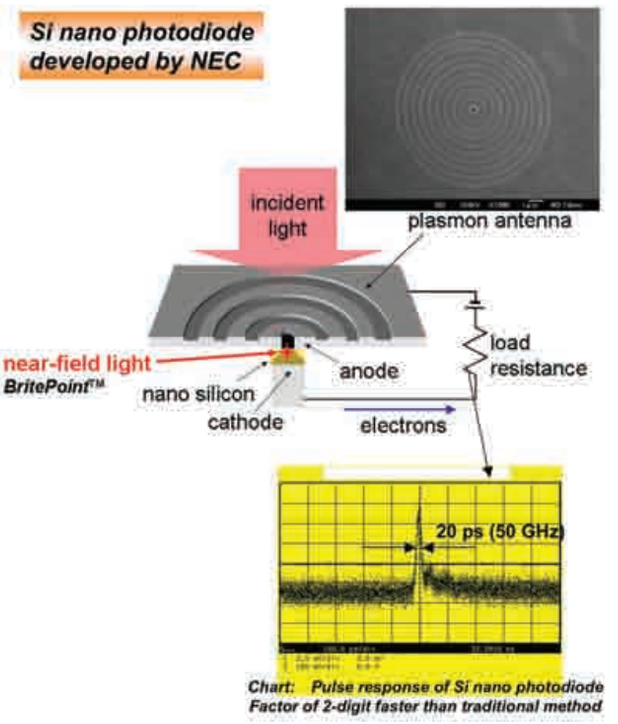


Chart: Pulse response of Si nano photodiode
Factor of 2-digit faster than traditional method

Above: Light is squeezed in a tiny area less than a wavelength using the surface plasmon antenna. Through a combination of the antenna and a tiny silicon photodiode, high-speed conversion from a light signal to an electric one is achieved. The device is expected to contribute to revolutionary innovations for telecommunications and on-chip optical interconnect technology.
[Image courtesy of NEC Corporation. Unauthorized use not permitted]

NEC decided to join MIG following participation in a number of preliminary meetings and a joint workshop held late last year. "We are thrilled to join MTL's Microsystems Industrial Group and look forward to building effective collaboration," said Dr. Takemitsu Kunio, Executive General Manager of NEC's Central Research Laboratories and Associate Senior Vice President at NEC. "We plan to dispatch NEC research staff to work on-site in the interactive and interdisciplinary environment at MIT in order to continue NEC's drive toward greater research excellence through open innovation." Dr. Fujio Okumura, Senior Manager at NEC's System Device Laboratory added, "We are excited to start collaborative research as a member of MIG. We aim to develop novel technology by working closely with MIT faculty including Professor Martin Schmidt."

Professor Chandrakasan commented, "We look forward to continued productive collaboration with NEC and our other MIG members in a number of research areas including MEMS, emerging device technologies, photonics, and low-power integrated circuits with applications in communications, medicine, and other disciplines." MTL is an interdisciplinary laboratory at the Massachusetts Institute of Technology, in which more than 100 principal investigators from various academic departments perform research. The laboratory supports research and education in nanosystems, including semiconductor process and design, integrated circuit design, and microelectromechanical systems (MEMS).

NEC's membership in the MIG is not the first time that NEC and the university have engaged in collaborative research. In the late 1970s, NEC's Chairman, Dr. Koji Kobayashi, began supporting research initiatives at MIT and became a dedicated advocate of industry-academic collaboration. This philosophy of collaboration extends to the present day in NEC's current chairman, Mr. Hajime Sasaki.

ABOUT NEC CORPORATION

NEC Corporation (NASDAQ: NIPNY) is one of the world's leading providers of internet, broadband network and enterprise business solutions dedicated to meeting the specialized needs of its diverse and global base of customers. NEC delivers tailored solutions in the key fields of computer, networking and electron devices, by integrating its technical strengths in IT and Networks, and by providing advanced semiconductor solutions through NEC Electronics Corporation. The NEC Group employs more than 150,000 people worldwide. For additional information, please visit the NEC home page at: http://www.nec.com.

CADENCE DESIGN SYSTEMS JOINS MTL INDUSTRIAL GROUP

by DUANE BONING • Professor, Department of Electrical Engineering and Computer Science, MIT

Above: Dr. David White, Senior Architect at Cadence Design Systems. Dr. White is a member of the MIG Industrial Advisory Board at MTL.

The newest addition to the Industrial Group of MIT's Microsystems Technology Laboratories (MTL) is Cadence Design Systems. Cadence is the first electronic design automation (EDA) company to join the Microsystems Industrial Group (MIG).

"Cadence brings a unique perspective to MTL's research and educational activities," notes Prof. Anantha Chandrakasan, Director of MTL, "and greatly enriches our access to design automation tools, approaches, and challenges, to complement MTL's research in integrated circuit design, semiconductor device and process technology, and emerging photonic, microelectromechanical (MEMS), and nanoscale technologies."

Dr. David White of Cadence says "By joining the MIG, Cadence is delighted to deepen its long-standing contributions to the MTL research community." Cadence tools are widely used by the circuits and systems research groups at MIT. The design of many integrated circuits (ICs) has been enabled by the Cadence environment, and this support from Cadence has been critical for undergraduate and graduate education in the integrated circuits area.

In addition to influencing MTL's broad research vision and directions through participation in the MIG Board, Cadence is initiating focused interactions with target MTL faculty and research groups. Work with Prof. Luca Daniel and his students will target variation-aware interconnect extraction and model reduction algorithms.

As part of a broad research agenda in design for manufacturability (DFM), Cadence is also initiating interactions with Prof. Duane Boning's group to advance the understanding and modeling of process variations and their effects.

ABOUT CADENCE

cadence™

Cadence enables global electronic-design innovation and plays an essential role in the creation of today's integrated circuits and electronics. Customers use Cadence software and hardware, methodologies, and services to design and verify advanced semiconductors, consumer electronics, networking and telecommunications equipment, and computer systems. Cadence reported 2006 revenues of approximately $1.5 billion, and has approximately 5,200 employees. The company is headquartered in San Jose, Calif., with sales offices, design centers, and research facilities around the world to serve the global electronics industry. More information about the company, its products, and services is available at www.cadence.com.

MTL SEMINAR SERIES

NETWORKING, SNACKS, AND TECHNOLOGY COME ALIVE

by RHONDA MAYNARD • Staff Writer

You're a grad student, and it's Tuesday. As four o'clock rolls around you realize you have spent several hours in the lab and are in dire need of a caffeine break. You probably ignored the email, but as luck would have it, a mysterious voice reminds you: "Today's MTL Seminar is about to begin. Our speaker for today is–" Yes! Your prayers have been answered. Today is seminar day, and where there's an MTL Seminar, there's coffee. And cookies. Two of the four major food groups for a grad student (pizza and beer are the others, of course).

Years from now, though, you'll look back on the seminars and realize they weren't all about the free cookies and coffee. "I wish I would have taken more advantage of seminars and other events offered while I was a student," Tonya Drake '03, Technology Specialist at Fish & Richardson P.C., said during the recent panel discussion at MARC 2007, "Career Paths after MTL." Drake was one of six alumni to participate in the discussion. John Kymissis, Ph.D.'03, now a professor at Columbia University, agreed, "Really broad exposure to people and technical topics is important."

Besides learning about the latest microelectronics research and manufacturing trends, the Seminar Series offers a unique networking opportunity. Attendees gain valuable exposure to industry leaders, potential research collaborators, and, perhaps, future employers.

According to Prof. Joel L. Dawson, MTL Seminar Series Committee Chair, "The committee is determined to have a series that is well-balanced among MTL disciplines, as well as between industry and academia." In order to achieve this balance, Dawson explained that beginning with the Spring 2007 term, the Series included MIT "insiders": an Institute-wide speaker, an MTL speaker, and, for the first time, a student speaker. "I am particularly excited about the MTL Doctoral Dissertation Seminar," Dawson stated. Lane Brooks, a graduating Ph.D. student of Prof. Hae-Seung Lee was chosen to give a talk about the latest developments in zero-crossing based circuits (ZCBC), an exciting piece of work with the potential to have an extremely high impact in his field. Brooks was chosen based on his nominations, as well as his 200-word statement describing the focus and impact of his research. "The MTL Doctoral Dissertation Seminar gives graduating Ph.D. students a chance to share their work with the entire MTL community. Actually, if it's great stuff, it's their duty to share it with all of us!"

Other spring term speakers included Gabriele Manganaro, National Semiconductor; Matthias Passlack, Freescale Semiconductor; Mildred Dresselhaus, MIT Institute Professor; George Whitesides, Harvard University; Dimitri Antoniadis, MTL; Tahir Ghani, Intel Corporation; and Roger Howe, Stanford University.

Seminars take place most Tuesdays at 4 p.m. in 34-101, located at 50 Vassar St.; refreshments available at 3:30 p.m. Streaming video of all seminars is accessible to the MTL community through the "Members Only" secured content section of the MTL web site (http://mtlweb.mit.edu).

Right: Still frames from March 13, 2007 presentation by Institute Professor Millie Dresselhaus (top) and April 24, 2007 presentation by Tahir Ghani of Intel Corporation (bottom). Seminar Series streaming video files are available to members of the MTL community (including MTL students, faculty, staff, and MIG members) online through the "Members Only" secured content section of the MTL website (http://mtlweb.mit.edu).

YOU HAVE CHOSEN WISELY

RICH TEMPLETON • FEBRUARY 1, 2007

by RHONDA MAYNARD • Staff Writer

"You have chosen wisely," Rich Templeton, Texas Instruments President and Chief Executive Officer, told engineering students at a February 1 talk sponsored by MTL, RLE and MIT ILP. Templeton's talk, "Building Technology that Matters: Global Opportunities in Engineering," emphasized the importance of electrical engineering education in today's global economy. "It's a great time to be an engineer," Templeton said.

Unlike that famous Patent commissioner who once announced everything worth inventing had already been invented, Templeton believes that "the great innovations are in front of us."

"I remember sitting in a conference room with one of the earliest pioneering [cell phone] companies," he told the packed lecture hall at MIT. "They said that if they were wildly successful they would sell 200 million cell phones. They did a little better. I encourage you to think forward." (There are now over 3 billion cell phone subscribers world-wide.)

"You are pursuing an engineering education, an engineering foundation, and I refer to it as a foundation as opposed to an occupation because we are in a world that is getting technically more sophisticated and the people that understand how this world works will be advantaged in what they do—you have chosen wisely."

-Rich Templeton, Texas Instruments president and chief executive officer

Templeton predicted the next great innovation could be in bioelectronics, citing diagnostic equipment, such as portable, low-power ultrasound, and other "almost science-fiction-like implantable devices" as having a potentially revolutionary impact, especially in growing economies. He went on to say that problems are out there just waiting to be solved by curious, creative people. "This is an exciting time," Templeton exclaimed.

Rich Templeton, second from left, enjoys the atmosphere at MTL with Dennis Buss, also of Texas Instruments, right. (Photo, Paul McGrath)

To view video of Rich Templeton's talk at MIT, please visit: **http://mitworld.mit.edu/stream/437/**

Besides "thinking forward," Templeton urged the audience to think globally: "We travel the world because our customers are all over the world and their customers are all over the world."

He also encouraged the audience to think about engineering study as a foundation, rather than an occupation: "You could be a great researcher, scientist, or developer, but there's also other paths: sales, law, investor relations, human resources." Whatever path one chooses, though, Templeton believes that problem solving, understanding the world, and the ability to work with people in a team environment are essential keys to success. Another key to success? Work on projects that are fun and challenging. "Work on things you are not familiar with," Templeton explained, "Work with things that challenge you, work on stuff that scares you."

More importantly, perhaps, Templeton asked the audience to view education as a gift and to "give back": "Encourage people to enter the science, engineering, and math fields. Convince the next generation that [engineering] is a great path."

Templeton has been president and CEO of Texas Instruments since May 2004. He also serves on the company's board of directors. He is credited with helping to define and execute TI's strategy to focus on semiconductors for signal processing. Operationally, he guided TI during the worst downturn in semiconductor history, while maintaining the company's strategic investments in R&D and advanced manufacturing. His leadership helped TI to emerge in stronger strategic, technological and product positions, and as a result the company has gained market share for each of the last two years.


WATERVILLE
VALLEY
CONFERENCE &
EVENT CENTER
WELCOME
MIT
MICROSYSTEMS
TECHNOLOGY LABORATORIES

MARC HITS THE SPOT

Microsystems Annual Research Conference 2007

by RHONDA MAYNARD • Staff Writer

(Photo, Paul McGrath)

MTL held its 17th Annual Research Conference at Waterville Valley Conference & Event Center on January 24-25. The conference offered students an opportunity to share their research with faculty, staff, and industry partners.

This year's conference, led by Prof. Anantha Chandrakasan, Steering Committee Chair, and Farinaz Edalat and Osama Nayfeh, Program Committee Co-Chairs, included skiing and snowboarding in the fresh New Hampshire snow, followed by a full technical program. And, for the first time ever, six MTL alumni returned to MARC to participate in a panel discussion: "Career Paths after MTL." Additionally, MTL was honored to welcome Dr. Johannes (Hans) M.C. Stork, Senior Vice President and Chief Technology Officer, Texas Instruments, as the keynote speaker. His talk, "Consequences of the Nanoscale in CMOS Engineering," proved to be one of the highlights of the conference.

"I enjoy the MARC conference every year," Prof. Judy Hoyt said. "The atmosphere is relaxed, yet the student presentations and posters are very professional." Dennis Buss, Texas Instruments, agreed. "In my experience, MARC is a unique conference. Not only does it provide a tremendous learning experience for students, it's a great learning opportunity for companies, as well – And everyone has a blast!"

For many grad students, the one-on-one contact with industry representatives is key to their MARC experience. For instance, grad student Ivan Nausieda received feedback from Hewlett-Packard and National Semiconductor on his project: "Optical feedback organic LED display: Design and characterization of organic circuits." Nausieda explained, "I asked industry people what they thought about [my research], and we were able to compare it to what they are doing." Nausieda added, "I think it's very useful to have this kind of dialogue, because they are the ones familiar with how industry approaches

Above: MARC2007 Planning committee. Back row, left to right: Paul McGrath, Leo Gomez, Debroah Hodges-Pabon, Tania Khanna, Ivan Nausieda, Vivienne Sze, Mara Karapetian, Niamh Waldron, Osama Nayfeh, Anantha Chandrakasan, Farinaz Edalat, Alexis Weber, Valerie Leblanc, Vladimir Bulovic, Jianping Fu, Juejun Hu, Philip Dextras, Alfonso Reina, Samuel Crooks. Front row: Fred Lee, Naveen Verma, Nigel Drego. (Photos, Paul McGrath, MTL)

Opposite page, middle: Debroah Hodges-Pabon escorts students off of the bus from MIT to Waterville Valley, New Hampshire for MARC2007. Opposite page, bottom: Visiting scientist Dr. Takeshi Honda and student Lirong Zheng.

This page, top left: Student Salil Desai explains his poster to MARC attendees. Bottom left: Iliana Chen catches up with MTL Associate Director Vicky Diadiuk. Top right: Student Daniel Truque shares a handshake with MARC2007 alumni panelist Andy Wei of AMD. (Photos, Paul McGrath, MTL)

things beyond the theoretical – they're the ones actually working on it."

Communication between industry members and students is equally important for company representatives. Martin Izzard, Texas Instruments, spent some time with grad student Farinaz Edalat discussing her TI sponsored project: "Adaptive modulation in wireless Giga-bit local area networks." "I'm interested in making sure we have a good connection," Izzard said. "This conference is a great opportunity to find out how [TI] can do better. Collaboration isn't just about funding – I see the relationship as a two-way street. We can learn from what you are developing here." Edalat agreed: "I think [industry representatives] see a lot of problems in industry that we don't see, so it's very helpful for me to be connected to people who have a lot of information about what challenges are out there – challenges that maybe I didn't think about."

Even though industry members, like Ian Young, Intel Corp., typically scope out projects relevant to their company, they appreciate the thematic diversity found at MARC. While Young paid particular attention to mixed-signal and high-speed low-power circuits research, as well as projects that involved Carbon Nanotubes, he stated, "I don't mean to focus on Intel's roadmap. I think some of the other materials in the optical and organic transistor areas are interesting."

Students and faculty, too, appreciate a chance to look at research outside their specialization. "I think the MEMS posters are really interesting," circuits and systems grad student David Wentzloff said. "When you're focused on your own project, you don't always have time to think about someone else's research, but MARC is a really good way see what other people are doing." Prof. Hoyt remarked, "It's a rare opportunity to see such a wide range of work, outside any one field."

Whether it was the fun in the snow or the enriching presentations MARC 2007 will be memorable. "The student organizers did an especially nice job this year," stated Prof. Hoyt. I thought the panel discussion on career paths was very interesting and entertaining. I also enjoyed Hans Stork's talk; he presented the big picture on scaling challenges as well as some 'nitty-gritty' details, so I thought there was something in that for everyone, novice and expert alike."

Alumni Make Their MARC

Alumni panelists, from left to right: Andy Wei, Rajan Naik, John Kymissis, Tonya Drake, Seth Coe-Sullivan, and Iliana Chen. (Photos, Paul McGrath, MTL)

One of the most daunting realizations as one nears graduation is the fact that it is time to face life "in the real world." While the perception might be that grad students get to sleep in every day and get summers off, we all know that's not really true. Grad school isn't that easy. Most students are in the lab more than they are at home, even over the summer, and, for some, "sleeping in" means sleeping under their desk in their cubicle during a tape-out.

In spite of the long hours and hard work spent in grad school, getting a nine to five job is a bit nerve-racking. After all, you've spent most of your life in school, and leaving MIT means leaving your comfort zone. Alas, not to worry. These fears are common. You're not the first to ask, "Now what?"

That's why six MTL grads were asked to address students' concerns at MTL's Annual Research Conference (MARC) held at Waterville Valley Conference & Event Center in January, a first for the conference.

The panel discussion, "Career Paths after MTL," was moderated by Prof. Vladimir Stojanović and featured Iliana Chen '02, Seth Coe-Sullivan '05, Tonya Drake '03, Ioannis (John) Kymissis '03, Rajan Naik '98, and Andy Wei '01. Each discussed the different paths they chose and described their lives after leaving grad school. The discussion was open, honest, and often humorous.

Iliana Chen, an IC design engineer at Analog Devices said, "I thought I was too social to be an engineer." And while Chen said she "thought about what [she] was going to do every day of [her] life at MIT," Andy Wei told the audience that he "didn't think about it at all" and that he got his job in transistor development at AMD "by accident."

On the other hand, Seth Coe-Sullivan's career choice was no accident. Building upon his MTL research on quantum dots, Coe-Sullivan founded QD Vision and now has over 20 papers and patents pending in the fields of organic light emitting devices, quantum dot LEDs and nanotechnology fabrication.

Not all MTL grads go into design or development, though, some choose other paths. Rajan Naik, a consultant at McKinsey & Company, explained, "MIT prepares you more than you realize for a career in consulting." Naik decided to change career paths after spending two and a half years in product development at Intel.

The intellectual property side of the industry fascinated alumnae Tonya Drake. A technology specialist at Fish & Richardson P.C., Drake now works with small semiconductor and biotech companies managing property rights.

Of course some graduates conclude academia is the right place for them. John Kymissis, for example, is now an assistant professor in electrical engineering at Columbia University. Kymissis cites the importance of balancing work and family as the basis for his decision to stay in academia. "It provides flexibility so I can spend time with my family," Kymissis explained.

When Prof. Martin Schmidt asked the panel, "What one thing are you glad you did, and what one thing do you wish you would have done differently?" the answers were surprising.

"Working with Charlie [Sodini] was the best thing I did," Chen said. "He taught me how to have fun." Drake also cited working with her advisor, Prof. Judy Hoyt, as the best thing she did.

Kymissis and Wei said hanging out with lots of different people was their favorite part of MTL, but Wei joked that he wished "he had learned more."

Coe-Sullivan on the other hand said he wished he had hung out more; he didn't spend a lot of time "smelling the roses."

No matter which career path they chose, all six panelists agreed that the leadership, team building, and networking skills they acquired during their time at MTL has helped them tremendously post-graduation.

According to the MIT Careers Office, 53% of MIT graduates go into industry, based on a 2006 graduating student survey. 24% earn post-doctoral fellowships, 13% go into academia, and 2% continue their education, while 8% choose other paths.

Presentation Award Winners: Top left: Fred Chen. Bottom left: Niamh Waldron. Right: Valerie Leblanc. (Photos, Paul McGrath, MTL)

Students Stand Out at MARC

"The following preview has been rated PG-13—it may contain technical language," joked Valerie Leblanc as she introduced her poster at MTL's Annual Research Conference (MARC) held at Waterville Valley Conference & Event Center on January 24-25, 2007. Anantha Chandrakasan, MTL Director, and Dennis Buss, Texas Instruments, later awarded Leblanc one of the coveted Presentation Awards for her poster: "MEMS-enabled direct evaporative patterning of molecular organic materials in ambient." Other award-winners include Fred Chen, Farinaz Edalat, Blaise Gassend, Osama Nayfeh, Gilbert Nessim, Jason Orcutt, Matt Park, Manu Prakash, and Niamh Waldron.

"This is the largest [MARC] conference I've been to – it's grown a lot," Ian Young, Intel Corp. stated. "I like the format of the large number of posters and the 90-second summary. It's great training for the students – speaking in front of a large audience – and it's a very efficient way for industry members to get glimpse of the technical elements."

In all, 76 students presented their work at MARC in the areas of Circuits & Systems, Photonics, MEMS & BioMEMS, Molecular & Nanotechnology, and Electronic Devices & Emerging Technologies. During each session, industry attendees evaluated student oral presentations based on the quality with which the presented research motivated, as well as the justification provided for the relevance of the technical contribution. Besides receiving a cash prize sponsored by Texas Instruments, winners repeated their presentations at the Microsystems Industrial Group (MIG) board meeting held on January 26 at MIT.

MARC 2007 PRESENTATION AWARD WINNERS

CIRCUITS & SYSTEMS

System Architecture Implications of CNT Interconnects
— Fred Chen

Adaptive Modulation in Wireless Giga-bit Local Area Network
— Farinaz Edalat

An Optical-Electrical Sub-Sampling Down-Conversion Receiver Employing Continuous-Time Sigma-Delta Modulation
— Matt Park

PHOTONICS

Integrated Group-IV Optoelectronic Devices for Board-Level WDM Interconnect in Strict Sub-100nm CMOS
— Jason Orcutt

MEMS & BioMEMS

A Fully Micro-Fabricated Planar Array of Electrospray Emitters for Space Propulsion Applications
— Blaise Gassend

MEMS-Enabled Direct Evaporative Patterning of Molecular Organic Materials in Ambient
— Valerie Leblanc

Microfluidic Bubble Logic
— Manu Prakash

MOLECULAR & NANOTECHNOLOGY

Carbon Nanotube Growth for Interconnect Applications
— Gilbert Nessim

ELECTRONIC DEVICES & EMERGING TECHNOLOGIES

Towards MOS Memory Devices Containing 1-nm Silicon Nanoparticles
— Osama Nayfeh

InGa as High-Electron Mobility Transistors for Post-Si Logic
— Niamh Waldron

Anantha Chandrakasan shakes the hand of presentation award winner Farinaz Edalat. Edalat was also a student chair of this event. (Photo, Paul McGrath, MTL)

LOW POWER TO THE PEOPLE

New analog circuits could impact consumer electronics

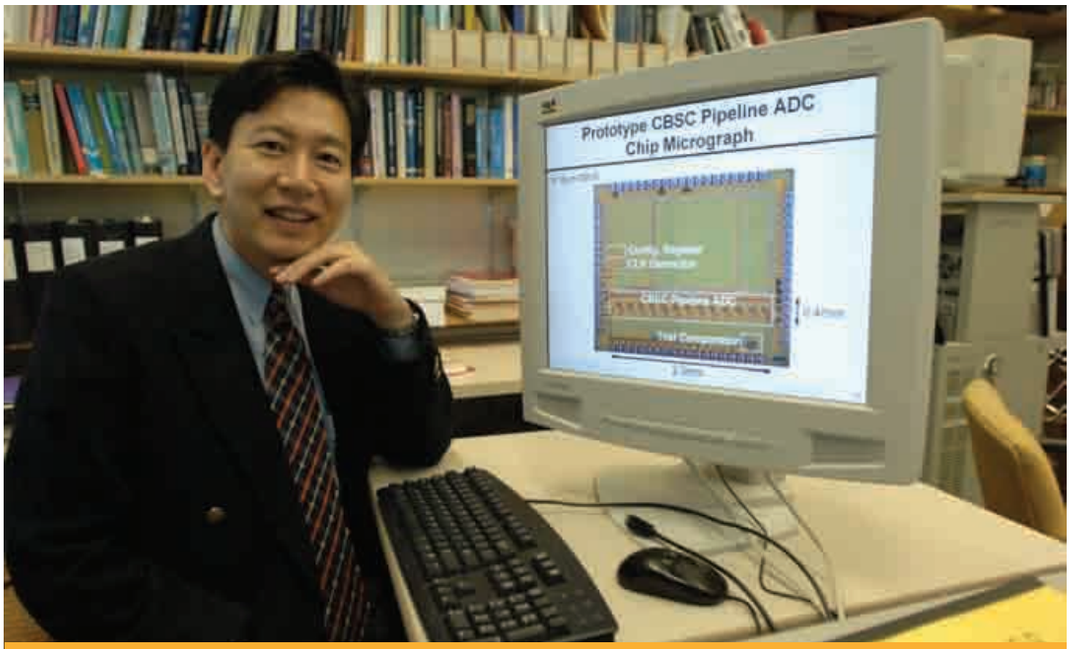
by ELIZABETH THOMSON • Senior Science & Engineering Editor, MIT News Office

Advances in digital electronic circuits have prompted the boost in functions and ever-smaller size of such popular consumer goods as digital cameras, MP3 players and digital televisions. But the same cannot be said of the older analog circuits in the same devices, which process natural sights and sounds in the real world. Because analog circuits haven't enjoyed a similar rate of progress, they are draining power and causing other bottlenecks in improved consumer electronic devices.

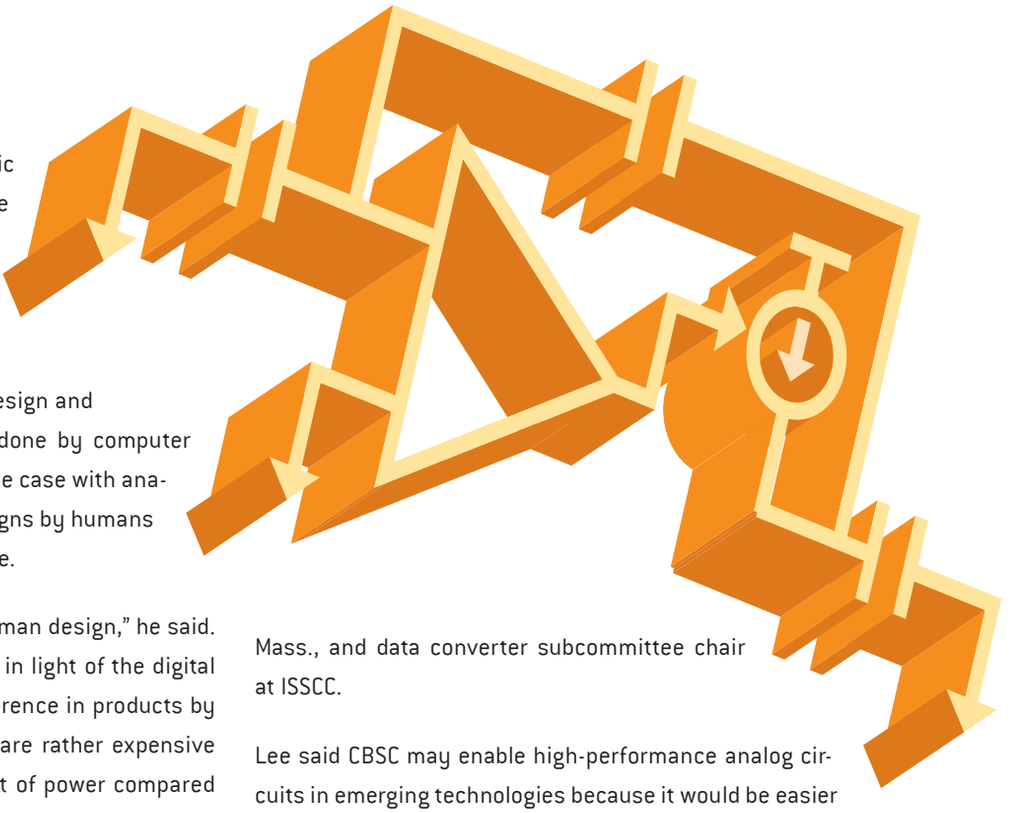
Now MIT engineers have devised new analog circuits they hope will change that. Their work was discussed at the International Solid State Circuits Conference (ISSCC) in San Francisco Feb. 5-8, 2006 and Feb. 11-15, 2007.

"During the past several decades, engineers have focused on allowing signals to be processed and stored in digital forms," said Hae-Seung Lee, a professor in MIT's Microsystems Technology Laboratories (MTL) and the Department of Electrical Engineering and Computer Science (EECS). "But most real-world signals are analog signals, so analog circuits are an essential part of most electronic systems."

Analog circuits are used to amplify, process and filter analog signals and convert them to digital signals, or vice versa, so the real world and electronic devices can talk to each other. Analog signals are continuous and they vary in size, whereas digital signals have specific or discrete values.



MIT professor Hae-Seung Lee and his colleagues have developed new analog circuits — comparator-based switched capacitor circuits — that handle voltage differently than conventional analog ones, resulting in greater power efficiency. (Photo, Donna Coveney, MIT News Office)



The reason the two different types of electronic signal circuits did not advance at the same pace, Lee said, is because they are very different. Digital circuits can be decreased in size more easily, for example, by using the popular complementary metal oxide semiconductor (CMOS) technology. And much of the design and performance enhancement can actually be done by computer software rather than by a human. That's not the case with analog circuits, which Lee said require clever designs by humans to be improved because of their variable nature.

"There is a lot of room for innovation in the human design," he said. "The importance of analog circuits is growing in light of the digital improvements, so engineers can make a difference in products by working on them." Currently, analog circuits are rather expensive and they consume a disproportionate amount of power compared with digital circuits.

Another blow to analog circuits is that the advancements in fabrication (manufacturing) technology to improve digital circuits have had a negative impact on them. Traditionally, many conventional analog circuits have relied upon devices known as operational amplifiers. Two negative side effects that advanced fabrication technologies have had on operational amplifier-based analog circuits are that when used in consumer or other devices, they have reduced the range of the analog signal and decreased the device's gain. To compensate for these shortcomings, analog circuits must consume much more power, thus draining precious energy from batteries.

In addition, it still is not clear whether traditional operational amplifier-based circuits can be applied to emerging technologies such as carbon nanotube/nanowire devices and molecular devices.

Lee's research group, in collaboration with Professor Charles Sodini's group in MIT's MTL and EECS, recently demonstrated a new class of analog circuits that Lee said eliminates operational amplifiers while maintaining virtually all benefits of operational amplifier-based circuits. These new comparator-based switched capacitor (CBSC) circuits handle voltage differently than conventional analog ones, resulting in greater power efficiency.

"The new work coming out of MIT offers the intriguing possibility of eliminating operational amplifiers by proposing an architecture that relies on circuit blocks that are much more readily implemented on supply voltages of 1 volt or less," said Dave Robertson, high-speed converter product line director at Analog Devices Inc. in Norwood, Mass., and data converter subcommittee chair at ISSCC.

Lee said CBSC may enable high-performance analog circuits in emerging technologies because it would be easier to implement comparators than operational amplifiers in these technologies.

The first prototype MIT CBSC was demonstrated in an analog-to-digital converter and presented at 2006 ISSCC. The second prototype, an 8-bit, 200 MHz analog-to-digital converter, was presented at the 2007 ISSCC.

Other key members of the research team are EECS graduate students John Fiorenza and Todd Sepke, who were involved in the work presented in 2006; EECS graduate student Lane Brooks, who worked on the current prototype; and Peter Holloway of National Semiconductor Corp.

The research leading to the 2006 ISSCC paper was funded by Microelectronics Advanced Research Corp. The research leading to the paper presented at the 2007 ISSCC was funded by the MIT Center for Integrated Circuits and Systems and a National Defense Science and Engineering Graduate Fellowship.

BEYOND SILICON

MIT demonstrates new transistor technology

by ELIZABETH THOMSON • Senior Science & Engineering Editor, MIT News Office

MIT engineers have demonstrated a technology that could introduce an important new phase of the microelectronics revolution that has already brought us iPods, laptops and much more.

The work was presented at the IEEE International Electron Devices Meeting Dec. 11-13 by Dae-Hyun Kim. Kim is a postdoctoral associate in the laboratory of Jesús del Alamo, an MIT professor of electrical engineering and computer science and member of MIT's Microsystems Technology Laboratories (MTL).

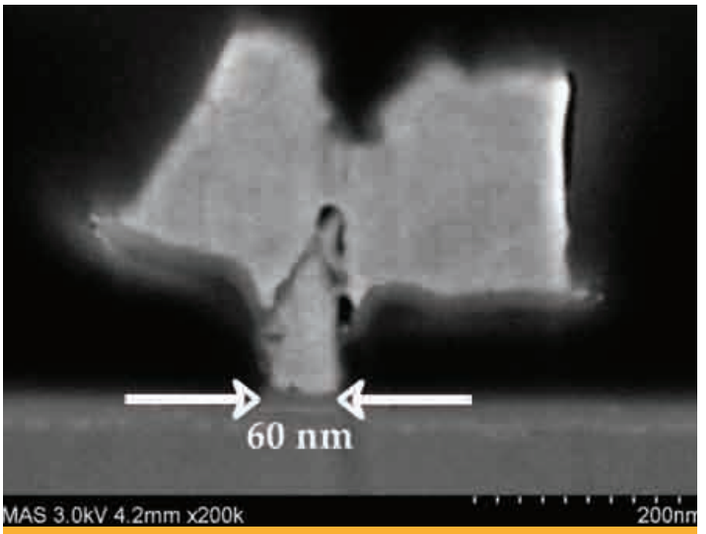
"Unless we do something very radical pretty soon, the microelectronics revolution that has enriched our lives in so many different ways might come to a screeching halt," said del Alamo.

Postdoctoral associate Dae-Hyun Kim, left, and Professor Jesús del Alamo look at a cross-section of the new transistor they have been developing. Behind them is the test equipment used to measure its characteristics. (Photo, Donna Coveney/MIT)

The problem? Engineers estimate that within the next 10 to 15 years we will reach the limit, in terms of size and performance, of the silicon transistors key to the industry. "Each of us has several billion transistors working on our behalf every day in our phone, laptop, iPod, car, kitchen and more," del Alamo noted.

As a result, del Alamo's lab and others around the world are working on new materials and technologies that may be able to reach beyond the limits of silicon. "We are looking at new semiconductor materials for transistors that will continue to improve in performance, while devices get smaller and smaller," del Alamo said.

One such material del Alamo and his students at the MTL are investigating is a family of semiconductors known as III-V compound semiconductors. Unlike silicon, these are composite materials. A particularly hot prospect is indium gallium arsenide, or InGaAs, a material in which electrons travel many times faster than in silicon. As a result, it should be possible to make very small transistors that can switch and process information very quickly.



This image shows a cross sectional view of the indium gallium arsenide transistor fabricated at MIT. The critical dimension is 60 nanometers, similar to that of state-of-the-art silicon transistors. (Photo, Jesús del Alamo)

"With more work, this semiconductor technology could greatly surpass silicon and allow us to continue the microelectronics revolution for years to come."

- Prof. Jesús del Alamo

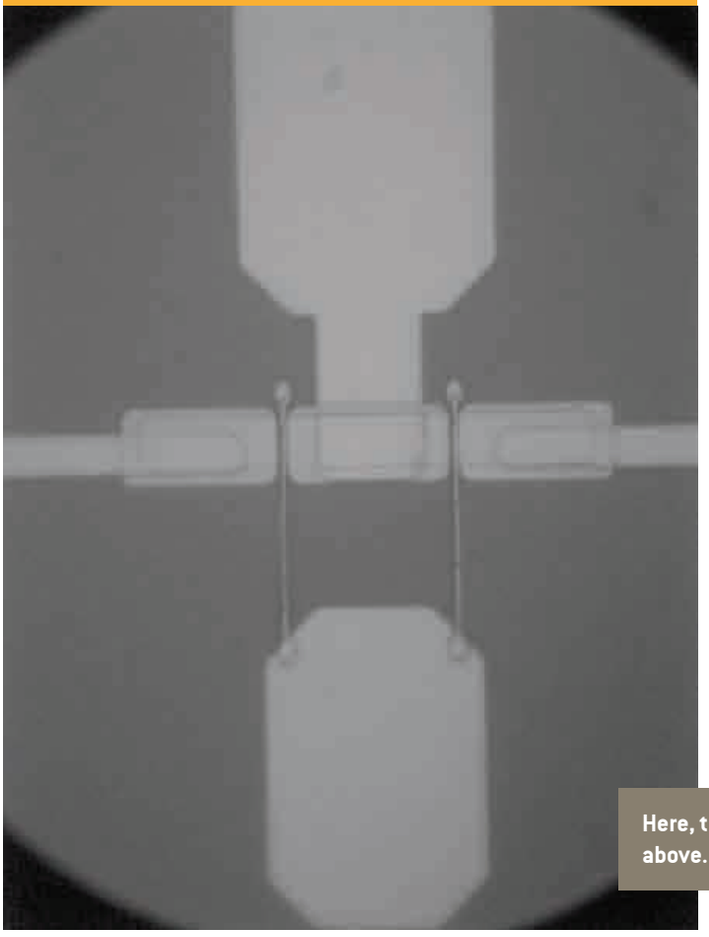
Del Alamo's group recently demonstrated this by fabricating InGaAs transistors that can carry 2.5 times more current than state-of-the-art silicon devices. More current is the key to faster operation. In addition, each InGaAs transistor is only 60 nanometers, or billionths of a meter, long. That's similar to the most advanced 65-nanometer silicon technology available in the world today.

"The 60-nanometer InGaAs quantum-well transistor demonstrated by Professor del Alamo's group shows some exciting results at low supply voltage (e.g. 0.5V) and is a very important research milestone," said Robert Chau, senior fellow and director of transistor research and nanotechnology at Intel, a sponsor of the work.

Del Alamo notes, however, that InGaAs transistor technology is still in its infancy. Some of the challenges include manufacturing transistors in large quantities, because InGaAs is more prone to breakage than silicon. But del Alamo expects prototype InGaAs microdevices at the required dimensions to be developed over the next two years and the technology to take off in a decade or so.

"With more work, this semiconductor technology could greatly surpass silicon and allow us to continue the microelectronics revolution for years to come," del Alamo said.

In addition to Intel, this research is sponsored by the Microelectronics Advanced Research Corporation. The MIT transistors were fabricated by pulling together the capabilities of three MIT laboratories: the Microsystems Technology Laboratories, the Scanning-Electron-Beam Lithography Facility and the Nanostructures Laboratory. Del Alamo notes that one reason for the exceptional performance of these transistors is the high quality of the semiconductor material, which was prepared by MBE Technology of Singapore.



Here, the indium gallium arsenide transistor fabricated at MIT is shown from above. (Photo, Jesús del Alamo)

CHIP UP

MIT improves protein sorting with a new microchip

by DEBORAH HALBER • MIT News Office Correspondent

A new MIT microchip system promises to speed up the separation and sorting of biomolecules such as proteins. The work is important because it could help scientists better detect certain molecules associated with diseases, potentially leading to earlier diagnoses or treatments.

The microchip system has an extremely tiny sieve structure built into it that can sort through continuous streams of biological fluids and separate proteins accurately by size. Conventional separation methods employ gels, which are slower and more labor-intensive to process. The new microchip system could sort proteins in minutes, as compared to the hours necessary for gel-based systems.

The MIT team's results appeared in the Feb. 5 issue of *Nature Nanotechnology*.

The new technology is an advance from a one-dimensional sieve structure reported by the same MIT group last year. The key to this new advance, called an anisotropic nanofluidic sieving structure, is that the researchers have designed the anisotropic sieve in two orthogonal dimensions (at a right angle), which enables rapid continuous-flow separation of the biological sample. This allows continuous isolation and harvesting of subsets of biomolecules that researchers want to study. And that increases the probability of detecting even the smallest number of molecules in the sample.

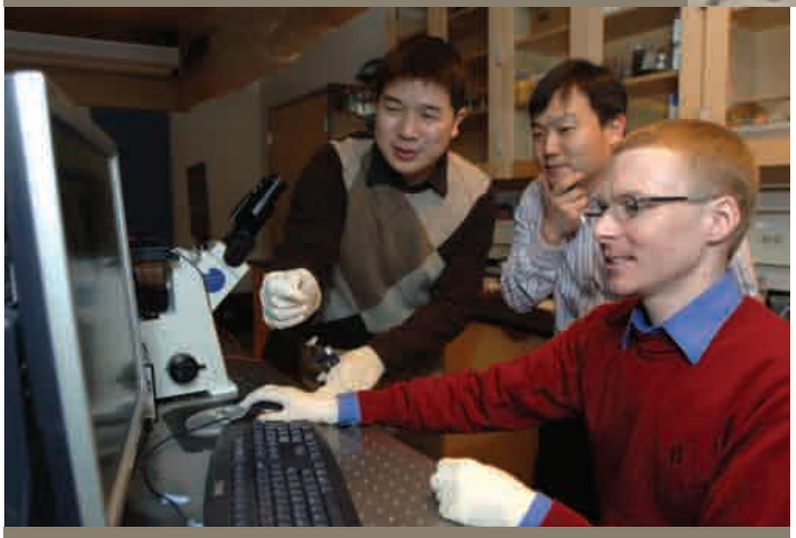
"With this technology we can isolate interesting proteins faster and more efficiently. And because it can process such small biologically relevant entities, it has the potential to be used as a generic molecular sieving structure for a more complex, integrated biomolecule preparation and analysis system," said Jongyoon Han, the Karl Van Tassel Associate Professor of Electrical Engineering and Associate Professor of Biological Engineering at MIT and head of the MIT team.

Han's coauthors of the *Nature Nanotechnology* paper are co-lead authors Jianping Fu, a Ph.D. candidate in the Department of Mechanical Engineering, and Reto B. Schoch, a postdoctoral associate in the Research Laboratory of Electronics (RLE). Additional authors are Anna Stevens, a postdoctoral associate in the Harvard-MIT Division of Health Sciences and Technology, and Professor Steven Tannenbaum of MIT's Biological Engineering Division.

Han noted that until the late 1990s, most advances in biological laboratory equipment were aimed at the Human Genome Project and discoveries related to DNA, which are larger molecules compared to proteins. However, because of the vital role proteins play in almost all biological processes, researchers began to focus their attention on proteins. But one obstacle has been the lack of good laboratory tools with which to prepare biological samples to analyze proteins, said Han, who also has affiliations in MIT's RLE, Computational and Systems Biology Initiative, Center for Materials Science and Engineering and Microsystems Technology Laboratories.

"I shifted my attention from DNA into the area of protein separation around 2002 with the shift to proteomics (the study of proteins)," Han said. "But the field was using decades-old gel electrophoresis technology. There is a big gap in the need for technology in this area."

The MIT researchers' "microsieve" promises to improve the sorting of biomolecules such as proteins. (Image, Jongyoon Han)



Graduate student Jianping Fu (left), Professor Jongyoon Han and postdoc Reto Schoch have created a microchip system that allows speedy separation and sorting of biomolecules. (Photo, Donna Coveney/MIT)

Han and Fu therefore devised the anisotropic sieve that is embedded into a silicon chip. A biological sample containing different proteins is placed in a sample reservoir above the chip. The sample is then run through the sieve of the chip continuously. The chip is designed with a network of microfluidic channels surrounding the sieve, and the anisotropy (directional property) in the sieve causes proteins of different sizes to follow distinct migration trajectories, leading to efficient continuous-flow separation. The current sieve has an array of nanofluidic filters of about 55 nanometers, or billionths of a meter, wide.

"The proteins to be sorted are forced to take two orthogonal paths. Each path is engineered with different sieving characters. When proteins of different sizes are injected into the sieve under applied electric fields, they will separate into different streams based on size," Han explained. At the bottom of the chip the separated proteins are collected in individual chambers. Scientists then can test the proteins.

While other scientists have used similar continuous flow techniques to separate large molecules like long DNA, the MIT team succeeded with the tinier proteins. "This is the first time physiologically relevant molecules like proteins have been separated in such a manner," said Han. "We can separate the molecules in about a minute with the current device versus hours for gels."

Another advantage of the microchip is that it can have so many different pore sizes, and unlike gels, it is possible to design an exact pore size to increase the separation accuracy. That in turn can help researchers look for so-called biomarkers, or proteins that can reveal that disease is present, and thus help researchers develop diagnostics and treatments for the disease. "Sample preparation is critical in detecting more biomarker signals," said Han.

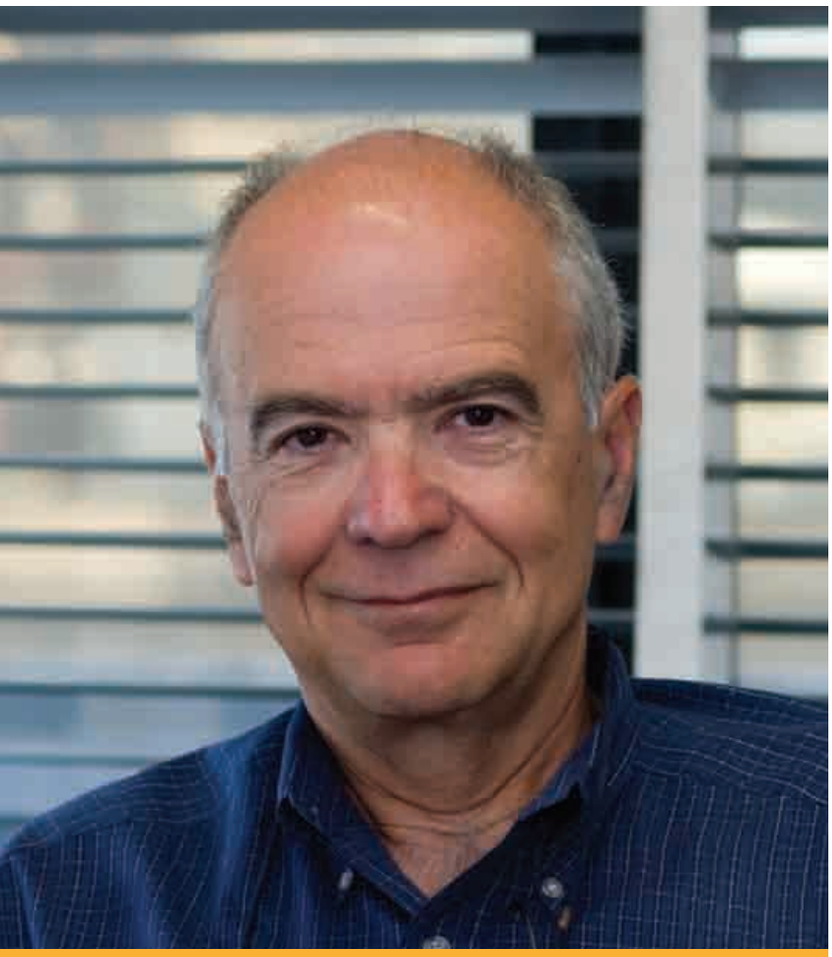
Funding came from the National Science Foundation, the National Institutes of Health and the Singapore-MIT Alliance.

PROFESSOR DIMITRI ANTONIADIS

Making Waves in the Semiconductor Industry and in the Sea

by JUDY L. HOYT • Professor, Department of Electrical Engineering and Computer Science, MIT

Professor Dimitri Antoniadis has been making waves in the semiconductor industry for some time starting with his lead role in the development of SUPREM, the first widely used simulator of semiconductor fabrication processes at Stanford in 1976.



Above: Professor Dimitri Antoniadis. [Photo, Patricia Sampson]

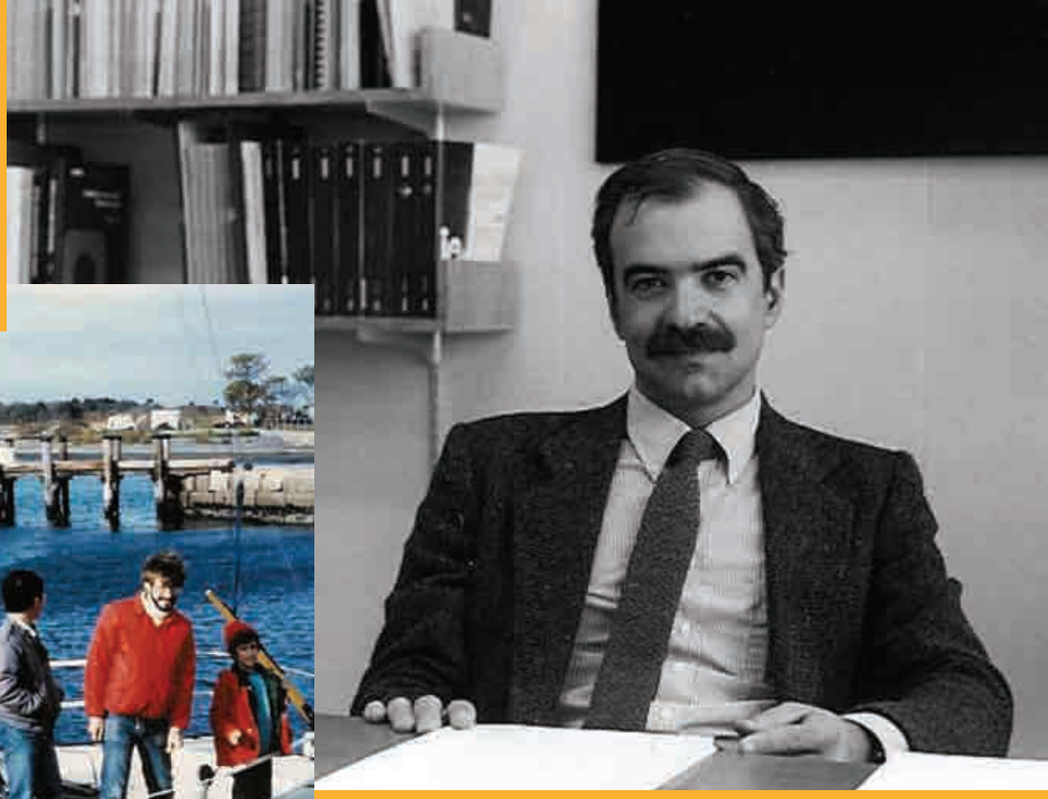
He joined the faculty in Electrical Engineering and Computer Science (EECS) at MIT in 1978. Antoniadis was founding Director of the Microsystems Technology Laboratories, which was created in 1982 with funding provided by a group of industrial sponsors, the Microsystems Industrial Group, or MIG. At that time it was clear that MIT needed a facility for silicon microelectronics fabrication and research, and Building 39 was chosen as the site for the new state-of-the-art cleanroom, which opened in 1985. The goal of MTL was to foster research related to the silicon microelectronics, which was revolutionizing the computer industry and other technologies, fueled by the development of silicon very large scale integrated circuits.

Early days: Antoniadis received his Ph.D. from Stanford in geophysics, modeling the upper atmosphere, a field that appears to be far removed from the tiny devices operating in microelectronic circuits here on earth. But, Antoniadis had always been fascinated with electronic devices and circuits and had studied device physics during his geophysics graduate career. His official entry into semiconductors was through a Postdoctoral position at Stanford, applying his numerical modeling skills to the development of sophisticated computer codes for simulating integrated circuit fabrication processes (such as the basic physics of how atoms move in crystals, during silicon wafer processing, by diffusion). But modeling the device fabrication and structure was not enough: "I was always intrigued by the connection between the fabrication process, the physical structure and the device electrical operation", says Antoniadis. In those early days of Technology Computer Aided Design (TCAD) "the holy grail was to be able to input fabrication conditions and model the resulting device structure as well as the final electrical behavior of the integrated circuit." This was a tall order. Says Antoniadis: "I, and many others underestimated the difficulty in imparting the right physics into the process models, to enable fully predictive simulations of the device structure."

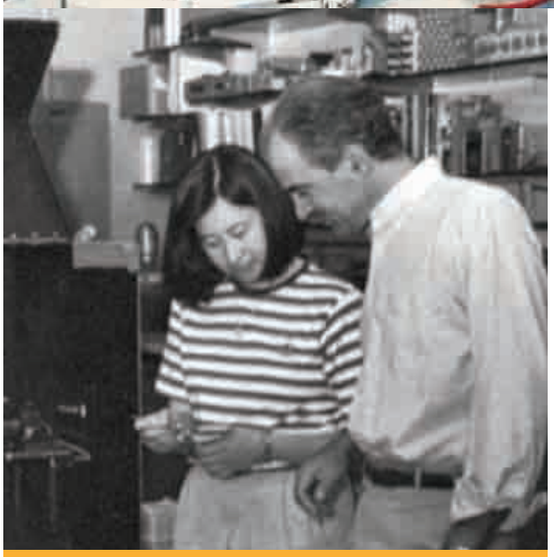
Understanding transistor fabrication: The next step in the research was to break-up the problem into first understanding the fabrication processes and then the electrical characteristics of individual transistors. For example, the process which moves the dopant atoms into their final positions in the silicon lattice during fabrication, known as diffusion, turned out to be extremely complex. Antoniadis' first major accomplishment at MIT was to experimentally prove that impurity diffusion in silicon was taking place by means of both interstitial and vacancy mechanisms. This was a highly contested topic at the time, and the formalism and experimental methods developed were later adopted by a number of research groups around the world.

New device physics: At the same time inroads were being made into understanding transistor fabrication processes, it became clear that making very small devices was of interest for exploring the limits

Below: October 1984, on a student outing on Dimitri's sail boat, from left to right: Sudhir Madan (standing), Alan Warren (seated), Steve Chou (standing), Mark Rodder (seated), Jarvis Jacobs (seated), Duane Boning, Thye-Lai Tung, Robert Harris, and Dimitri's son, Alexi Antoniadis. (Photo, Dimitri Antoniadis)



Above: MIT, circa 1985, in his new office after the move into the recently-renovated Building 39. (Photo, John Cook)



Above: In the laboratory with graduate student Lisa Su, circa 1993. (Photographer unknown)

Above: Dimitri Antoniadis with Andy Grove (right), one of the co-founders of Intel, at the 2002 awards ceremony where Dimitri received the IEEE Andrew S. Grove Award, "For seminal contributions to field-effect devices and silicon process modeling." (Photo, Robert Dutton, Professor, Stanford University)

of electronic transport in transistors – just how fast can electrons go? Collaborating with Prof. Hank Smith on his x-ray lithography techniques, Antoniadis' group made the first sub-100-nm gate length MOSFETs at MIT. This work showed for the first time that the electron velocity in silicon could exceed the published saturation velocity values. At the same time, Antoniadis and Smith began research in collaboration with Prof. Mark Kastner, looking early-on at quantum effects in silicon and III-V transistors.

Besides his academic research, Antoniadis has also had a large impact on the semiconductor industry through the careers of his graduate students after they left MIT. Distinguished alumni of his group in today's semiconductor industry include Ghavam Shahidi (IBM Fellow and Director of Advanced Si Research at T. J. Watson Research Laboratory) as well as Mark Rodder (TI Fellow) and Lisa Su, Senior Vice President and CTO, Freescale Semiconductor, who are shown in early photos in this page. Other students chose career paths in academia, where they have made large waves. This includes Prof. Steven Chou, a faculty member in EE at Princeton, and Duane Boning, currently Associate Department Head of EECS at MIT.

The future of microelectronics: As early as the late 1970's, there were discussions about the limits of scaling the dimensions of silicon transistors. For 30 years, "all of the ostensible barriers to scaling were surmounted; but now we have reached some fundamental limits," he explains. For example, the thickness of the silicon dioxide gate insulator can no longer be scaled. Alternate dielectrics are being pursued, but it is the unique perfection of the silicon/silicon-dioxide interface that is largely responsible for the success of silicon ICs. Because of such limits, there is an unprecedented opportunity to find new ways to continue transistor performance enhancement. "How do you make ideal electronic switches for high performance logic at very small dimensions, without being killed by parasitic effects or electrostatic problems?" There is an enormous opportunity for research by those who understand nanoscale fabrication, quantum mechanics and the physics of electronic transport in small structures to solve these problems. Today Professor Antoniadis is Director of Multi-university FCRP Center on "Materials, Structures on Devices," which is exploring research on these solutions.

In his spare time, Professor Antoniadis enjoys spending time in the water. He has been an avid sailor since his early years in Greece, and is still sailing for cruising pleasure as well as competitive long distance ocean racing.

TOMÁS PALACIOS

NEW FACE AT MTL

by RHONDA MAYNARD • Staff Writer

The Department of Electrical Engineering and Computer Science at MIT welcomed its newest faculty member, Tomás Palacios, in September 2006. Palacios is also set to conduct research at the Institute's Microsystems Technology Laboratories (MTL).

"I am thrilled to join the Microsystems Technology Laboratories at MIT," Palacios said. "I believe that electronics is going to be redefined in the near future - it's going to be all about the integration of heterogeneous properties and materials to fabricate new devices with novel or improved functionalities. At MTL, I have found outstanding faculty, students and staff with tremendous expertise. I think MTL is in an extraordinary position from which to help the field of electrical engineering prepare for the exciting new challenges ahead."

As an MTL faculty member, Palacios brings experience in wide bandgap semiconductors and new devices, and hopes to find new solutions for high-frequency electronics and the interaction of electronics and biological systems. According to Palacios, the answers to these challenges have the potential to change the world "and I am sure MTL is going to play a very important role in their discovery."

MTL's Director, Anantha Chandrakasan, stated, "We are very excited to have Tomás join MTL. His research on compound semiconductors impacts a number of important areas such photonics, wireless communications, biosensors, high-speed digital logic and energy. The inter-disciplinary nature of his research will enable exciting new collaborations with many research groups at MIT."

Palacios completed his undergraduate work at the Polytechnic University of Madrid in 2001, where he specialized in telecommunication engineering. He received his MS and PhD in 2004 and 2006, respectively, from the University of California Santa Barbara. Palacios has been working in semiconductor materials and devices since 1997, and is the recipient of several awards, including the UCSB Lancaster Award, the 6th International Conference on Nitride Semiconductors Young Researcher Award, the 63rd Device Research Conference Best Student Paper Award, and the European Prize Salva i Campillo (for "most promising European newcomer to engineering").

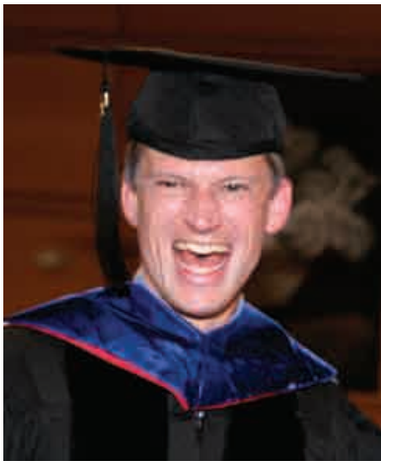
Above: Prof. Palacios discusses new ideas for advanced semiconductor devices with graduate student Will Chung. Below: Professor Palacios enjoys the conversation during MARC 2007. (Photos: top, Patricia Sampson; bottom, Paul McGrath, MTL)

MTL GRADUATE RECEPTION

GRAD STUDENTS LEAVE THE NEST • JUNE 8, 2007

Above, front row: Willie Sanchez, Alexandra Kern, Hong Cai, Karen Gonzales Valentin-Gettings, Anita Villanueva, Anantha Chandrakasan, Tanya Cruz-Garza, Liang-Yu Chen, Valerie Leblanc, Namiko Yamamoto, and Khoa Nguyen. Rear: John Fiorenza, Wojciech Giziewicz, Jesús del Alamo, Olumuyiwa Olubuyide, Charlie Sodini, Blaise Gassend, Martin Schmidt, Joel Voldman, Joyce Wu, David Wentzloff, Todd Sepke.

Left: Joyce Wu . Bottom middle: David Wentzloff (second from right) poses with his proud family and thesis advisor Anantha Chandrakasan. Bottom right: Andrew Ritenour.



ALUMNI UPDATES

How did MTL help shape the lives of its grads? Here's what these six alumni have to say!

VIDA ILDEREM
Ph.D 1988

Vida Ilderem's PhD work at MIT prepared her to look at problems from different angles. It was an experience that she says was "invaluable" to her not only as a technologist, but also in teaching her how to manage, connect, and influence people—experience necessary for her current role as Vice President, Embedded Systems and Physical Realization Research at Motorola Labs. The initial challenge of her role was to focus on non-semiconductor activities when Motorola left the semiconductor market. This required a unique approach of applying her team's semiconductor experiences and tools to solve non-semiconductor problems. "We have been very successful in this transition," she comments, "The constant from the years that I was a student to now is that you still have to work hard, if not harder, to achieve your goals!"

ADVICE FOR AN ENTRY-LEVEL ENGINEERING GRADUATE TODAY? "My advice would be to always do your best and to deliver on your commitments. Do not be afraid to ask questions if you do not know the answers. Do not under estimate the power of networking. Be open and work well with others."

HANG LU
Ph.D 2003

Hang Lu's research lies at the interface of engineering and biology. The interdisciplinary nature was a big draw, and "being able to talk to biologists and engineers is exciting." As a newer faculty member at the Georgia Tech School of Chemical and Biomolecular Engineering, she credits MTL's large repertoire of "eye-opening and exciting" research topics as valuable preparation for her current career. "I was certainly trained in a highly interdisciplinary environment and was collaborating with many labs, which was the best experience one could ask [for]." As an Assistant Professor, she enjoys seeing her students using "engineered systems to do biology and impress biologists. There is definitely a healthy marriage between the research project and training students through these projects."

ADVICE FOR AN ENTRY-LEVEL ENGINEERING GRADUATE TODAY? "Have an open mind and don't be afraid of getting into new areas."

FARIBORZ MASEEH
Sc.D. 1990

Fariborz Maseeh graduated from MIT and formed a start-up company called IntelliSense in 1991. During its development, Maseeh reflected: "Our biggest issue was in hiring the most talented individuals [for] our team and motivating them towards the same goal. We were successful due to our commitment to studying and understanding the art of hiring." How did MTL influence him? "My technical work at MTL was the key to my business success at IntelliSense," Maseeh states. "And my work today as an Investment Manager draws on my business skills developed at IntelliSense." Perhaps what Maseeh is best known for, however, is his philanthropic Massiah Foundation, established to address the issues faced in education, health, humanities, and science.

ADVICE FOR AN ENTRY-LEVEL ENGINEERING GRADUATE TODAY? "Few majors are as versatile as engineering [majors]. Engineers can and often do pursue careers outside engineering and can find success in so many areas. Examples are engineers who have advanced their studies in law, medicine, music, economics and business. The reverse is not necessarily true."

KEEP IN TOUCH!

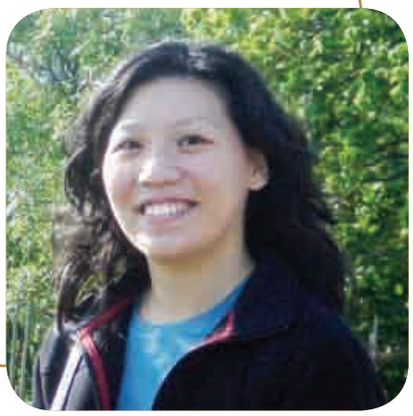
We want to hear from our alumni! To send us notes, pictures, stories, updates, or any other good news, please contact us!

http://mtlweb.mit.edu/alumni.html

GHAVAM SHAHIDI
Ph.D. 1989

After attending "the best engineering school," Ghavam Shahidi joined IBM Research in 1989 and initiated the silicon-on-insulator development program, a means of improving the silicon chip performancee power and speed. While the early focus of SOI technology has been chip speed, IBM and a number of companies have adopted SOI technology for their chips, even powering the latest gaming consoles from Sony, Nintendo, and Microsoft. "Being able to come up with a new generation every 2 years, and see the fruit of your work in the market place is very exciting for many of us. At the same time we look for new material systems that will go beyond Si (power or speed), If and when we can replace Si, then that is also extremely exciting!" What about the future of SOI? "Scaling is becoming more challenging. I hope I will be able to be part of a world class engineering team and push our industry to new heights."

ADVICE FOR AN ENTRY-LEVEL ENGINEERING GRADUATE TODAY? "First and foremost, try to work on what you are passionate about. Then comes working hard and looking for opportunities. Always think about how you can be among the very best in whatever that you do."



ALICE WANG
Ph.D. 2004

Currently Senior Member of the Technical Staff (SMTS) at Texas Instruments, Inc., Alice is lauded for energy-efficient DSP design, noting that she has seen a lot of interest in ultra-low voltage operation since she first presented the idea at ISSCC 2004, an area of interest to academia and industry "not only for optimizing power dissipation, but also because low-voltage operation is increasingly difficult to do in very advanced process technologies." This research topic is applicable to practical applications from wireless to medical apps and beyond. She's involved with IEEE as a technical program committee member of the ISSCC and ISLPED conferences, and she's also a member of the Solid-State Circuits Society Educational Committee. She's given a tutorial at DAC on "Adaptive Techniques: Theory to Practice." In 2006, she co-authored a book called *Subthreshold Design for Ultra Low-Power Systems.* She also volunteers as an MIT educational counselor where she interviews high school seniors applying to MIT.

ADVICE FOR AN ENTRY-LEVEL ENGINEERING GRADUATE TODAY? "Even though I've been out of school for a few years, I feel like there is still a lot to learn! My advice is to hit the ground running by finding a challenging project and work with people you can trust and learn from. Also, be humble."

DAVID WHITE
Sc.D. 2001

David White's career is driven by solving problems related to his varied technical interests. With a common thread of integrating business opportunity and technical vision, he has co-founded two startups and also led research and development efforts at McDonnel-Douglas before resuming his studies at MIT. He credits three factors from his work at MTL as shaping his experience co-founding the startup company Praesagus with MTL alum Taber Smith: MTL's strong relationship with industry, his thesis advisor Duane Boning's team-oriented research environment, and subsequent access to advanced manufacturing facilities that enabled broad research possibilities. After Praesagus was acquired by Cadence in 2006, White experienced immediate synergy with shared organizational values between the two companies, such as an entrepreneurial spirit and a strong emphasis on innovation.

ADVICE FOR AN ENTRY-LEVEL ENGINEERING GRADUATE TODAY? "Take some time early in your career to determine what you are really passionate about and let that guide your career direction. It is amazing how many successful, genuinely happy people I have met that have shaped their work life around their individual interests and stage of life."

MTL DAY

In 2007, MTL graduate students visited three MIG companies – IBM, National Semiconductor, and Texas Instruments – as part of a new initiative: MTL visit day to MIG member companies. During each visit, our graduate students presented leading-edge research results to the MIG companies and engaged members in detailed, focused technical discussions.

YORKTOWN HEIGHTS, NY

MTL Day at IBM

Front, left to right: Leland Chang (IBM), Robert Denard (IBM), Joyce Kwong (MIT), Masoud Qazi (MIT), Khoa Ngyuen (MIT), Jin Cai (IBM), and Naveen Verma (MIT).

Back, left to right: Dimitri Antoniadis (MIT), Ghavam Shahidi (IBM), Steve Koester (IBM), Yogesh Ramadass (MIT), Anantha Chandrakasan (MIT), David Frank (IBM), Wilfried Haensch (IBM), and Nigel Drego (IBM).

SANTA CLARA, CA

MTL Day at National Semiconductor

Left to right: Naveen Verma (MIT), Tae-Sung Park (MIT), Nigel Drego (MIT), Ivan Nausieda (MIT), Denis Daly (MIT), Lane Brooks (MIT), Sanquan Song (MIT), Matt Park (MIT), Michael Perrott (MIT), Wei Ma (National Semiconductor), Raj Subramoniam(National Semiconductor), Peter Holloway (National Semiconductor), Anantha Chandrakasan (MIT), Ahmed Bahai (CTO, National Semiconductor), Fran Wilkinson (National Semiconductor), and Masood Yousefi (National Semiconductor).

continued on next page

MTL DAY

MIT Student Day at Texas Instruments

by DENNIS BUSS • Texas Instruments

On June 18, 2007, Prof. Anantha Chandrakasan visited TI together with 8 students from MTL and from the TI-MIT Leadership University Program.* The 8 students who traveled from Cambridge to Dallas were joined by 5 additional Ph.D. students, who are doing summer internships at TI. The 13 students presented seminars in the morning.

- Dennis Wei: Sampling Based on Local Bandwidth
- Daniel Weller: Bandlimited Signal Estimation in the Presence of Timing Noise
- Archana Venkataraman: Bilinear Sampling of Continuous-Time Signals for Matched Filtering Applications
- Sheng Jing: Joint Source Channel Coding: A Distortion-Diversity Perspective
- Vivienne Sze: Algorithms and Architectures for Ultra-Low Power Video Coding
- Nathan Ickes: A Micropower DSP for Microsensor Applications
- Joyce Kwong: Design of a Sub-Threshold MSP430 in 65 nm CMOS
- Naveen Verma: Ultra-Low-Voltage SRAM for Low-Power Systems and Fast Sense-Amplifiers for 45 nm SRAM
- Yogesh Ramadass: Switched Capacitor DC-DC Converter for Ultra-Low Power Applications
- Denis Daly: A Low-Power, Highly-Integrated Pulsed Ultra-Wideband Radio
- Sungwon Chung: Wideband Predistortion Using Cartesian Feedback
- Johnna Powell: A 77 GHz Front End Receiver for Millimeter-Wave Passive Imaging
- Surapap Rayanakorn: Wideband, Two-Point Modulators with Adaptive Predistortion

At lunch, the students heard presentations about TI by:

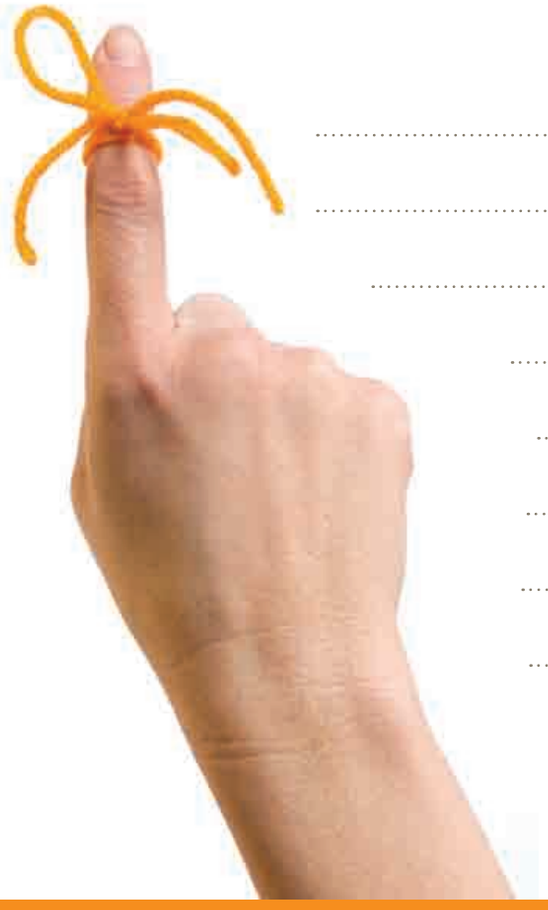
- Dr. Hans Stork: CTO and Sr VP of Si Technology development
- Dr. Raul Blazquez: Formerly of MTL. Raul celebrated his first year at TI on 19 June.

In the afternoon, the students held technical discussions with product development engineers and managers.

The student talks were all of exceptional quality, and reflected excellent research. TI engineers and managers benefited greatly from the stimulation of new ideas, and we hope the students found the day equally informative and interesting. We are very grateful to Prof. Anantha Chandrakasan for organizing this visit.

** The TI-MIT Leadership University Program funds research in Digital Signal Processing. It has been in existence for 8 years. Prof. Alan Oppenheim is the lead faculty researcher at MIT.*

NOTES



MTL CALENDAR, 2007-2008

September

S	M	Tu	W	Th	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

October

S	M	Tu	W	Th	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

November

S	M	Tu	W	Th	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

December

S	M	Tu	W	Th	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

January

S	M	Tu	W	Th	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

February

S	M	Tu	W	Th	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	

March

S	M	Tu	W	Th	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

April

S	M	Tu	W	Th	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

May

S	M	Tu	W	Th	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

June

S	M	Tu	W	Th	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

MTL
microsystems technology laboratories
massachusetts institute of technology

Visit the MTL News website — not only for news, but for event listings, seminars, and more!

http://mtlweb.mit.edu/news

Microsystems Technology Laboratories
Massachusetts Institute of Technology
60 Vassar Street
Building 39, Room 321
Cambridge, MA 02139

With gratitude for our Microsystems Industrial Group member companies:

APPLIED MATERIALS
ANALOG DEVICES
cadence
hp invent
IBM
intel
National Semiconductor
NEC
NOVELLUS
SAMSUNG
Texas Instruments