Wireless Integrated MicroSensing & Systems
WIMS²
Michigan Engineering

Horizons

Microsystems for the Next Generation

January 2013

Guest Editorial

Professor Sridhar Kota
Former Assistant Director, White House
Office of Science and Technology
Professor, Mechanical Engineering
University of Michigan

Innovation and Manufacturing

There has been a growing national dialogue on American manufacturing and innovation in the past two years. Our comparative advantage continues to be in high-technology products, high productivity, and a highly skilled workforce. Being "the best in the world" in scientific discoveries is still important, but it's not, by itself, sufficient to remain viable in the global economy. For instance, although the federal government invests over $140 billion annually in Science and Technology, roughly half of which in Defense R&D, the U.S. trade deficit in the Advanced Technology Products (ATP) category[1] has grown to $100 billion in 2011. It exceeded the total net foreign earnings on all Intellectual Property royalties and fees (including franchise fees) by all "U.S." incorporated companies, from Apple and Intel to Starbucks and McDonald's. So, the idea that we will simply create knowledge and let other nations build high-tech products is not economically sustainable and it also poses a national security risk.

We must continue to invest in science but we must also promote a pathway to turn that science into U.S.-made high-tech products through translational research and engineering by putting & back in R&D. The basic science behind a vast majority of high-tech products such as MRI machines, computers, MP3 players, flat panel displays, solar cells, lithium-ion batteries, cell phones, etc., was largely established first in the U.S., and in fact these products were largely invented in the U.S., but the real innovation – that is transforming a promising invention into a marketable product – and the subsequent wealth creation has taken place in other countries. When we fail to manufacture today's advanced technology products, we risk losing our ability to innovate the next generation of those and related products as well. According to 2010 Lux Research report, Germany, Japan, S. Korea, Taiwan, and the U.S. all rank very high on nanotechnology activity but the U.S. ranks lowest of the five in developing the technology, and we continue to fall further behind.

Since the days of Edison, American research and development institutions have provided a full-service technology development model for the modern age. Those were the places where 1% inspiration was hammered into modern miracles by the

[1]ATP category includes semiconductors, aerospace/avionics, medical equipment, precision machinery, biotechnology and advanced materials.

(Continued on page 2)

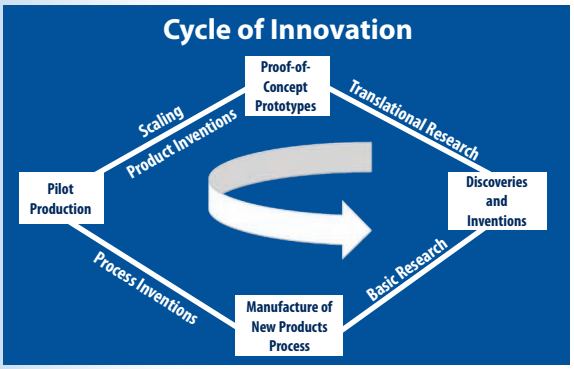
Workshop on Nano and Micro Manufacturing

WIMS² is organizing a workshop on **Nano and Micro Manufacturing**, which will be held in Dearborn, MI, on May 22–23, 2013. (For the convenience of our industrial members, the WIMS² Spring IAB meeting will be held on May 21, immediately before the Workshop). The intent of the workshop is to bring together manufacturers, researchers, and end users of nano and micro technologies. Attendees will represent applications of nano and micro technologies in the areas of biomedical devices, communications and information technology, defense and homeland security, energy, infrastructure, and transportation. Invited experts will discuss the requirements for technology commercialization in these areas. Panel discussions will focus on the needs for improved materials, standards, and equipment. Challenges and opportunities in micro/nano manufacturing, future research directions, and technology transfer and commercialization will be addressed in the breakout discussions. The meeting will be held at the Ford Conference and Events Center in Dearborn, MI. An evening reception and banquet will be held at one of America's premier museums —The Henry Ford Museum.

The workshop is supported by the National Science Foundation. Additional sponsorship and exhibition opportunities are available. The abstract submission deadline is March 11 and the Early Bird Registration deadline is April 1, 2013. The workshop website is **http://nano-microworkshop.com.** ■

Guest Editorial

(Continued from page 1)



Innovation and manufacturing are intricately linked.

99% perspiration that turned their genius into reality. They had the means to discover and the skills, infrastructure, and leadership to transform scientific breakthroughs into modern technological marvels. But, the Menlo Parks and Bell Labs that brought us light bulbs and lasers are museums now. Corporate-level R&D goals today amounts to little more than making current products better, cheaper, and faster to compete in the global arena. We urgently need to return the focus to long-term investments in engineering the "next big thing" or concede forever the innovation and prosperity that institutions like Bell Labs epitomized. This also means that engineering researchers must refocus on innovation — which requires not just 1% inspiration from science but also the 99% perspiration that defines engineering.

We must also create a pipeline of skilled engineers. But, fewer and fewer of America's "best and brightest" are clamoring to get into our engineering schools. Part of the reason is that engineering is generally portrayed as a discipline only for the mathematically gifted and analytically minded, which scares away our most creative minds. We must extoll the virtues of engineering as one of the most creative disciplines that enables innovation and teaches how to build things.

The Obama Administration, to its credit, has put a number of programs in place to promote advanced manufacturing and technology transition through manufacturing tax credits, entrepreneurship, and access to capital. New partnerships, programs, and proof of concept centers are seeking to nurture innovation at the university level to bring basic research into the marketplace. In March of 2012, President Obama proposed establishing 15 Manufacturing Innovation Institutes to conduct applied research through public-private partnerships to mature emerging technologies and their manufacturing readiness. This is certainly a significant step in the right direction to establish the skills, infrastructure, and knowledge needed for a robust manufacturing base. ■

WIMS² Welcomes New Associate Partner

The WIMS² Center is pleased to welcome MESO, Inc. as our newest associate member. MESO, Inc. has been a leader in atmospheric modeling since 1985 and specializes in the development and application of atmospheric and hydrological numerical models. MESO, Inc. is dedicated to furthering the understanding of environmental processes at the mesoscale and microscale and to applying this understanding to a variety of research and operational environmental problems. MESO's products not only describe the earth's atmosphere, but also the oceans, hydrological processes, soil surface, and vegetation conditions. ■

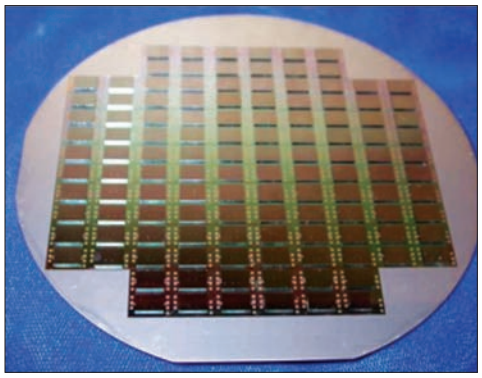
MESO
ATMOSPHERIC RESEARCH
FORECASTING • SIMULATIONS

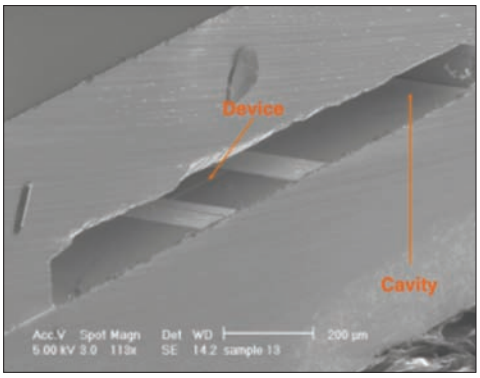
Lab on a Chip Features Optofluidic Technologies on the Cover

Prof. Katsuo Kurabayashi's work was featured on the cover of the October 2012 issue of *Lab on a Chip*. The issue features an article by Prof. Kurabayashi that critically reviews recent developments of optofluidic technologies for cellular phenotyping applications, which can be used to screen for diseases or for personalized medicine. It discusses four representative techniques in optofluidic detection: (1) fluorescence detection, (2) surface enhanced Raman spectroscopy (SERS), (3) surface plasmon resonance (SPR), and (4) interferometry as representative methods employed in optofluidic detection. It then presents a review on optofluidic devices that quantified cellular phenotypes by using these optical techniques including the promises and limitations of each optofluidic scheme. Finally, the paper discusses how the optofluidics research field may evolve to establish these techniques on a "lab-on-a-chip" scale. The cover art was conceived by Prof. Kurabayashi and his students Nien-Tsu Huang and Boram Oh, and designed and executed by Rose Anderson, the WIMS² graphic designer. Congratulations to all on a job well done. ■

Manufacturing Technologies for Inertial Sensors and Packaging

Professor Khalil Najafi's Research Group





(Left) Wafer-level gold-silicon eutectic bonding to provide stable vacuum package for MEMS (Right).

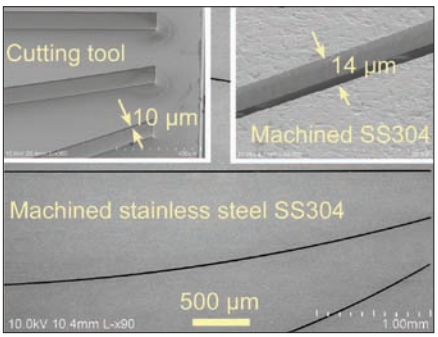
Wafer-level packaging is a critical need in MEMS manufacturing and commercialization. Inertial sensors are widely used today in consumer applications such as cell phones and gaming controllers for motion sensing. To expand the market and enable broader application of high-performance inertial sensors, new methods are needed for both vacuum sealing and environmental MEMS packaging. Packaging processes must be wafer-level, low-cost, low-temperature, and compatible with the underlying MEMS structure, while providing hermetic and/or vacuum environments with pressures in the range of 1 to 100mTorr and leakage rates of <10mTorr per year. Future MEMS packages, especially those needed for high-performance inertial sensors such as gyroscopes, should provide a controlled thermal environment and protect the MEMS device from shock and vibration. WIMS^2 has long-standing research efforts on MEMS packaging, and has developed a variety of processes including thin-film packaging using metals, anodic silicon-glass bonding, eutectic silicon-gold bonding, and low-temperature solder bonding. Vacuum packaged devices with gold-silicon eutectic bonds and NanoGetter® from ISSYS, a local company founded by WIMS^2 faculty, have shown stable internal pressure of ±2 mTorr over more than 5 years. Transient liquid phase bonding has also been applied to MEMS packaging. This process uses a low-temperature reaction between two different metals to create an intermetallic bond which is stable to much higher temperatures. To facilitate device integration, WIMS^2 has developed vertical and lateral feedthrough interconnect technologies in silicon and glass. New research efforts include multi-layer stack bonding, vertical feedthroughs in insulating (e.g., glassy) substrates, bonding with soft materials/fragile substrates, and packaging of inertial sensors. The company e-Pack (a WIMS^2 associate member) was founded by Drs. Jay Mitchell and Sangwoo Lee to provide packaging services to MEMS companies. The MEMS packaging area remains a critical topic, with new fundamental approaches needed to enable new MEMS applications. ■

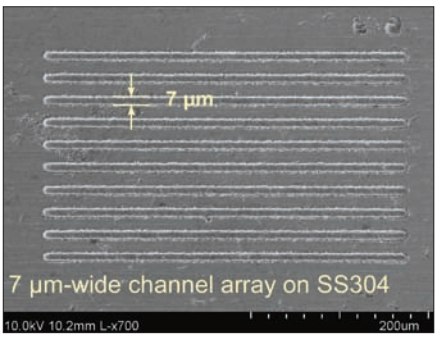
Batch Mode Micromanufacturing Based on Micro Electro-Discharge Machining and Micro Ultrasonic Machining for Bulk Metal Alloys and Ceramics

Dr. Tao Li and Professor Yogesh Gianchandani

Stainless steel and other metal alloys have material properties that are attractive for applications ranging from smart stents to packaging. However, these materials present a challenge for process integration within a lithographic manufacturing sequence. Batch mode micro electro-discharge machining (μEDM) provides a solution: lithographically-fabricated electrode arrays for high-throughput and high-precision micromachining of any alloy substrate. Recent advances focus on using high-aspect-ratio and high-resolution silicon microstructures formed by deep reactive ion etching (DRIE) as cutting tools. A minimum feature size of ≈7 μm and an aspect ratio of ≈2.8 have been demonstrated on stainless steel 304 (SS304). Features showed excellent repeatability and uniformity, with machining rates up to ≈5 μm/min. This work has been supported in part by a gift from Agilent Research Laboratories.

For hard dielectric materials such as ceramics and glass, batch mode micro ultrasonic machining (μUSM) provides lithography-compatible manufacturing. This technique has been used for glass-mica (Macor®) ceramic, lead zirconate titanate (PZT), single-crystal quartz, ruby, etc. First, batch μEDM is used to define a cutting tool with the desired pattern, typically in stainless steel. Patterns with 25 μm features are then transferred onto Macor® substrates with a cutting rate >18 μm/min. This technique has been demonstrated for batch fabrication of piezoelectric transducers for smart biopsy tools and structurally complex microresonators.





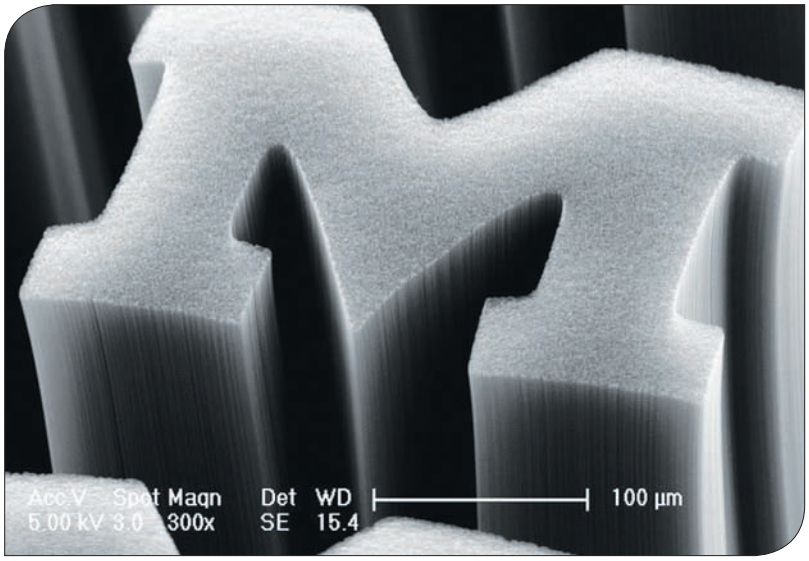
Both the μEDM and μUSM can be used in fabrication of harsh-environment sensors and packages, which can greatly benefit from the broader material selection enabled by these technologies. ■

(Continued from page 3)

Nanomanufacturing Research at WIMS²

Professor John Hart

The Mechanosynthesis Group at the University of Michigan, led by Prof. John Hart, aims to create new manufacturing technologies for micro- and nanoscale materials and devices, and for their assembly and integration at larger scales. Applications of their work include new and improved manufacturing tools, microsystems, lightweight structures, electronic materials, energy storage systems, medical devices, and bio/chemical sensors. The aim is to transition our results to industry and eventually to the marketplace, and to do novel, well-informed, and comprehensive research along the way.



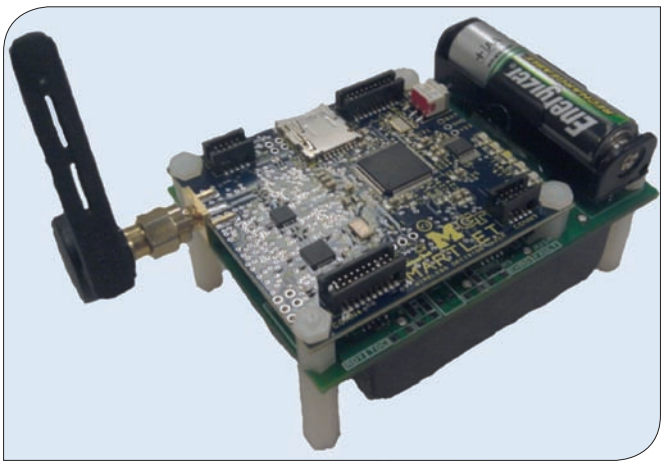
A patterned forest of carbon nanotubes.

Hart's group seeks to have five key strengths in their work: mastering the fundamentals of nanoscale materials synthesis and processing; designing and building new laboratory instruments for process discovery and optimization; inventing creative machines and methods for scalable manufacturing; combining analytical modeling with precision measurements; and having a keen vision of how new materials and manu-facturing technologies can result in disruptive value propositions. Some of the group's interest areas include: carbon nanomaterials, self assembly, nanomanufacturing machines, metrology, microsystems, nanocomposites, energy materials, and biointerfaces. ■

WIMS²-Driven Wireless Monitoring and Control of Buildings to Minimize Energy Consumption

Professor Jerry Lynch

A diverse team of University of Michigan architects, civil engineers, and electrical engineers including the WIMS² faculty Jerome "Jerry" Lynch and Geoffrey Thün are working on a collaborative project called Integrated Responsive Building Envelopes (IRBE). Together they are exploring the potential of intelligent building exteriors, or envelopes, that are capable of monitoring weather, daylight, and occupant use to manage building heating, cooling, and lighting in dynamic ways that protect the environment and promote energy efficiency. This work leverages the technologies, ideas, and expertise developed in the WIMS² research thrusts in the Built Environment, Wireless Circuits, Low Power Circuits, and AMPP (Advanced Materials, Processes, and Packaging). It is intended to develop advanced building materials with embedded sensing and control devices that respond to shifting exterior conditions and occupants' preferences. These include windows that automatically balance the availability of natural light with artificial light to meet occupants' needs and walls that can store heat, and transmit a comfortable supply of air as temperatures fluctuate throughout the day. At the core of the effort is a low-power wireless sensor node designed by WIMS² researchers called Martlet. This revolutionary wireless sensor and actuator node features a dual core DSP microcontroller for more energy efficient operation when engaged in feedback control of building automation systems and intelligent envelopes. Currently, the team is investigating the possibility of demonstrating their ideas on university buildings, including the new Bob and Betty Beyster Computer Science and Engineering Building.



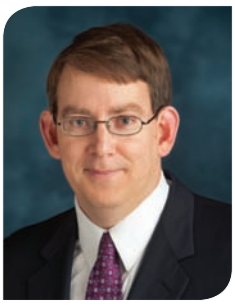
Narada wireless sensor node from Professor Lynch's group.

The technologies and concepts developed and leveraged on this project include power harvesting, sensor networks and communication strategies, low-power wireless communication, and MEMS-based sensors. The project also applies the expertise that Prof. Lynch's team has developed in instrumenting and monitoring bridges. The driving principle behind the Built Environment Thrust is to take advantage of the dramatic reductions in the cost of microsensors and wireless microsystems combined with their increasing levels of sophistication to improve the energy efficiency and safety of infrastructure. ■

Industrial Liaison Report

Dr. Andy Oliver

Industrial Liaison and Principal Staff Scientist



The past several months have brought some important changes in the WIMS^2 Center. One development is a much greater emphasis on outreach. This is not a tactical change but rather a long-term strategic effort to increase the engagement of the Center and its faculty and research programs with a larger community. It also helps further our technology transfer mission. In addition, our partnerships and joint marketing efforts with the MEMS Industry Group and Roger Grace Associates further this goal. These have given us greater exposure outside the academic community. We have had booths or activities at the *Hilton Head Solid State Sensors, Actuators, and Microsystems Workshop; Advanced Process Control Conference*; *International Wafer Level Packaging Conference;* and *Photonics West*. Also, we organized our own event in Sunnyvale, CA, this past April. Online, we have increased our presence with a new website and more active use of email lists and LinkedIn. Future plans include more web-inars, the *Workshop on Nano and Micro Manufacturing* in May 2013, and an event in November 2013 in Baltimore, MD, at *Sensors*. We also have some trade journal articles planned, some of them with our colleague Mr. Roger Grace.

The purpose of all these activities is to increase the engagement of the Center, the faculty, the College of Engineering, and the University with researchers and industrial practitioners as a whole across the country and globe.

The emphasis on outreach has not replaced any part of the traditional WIMS^2 industrial program. We are still serving the needs of our member companies by working to connect member companies with the faculty; helping with proposals; targeting research; prototyping projects; and in helping to place Center graduates with member companies.

Another change is that David Wentzloff is now the leader of the Wireless Thrust. We are grateful to Michael Flynn for his many years of selfless service as thrust leader and are saddened that he has decided to step down from this position. However, Prof. Flynn will continue to be a technical contributor in the Center as a team member in the Wireless Thrust and we look forward to future technical achievements by him and his students. We are excited, however, that Prof. David Wentzloff has assumed this role. David is a dynamic and energetic rising star in the area of wireless and we know that the Wireless Thrust will be in good hands.

Lastly, Karen Richardson, our Administrative Director, has retired (see page 8). Karen, however, has agreed to stay on for a few months to help with the workshop and to train Ms. Lynette Bush, who will be assuming some of Karen's responsibilities.

If you are interested in learning more about the WIMS^2 Center, getting in touch with the researchers, or hiring Center graduates, I invite you to contact me at 734-615-2325 or ado@umich.edu. ■

WIMS^2 Webinars

As part of our efforts to magnify the impact of the WIMS^2 Research Center, we have started a series of webinars that highlight the work of our faculty and other researchers around the world. Webinars provide a way for people who cannot attend our seminars in person to hear the presentation, see the slides and videos live, and ask questions in real time. This is more interactive and immediate than our previous series of seminars which were recorded and placed on the WIMS^2 website after the event was over and thus did not allow for remote attendees to ask questions. However, like the recorded seminars, the content is also available after the event on the WIMS^2 website.

The webinar series was inaugurated by Prof. Ken Wise with a talk entitled "Wireless Integrated MicroSystems: Creating a Revolution in Health Care". Other webinar speakers and topics include: Mike Daneman, "The Invensense NF Shuttle Program;" Prof. Kazuo Sato, "Variable Anisotropy in Wet Silicon Etching;" Prof. Mina Rais-Zadeh, "RF MEMS;" Prof. Khalil Najafi, "Biomimetic Hair Sensors;" and Prof. Yuji Suzuki, "MEMS Energy Harvesting."

To date, we have had more than 300 people view the webinars live and many more have downloaded the webinars after the event.

The webinars are announced via the WIMS^2 website, email, and LinkedIn. Sign up for upcoming webinars and download previous webinars at **http://wims2.org/media/webinars.html** ■

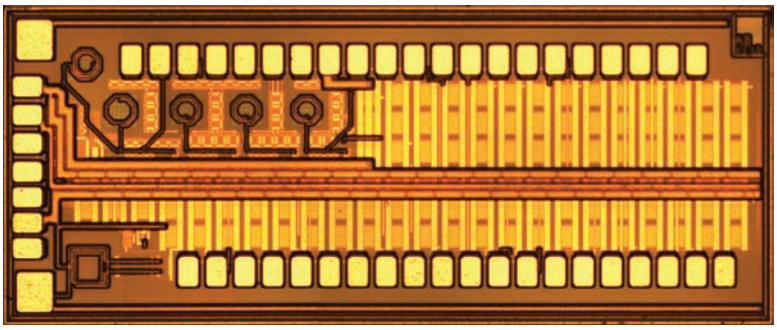
Mike Daneman from InvenSense.

David Wentzloff

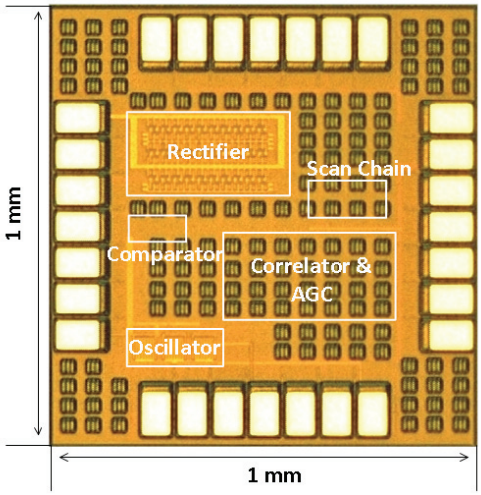
Thrust Leader – Wireless Interfaces
Assistant Professor, EECS, College of Engineering

David D. Wentzloff received the BSE degree in Electrical Engineering from the University of Michigan, Ann Arbor, in 1999, and the SM and PhD degrees from the Massachusetts Institute of Technology, Cambridge, in 2002 and 2007, respectively. In the summer of 2004, he worked in the Portland Technology Development group at Intel in Hillsboro, OR. Since August 2007, he has been with the University of Michigan, Ann Arbor, where he is currently an Assistant Professor of Electrical Engineering and Computer Science. He is the recipient of the 2009 DARPA Young Faculty Award, the 2009–2010 Eta Kappa Nu Professor of the Year Award, and the 2011 DAC/ISSCC Student Design Contest Award. He has served on the technical program committee for *ICUWB 2008–2010* and *ISLPED 2011–2012*, and as a guest editor for the *IEEE T-MTT*, the *IEEE Communications Magazine*, and the *Elsevier Journal of Signal Processing: Image Communication*. He is a member of IEEE, IEEE Circuits and Systems Society, IEEE Microwave Theory and Techniques Society, IEEE Solid-State Circuits Society, and Tau Beta Pi.

David's research interests are in integrated circuit design for adaptable wireless communication systems for both high-performance and energy constrained applications. This includes analog and mixed-signal circuit design, co-design with integrated antennas, all-digital PLLs, body area networks, and ultra-low power radios for cubic-mm sensor nodes. ■



A die photo of a low-power 9.8GHz UWB transceiver with modem.



116nW multi-band CDMA based Wakeup Receiver.

David Blaauw Becomes IEEE Fellow

Prof. David Blaauw has been named an IEEE Fellow, Class of 2012, "for contributions to adaptive and low-power circuit design." Prof. Blaauw was a core member of the Michigan team that developed the award-winning circuit known as Razor in 2003, which at the time showed a radical departure from traditional circuit design. Typical circuits are designed to operate virtually perfectly at all times, which leads to higher power consumption and lower performance. Razor, on the other hand, was designed to eliminate safety margins and instead use self-checking, or adaptive, mechanisms that ensured computational correctness at the same time that it reduced power consumption and increased overall performance.

Prof. Blaauw co-founded the startup company Ambiq Micro in 2010 with Prof. Dennis Sylvester and Dr. Scott Hanson (BSE MSE PhD EE '04 '06 '09). Ambiq Micro is an early stage fabless semiconductor company that is developing ultra-low power, mixed-signal solutions for a new generation of wireless electronics; it recently attracted seed funding of $2.4M.

Prof. Blaauw joined the faculty at the University of Michigan in 2001, after nearly a decade working in industry at IBM, Motorola, and Advanced Design Technology. He received his master's and PhD degrees from University of Illinois at Urbana-Champaign in 1989 and 1992, respectively, and his bachelor's degree from Duke University. ■

Seminar/Webinar Series

July 13, 2012
Prof. Gaurav Bahl/Seminar
Assistant Professor
Mechanical Science and Engineering Department
University of Illinois at Urbana-Champaign
"Brillouin MEMS"

August 14, 2012
Dr. Mike Daneman/Webinar
InvenSense
"NF Shuttle – Bringing the Fabless Model to the MEMS Industry"

August 16, 2012
Prof. Jaesung Park/Seminar
Assistant Professor
Department of Mechanical Engineering/I-Bio
Pohang University of Science and Technology
"Critical Issues for Extracorporeal Liver-Assist Devices"

August 28, 2012
Prof. Kazuo Sato/Webinar
Aichi Institute of Technology, Japan
"Variable Anisotropy in Wet Alkaline Etching of Si Applied for 3-D Structuring"

October 5, 2012
Prof. Mina Rais-Zadeh/Webinar
Assistant Professor
EECS Department, University of Michigan
"Passive MEMS for Communication and Sensing Applications"

November 30, 2012
Prof. Khalil Najafi/Webinar
Schlumberger Professor of Engineering and Chair,
Electrical and Computer Engineering,
University of Michigan
"Biomimetic Hair Sensors: Utilizing the Third Dimension"

December 7, 2012
Prof. Yuji Suzuki/Webinar
Professor, Department of Mechanical Engineering,
The University of Tokyo, Japan
"MEMS Energy Harvester Using Polymer Electret Piezoelectret"

Seminars can be viewed at http://wims2.org/media/webinars.html

Mina Rais-Zadeh Receives NASA Early Career Grant to Develop Technology Needed for PicoSatellites

Mina Rais-Zadeh received the NASA Space Technology Research Opportunities for Early Career Faculty grant for her project, "Chip-Scale Precision Timing Unit for PicoSatellites." She intends to use the grant to develop a chip-scale timing unit that offers an order of magnitude higher performance and better thermal stability than existing solutions.

Prof. Rais-Zadeh's research aims to replace quartz-based clocks which do not perform well in the high mechanical shock and vibration environment of space craft launch and the wide temperature variations of outer space. Her solution involves an array of temperature compensated mechanical resonators that have different temperature coefficients of frequency. This will allow the system to compensate for variations in frequency using weighted average of the resonators in a wide temperature range. The devices also have high *Q* and low impedance and are smaller than existing timing units.

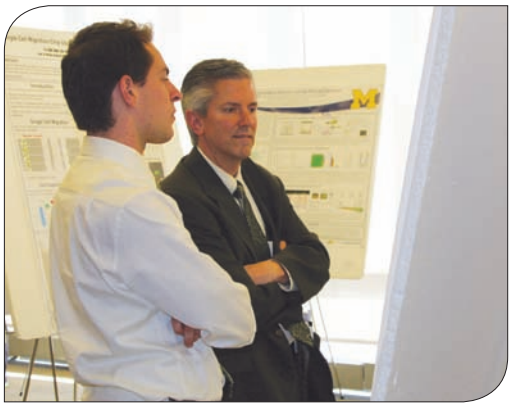
Prof. Rais-Zadeh's research interests include integrated RF MEMS, GaN-based micromechanical devices and sensors, MEMS-enabled ICs, and micro/nano-fabrication techniques. She is the leader of the WIMS^2 High Frequency MEMS Thrust. ■

Spring Industrial Advisory Board Meeting

May 21, 2013

Fall 2012 Industrial Advisory Board Meeting

The Fall Industrial Advisory Board Meeting was held on October 9, 2012. The format of this event was similar to the Spring IAB meeting and included two student poster sessions and brief student presentations of all the posters. More than 100 industrial representatives, students, faculty, and staff attended the meeting in the Lurie Engineering Center on U-M's North Campus. The meeting was divided into morning and afternoon sessions where the results of the seven thrust areas were presented along with a special presentation by Prof. Prabal Dutta on the architecture and software for embedded computing in wireless systems. After the technical sessions, there were meetings of the Industrial Advisory Board and the associate members. Also, the Strategic Advisory Board members provided feedback for the Center. After the meetings, an excellent dinner at the Dahlmann Campus Inn was followed by an enlightening talk by Dr. Kevin Ward from Michigan's Emergency Medicine Department on "Critical Care Medicine: Engineering to the Rescue?" The following day, several of the industrial members had private meetings with the faculty and students. ■



Dr. Kevin Ward, guest dinner speaker, discusses recent results with student at the poster session.

Professor Khalil Najafi Presents Plenary Talk at *IEEE Sensors Conference*

WIMS^2 Prof. Khalil Najafi gave a plenary talk on "Hair Sensors: Utilizing the Third Dimension" at the *2012 IEEE Sensors Conference* in Taipei, Taiwan in October 2012. The talk discussed novel and exciting work by Prof. Najafi and his group in building microscale "hair" like structures for sensing applications. Specific examples include using "hairs" for measuring airflow and for hydraulic actuation. *IEEE Sensors* is the flagship conference of the IEEE Sensors Council and is held annually rotating between the Americas, Europe, and Asia. The *2013 IEEE Sensors Conference* will be held in November and Prof. Yogesh Gianchandani from WIMS^2 is the Technical Program Chair. Following the conference, faculty and staff from WIMS^2 visited TSMC, NCTU, NTHU, and several other institutions in Taiwan. Joint activities and collaborations are expected to emerge in the near future. ■

Karen Richardson Retires

Karen Richardson, WIMS^2 Administrative Director, retired at the end of December 2012, after having completed nearly 18 years of service at the University. Karen has worked in the WIMS^2 Center since its inception and has been the Administrative Director since 2000. Karen contributed to the original WIMS ERC proposal, all of the reports that were necessary for continued funding, the newsletters, the IAB meetings, and other contributions too numerous to list here. She will remain at the WIMS^2 Center as a consultant for the next few months. All of us at WIMS^2 want to thank Karen for her years of dedicated service and wish her a happy retirement. ■

Member Partners

Agilent Technologies, Inc.
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Ricoh Innovations, Inc.
Stryker Corporation
Texas Instruments, Inc.

Associate Members

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InvenSense, Inc.
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PicoCal, Inc.
Sandia National Laboratories
Twisthink, Inc.
Virginia Technologies, Inc.
Virtual EM Inc.

Strategic Partners

MEMS Industry Group
Roger Grace Associates

IAB '13

Spring Industrial Advisory Board Meeting

Tuesday, May 21, 2013
Lurie Engineering Center, U-M North Campus
Ann Arbor, Michigan

SAVE the DATE

Registration Begins April 9

Journal Articles

(From July 2012 – January 2013)

S. A. Wright, H. Z. Harvey, and Y. B. Gianchandani, "Microdischarge-Based Deflecting-Cathode Pressure Sensor in a Ceramic Package," *IEEE/ASME Journal of Microelectromechanical Systems*, in press, August 17, 2012, pp. 1–7 DOI 10.1109/JMEMS.2012.2215009

S. Green, R. Malhotra, and Y. Gianchandani, "Sub-Torr Chip-Scale Sputter-Ion Pump Based on a Penning Cell Array Architecture," *IEEE/ASME Journal of Microelectromechanical Systems*, in press, September 13, 2012, pp. 1–9, DOI 10.1109/JMEMS.2012.2221159

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Conference Publications

(From July 2012 – January 2013)

ACM/IEEE Design Automation Conference (DAC), San Francisco, CA, June 2012

Y. Lee, Y. Kim, D. Yoon, D. Blaauw, and D. Sylvester, "Circuit and System Design Guidelines for Ultra-Low Power Sensor Nodes"

EMI/PMC 2012 Joint Conference of the Engineering Mechanics Institute and the 11th ASCE Joint Specialty Conference on Probabilistic Mechanics and Structural Reliability, South Bend, IN, June 2012

J. D. Bergman and J. P. Lynch, "GPS-Assisted Wireless Data Collection Techniques for Vehicle Bridge Interaction Studies"

S. M. O'Connor, J. P. Lynch, and A. C. Gilbert, "A Modal Analysis Application of Compressed Sensing for Enhanced Energy Efficiency in Wireless Structural Monitoring Systems"

NDE/NDT for Highways & Bridges: Structural Materials Technology (SMT) Conference 2012, ASNT, New York, NY, August 2012

S. O'Connor, J. P. Lynch, M. Ettouney, G. van der Linden, and S. Alampalli, "Cyber-enabled Decision Making System for Bridge Management Using Wireless Monitoring Systems: Telegraph Road Bridge Demonstration Project"

A. A. Mosavi, H. Sedarat, M. Kurata, Y. Zhang, A. Emami-Naeini, V. Jacob, and J. P. Lynch, "Finite Element Model Updating of a Long-span Suspension Bridge Using Measured Vibration Data"

IEEE Sensors Conference, Taipei, Taiwan, October 2012

K. Najafi, "Biomimetic Hair Sensors: Utilizing the Third Dimension"

IEEE Subthreshold Microelectronics Conference, Waltham, MA, October 2012

N. E. Roberts and D. Wentzloff, "915MHz Ultra Low Power Receiver Using Sub-Vt Active Rectifiers," Best Paper Award Winner

D. Blaauw, D. Sylvester, Y. Lee, I. Lee, S. Bang, Y. Kim, G. Kim, and H. Ghaed, "From Digital Processors to Analog Building Blocks: Enabling New Applications Through Ultra-Low Voltage Design," Invited Paper, Plenary Keynote

Conference Publications

(From July 2012 – January 2013)

(μTAS) International Conference on Miniaturized Systems for Chemistry and Life Sciences, Okinawa, Japan, October 2012

S. Takayama, "Microfluidic Tools to Model and Analyze the Body," Plenary Speaker, (Invited)

M. N. Gulari, A. Tripathi, and N. Chronis, "Microfluidic-Based Oil Immersion Lens for High Resolution Microscopy," pp. 49–51

ASME 2012 International Mechanical Congress & Exposition (IMECE 2012), Houston, Texas, November 2012

K. Kumar, A. Besharatian, L. P. Bernal, R. L. Peterson, and K. Najafi, "A Multiphysics Reduced Order Model of Valve Pumping in a 4-Stage Vacuum MicroPump"

IEEE-EMBS Micro- and Nanoengineering in Medicine Conference, Ka'anapali, HI, December 2012

M. Ghannad-Rezaie, M. N. Gulari, and N. Chronis, "A Powerless, Fabry-Perot Laser-based Pressure Microsensor"

International Electron Devices Meeting (IEDM), San Francisco, CA, December 2012

A. Ansari, V. Gokhale, J. Roberts, and M. Rais-Zadeh, "Monolithic Integration of GaN-based Micromechanical Resonators and HEMTs for Timing Application"

12th International Workshop on Micro and Nanotechnology for Power Generation and Energy Conversion Applications (PowerMEMS 2012), Atlanta, GA, December 2012

E. E. Aktakka, C. E. Smith, N. Ghafouri, R. L. Peterson, M. M. Hussain, and K. Najafi, "Heterogeneous Integration of Co-Evaporated Bismuth/Antimony Telluride Thin Films Based Thermoelectric Harvesters on FinFET CMOS Chip," pp. 97–100

J. McCullagh, R. L. Peterson, T. Galchev, R. Gordenker, Y. Zhang, J. Lynch, and K. Najafi, "Short-Term and Long-Term Testing of a Vibration Harvesting System for Bridge Health Monitoring," pp. 109–112

IEEE International Conference on Micro Electro Mechanical Systems (MEMS), Taipei, Taiwan, January 2013

Z. Wu, A. Peczalski, V. A. Thakar, Z. Cao, Y. Yuan, G. He, R. L. Peterson, K. Najafi, and M. Rais-Zadeh, "Piezoelectrically Transduced High-Q Silica Micro Resonators," pp. 122–125.

J. Cho, J. Yan, J. A. Gregory, H. Eberhart, R. L. Peterson, and K. Najafi, "High-Q Fused Silica Birdbath and Hemispherical 3-D Resonators Made by Blow Torch Molding," pp. 177–180.

D. Egert, J. Kaplan, R. L. Peterson, and K. Najafi, "Iodine-Treated Starch as Easy-to-use, Biodegradable Material With Controllable Swelling and Stiffening Properties," pp. 217–220.

Y. Shim, G. Hummel, and M. Rais-Zadeh, "RF Switches Using Phase Change Materials," pp. 237–240.

Y. Tang, R. L. Peterson, and K. Najafi, "Technology for Fabricating Dense 3-D Microstructure Arrays for Biomimetic Hair-Like Sensors," pp. 355–358.

Z. Cao, B. VanDerElzen, K. J. Owen, J. Yan, G. He, R. L. Peterson, D. Grimard, and K. Najafi, "Drie of Fused Silica," pp. 361–364.

D. Castro, P. Ingram, R. Kodzius, D. Conchouso, E. Yoon, and I. G. Foulds, "Characterization of Solid UV Cross-linked Pegda for Biological Applications," pp. 457–460.

E. E. Aktakka, R. L. Peterson, and K. Najafi, "A 3-DOF Piezoelectric Micro Vibratory Stage Based on Bulk-PZT/Silicon Crab-Leg Suspensions," pp. 576–579.

M. M. Sadeghi, K. Dowling, R. L. Peterson, and K. Najafi, "High Sensitivity, High Density Micro-Hydraulic Force Sensor Array Utilizing Stereo-Lithography Fabrication Technique," pp. 673–676.

A.Viswanath, S. R. Green, J. Kosel, and Y. B. Gianchandani, "Conformally Integrated Stent Cell Resonators for Wireless Monitoring of Peripheral Artery Disease," pp. 1069–1072.

Y-C. Chen, P. Ingram, X. Lou, and E. Yoon, "Osmotic Actuation for Microfluidic Components in Point-of-care Applications," pp. 1125–1128.

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Brief Abstracts

2012 Lorentz Workshop for Organs on Chips: Human Disease Models, Leiden, Netherlands, September 2012

S. Takayama, "Approaches to Microfluidic Spatio-Temporal Patterning and 3D Cultures Needed"

The Second Symposium of the Institute for Basic Science in 2012, Seoul, Korea, September 2012

S. Takayama, "Nano Imaging Sciences for Biomedical Exploration"

2nd Midwest Conference on Stem Cell Biology and Therapy, Rochester, MI, October 2012

S. Takayama, "Microfluidic Stem Cell Manipulations" ■

Doctoral Dissertations

Gustavo Serrano (April 2012)
"Gas Chromatographic Microsystems: Development and Application to Problems in Homeland Security and Environmental Health"
Chair: Prof. Ted Zellers

Anurag Tripathi (August 2012)
"Lab-on-chip Microdevices for Capturing, Imaging and Counting White Blood Cells"
Chair: Prof. Nikos Chronis

Amy Hsiao (September 2011)
"3D Spheroid Culture Systems for Metastatic Prostate Cancer Dormancy Studies and Anti-Cancer Therapeutics Development"
Chair: Prof. Shuichi Takayama

Xia Lou (September 2012)
"A High-throughput Microfluidic Platform for Profiling Photosensitizer Efficacy in Cancer Therapeutic Applications"
Chair: Prof. Euisik Yoon

Jorge Pernillo (December 2012)
"Analog To Digital Conversion Techniques for Nanometer CMOS"
Chair: Prof. Michael Flynn ■

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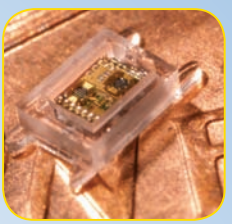
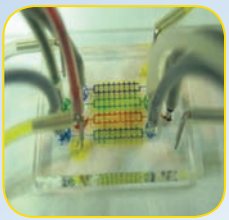
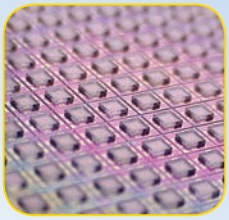
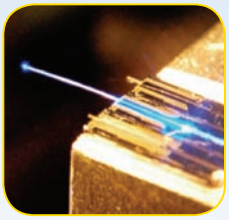
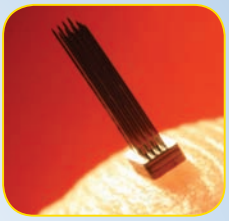
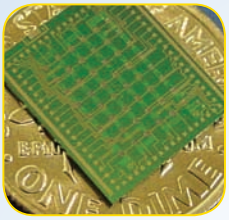
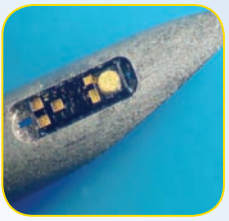
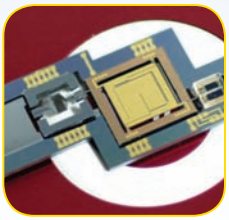

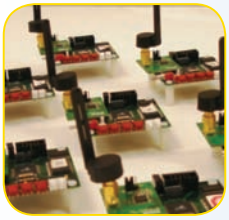

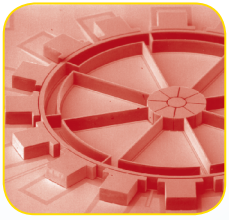
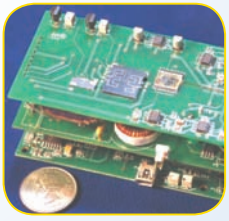


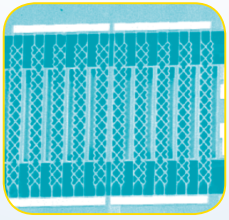
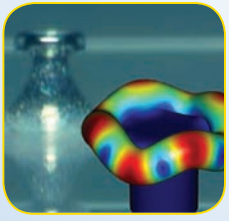
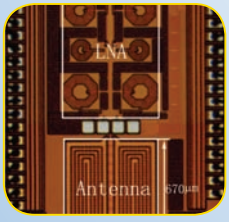
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