Wireless Integrated MicroSensing & Systems
WIMS²
Michigan Engineering

Horizons

Microsystems for the Next Generation

Summer 2013

Guest Editorial

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University of Michigan
Member, National Academy of Engineering

Meso/Micro/Nano Manufacturing: Envisioning the Adventures Ahead

Engineers working creatively across fields such as materials science, microelectronics, MEMS, computing, communications, robotics, bioengineering and synthetic biology are making ever more useful things, using ever smaller and more diverse componentry.

As iWatches displace watches, Google Glasses displace eyeglasses, robotic prosthetics displace wheelchairs, intelligent vehicles replace automobiles and increasingly powerful CubeSats displace large space satellites, we get glimpses of the incoming revolution in meso/micro/nano manufacturing.

Each passing month we learn of innovations in meso/micro/nano materials, processes, components and systems. While these innovations may seem mere laboratory curiousities to some, they are in reality landmarks for modern explorers of the vast sea of possibilities for creating micro-scale worlds.

For example, when Harvard researchers recently announced the *first controlled flight of robotic insects* [1], it seemed like 'lab magic' to those who seldom wonder how things are made. However, to the engineer it contained a deep message: Although the team dreamt for years of creating "robotic bees," it was their innovation of a laser-cut, laminated-material, origami-like, pop-up-book-like, production method that enabled them to conceive, prototype, and evolve a successful design. Furthermore, that system architectural and production method will enable construction of countless other meso/micro designs.

When a team at North Carolina State recently *lithographically formed 3-D micro-scale flexible, bendable structures and wires by using liquid metals* [2], they revealed how surface tension scaling-effects can provide needed micro-scale structural integrity. When yet another team at Harvard *used 3-D lithography to construct a lithium-ion battery less than a millimeter on a side* [3], they revealed how meso/micro-scale subsystems might someday be powered.

In each of these cases, the impactful innovation wasn't "the thing" itself. It was "how to make such things", i.e., how to manufacture whole classes of analogous things. As

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Workshop on Nano and Micro Manufacturing

WIMS² recently organized a workshop on Nano and Micro Manufacturing. The workshop brought together more than 150 nano/microscale device and material manufacturers, researchers, and end users of these technologies to discuss how to rapidly and effectively translate research into practical products. The event was held May 22–23 at the Ford Motor Company Conference and Event Center in Dearborn, MI.

The workshop addressed the challenges encountered in moving from research to production. There were more than 20 talks by individuals from industry and academia that spoke about the needs and the challenges encountered in nano and micro manufacturing. Attendees at the workshop represented the energy, semiconductor, medical device, defense, and automotive sectors, including Shell, Toyota, Freescale Semiconductor, and Stryker Instruments. Discussions included the need for new technologies in agriculture and medicine, the remarkable advances being made at universities, resources to aid entrepreneurs in the commercialization of technology, and the environmental and safety issues associated with nano technology.

"This workshop is a first step toward developing a roadmap for practical innovations in nano/micro-manufacturing. The aim is to promote application-driven research and commercialization of relevant manufacturing technologies which will lead to well-paying jobs in Michigan and the United States," said Yogesh Gianchandani, Workshop Chair and Director of the WIMS² Center.

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more such landmarks are discovered and shared, ever more engineers will begin connecting the dots to innovate meso/micro/nano-scale systems – searching for routes, for passageways, for breakthroughs, as they prospect for gold in this new world. Each new landmark will compound the possibilities for such connections, increasing the pace of discovery.

When this exponentiation reaches the tipping point, it will trigger disruptive change: the micro-scale world will suddenly become widely visible, extensively explored, intensely exploited. This eventuality is technologically, economically, politically, and socially inevitable, because the long-term success of humanity depends on sustainably providing ever-more per person while consuming ever-less energy and material resources per person.

Disruptive change provokes questions about old ways of doing things. For example: Does a major manufacturing facility have to be 'large'? Not necessarily, if it makes micro-scale things. Some micro/nano part-production factories might even fit in a suitcase, some meso/micro assembly plants might even fit in a garage.

But how do we shed old habits and get from here to there? Current-day robotic assembly plants provide an abstraction and a thought experiment on where to start. Given that people are no longer inside such a factory, how might we shrink it down from mega/macro-scale to macro/meso/micro-scale?

This is analogous to making a 'ship in a bottle.' The desired final product is clear, but there are open questions about how to remotely construct it within volumetric constraints. We'll have to know a lot more about how to make assemblages of automated micro tools, before we can make and assemble lots of micro things.

Even then, how will future manufacturing system architects fully conceptualize such meso/micro/nano production facilities? How will they figure out what to 'put in the bottle' and 'how to get it all in there'?

They'll have to think holistically about all relevant factors reduced to meso/micro/nano-scale – about materials, refining, processing, tooling, staging, feeding, shaping, machining, handling, composing, constructing, staging, assembling and storing; about sensors, transducers, manipulators and conveyors; about specifications, tolerances, scaling-effects, scaling rules, design-rules, digitizations, encodings and standards; about product innovation, system architecture, design, simulation and validation; about observing, sensing, metrology, measuring, controlling, monitoring and testing; about rapid-prototyping, parametric variation, plug-n-play modularization, customization, short-runs and volume-runs; about system integration, infrastructure, logistics, shipping, tracking and coordinating; about QA, user training, user feedback, EC's, maintenance and life-cycle monitoring; about product evolution, marketing, financial, economic and sustainability factors – and not just for the products, but for the overall manufacturing plant.

Such facilities promise to be among the most complex systems ever created, thus the incoming revolution will present many challenges to traditional scientific and engineering culture: What's the new game? Who gets to play? How do we team-up? What rules do we play by?

In a recent editorial in *Science Magazine*, Keith Yamamoto asked [4]: *"What if baseball were organized like science? Aspiring catchers or shortstops, like students of physics or molecular biology, would be trained by professional counterparts, and top prospects with dazzling skills would turn pro without learning that by combining their specialized talents, they could create an entirely different game. Managers, owners, and marketers would seek and reward individual stars at each position but would not facilitate or nurture a team culture or even a team game. In science, traditions, policies, and bureaucracies isolate scientific disciplines and their discoveries and technologies, squandering exciting opportunities that could be empowered by merged ideas and efforts—in short, by teamwork."*

Bottom line: It's "Time to Play Ball"!

[1] "Robotic insects make first controlled flight: In culmination of a decade's work, RoboBees achieve vertical takeoff, hovering, and steering", *Harvard Gazette*, May 2, 2013.

http://news.harvard.edu/gazette/story/2013/05/robotic-insects-make-first-controlled-flight/

[2] "3D-printing with liquid metal at room temperature: A new method for printing 3D structures and wires from liquid metal opens up possibilities for flexible and stretchable electronic connections", *CNET*, July 9, 2013.

http://news.cnet.com/8301-17938_105-57592867-1/3d-printing-with-liquid-metal-at-room-temperature/

[3] "Pin-sized battery printed in 3D packs a powerful punch: Miniature lithium-ion device could power medical devices or miniature robots", *Nature: News*, 20 June 2013.

http://www.nature.com/news/pin-sized-battery-printed-in-3d-packs-a-powerful-punch-1.13246

[4] Keith Yamamoto, "Editorial: Time to Play Ball", *Science* 21 June 2013: vol. 340 no. 6139 p. 1375.

http://www.sciencemag.org/content/340/6139/1375.full

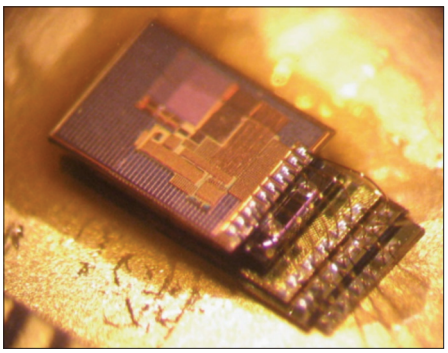
mm³-scale Sensor Platform Research at WIMS²

Dennis Sylvester, David Blaauw, David Wentzloff, Prabal Dutta, and Yoonmyung Lee

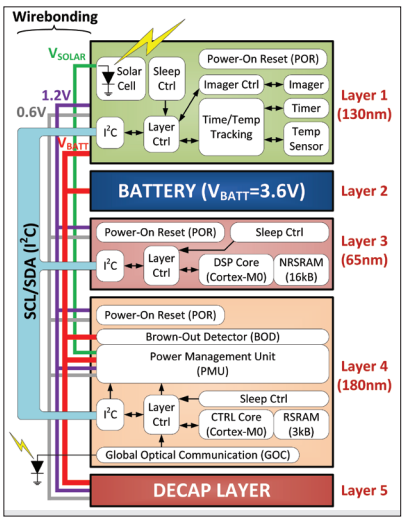
The emergence of tiny computers has long been predicted. However, modern state-of-the-art miniature computers have remained larger than 100mm³ due to significant challenges with limited battery volume and ultra-low power budgets. A team of WIMS² researchers comprised Dennis Sylvester, David Blaauw, David Wentzloff, Prabal Dutta, and Yoonmyung Lee are working on mm³-scale general-purpose sensor node platform for the next generation of 'tiny' microsystems. These microsystems can be used for a variety of applications including implantable medical devices, security and surveillance systems, structural health monitoring, and environmental sensing, and anywhere small sensor nodes with long lifetime are required.

The research team recently introduced a prototype micro-sensor system with a heterogeneous multi-layer structure. The prototype system includes two ARM® microprocessors, 19kB memory, a radio transmitter, a power management unit with multi-modal energy harvesting, a thin film Li battery, a low-power timer, an optical wake-up receiver, a temperature sensor and an image sensor – everything in 1.0mm³ volume. The key challenge for realizing such tiny microsystem is re-designing every single microsystem component to meet a stringent power budget required by the integrated thin-film battery. This requires not only the expertise on individual components but also a comprehensive understanding of system level power and energy management.

Currently, the team is investigating a next-generation version of the mm-scale sensor platform with higher reliability and lower power inter-layer communication. It also has added sensor front-ends including magnetic sensing, strain sensing, and audio recording to support a wider range of applications. The goal is to develop a comprehensive set of sensing/computing modalities for generic microsystems and distribute the resulting devices to the research community. This will enable many research opportunities that were previously impossible due to the size and lifetime of sensors. The team is currently collaborating with researchers from engineering, medicine, and dentistry, both inside and outside Michigan, to exploit these unique capabilities. ■



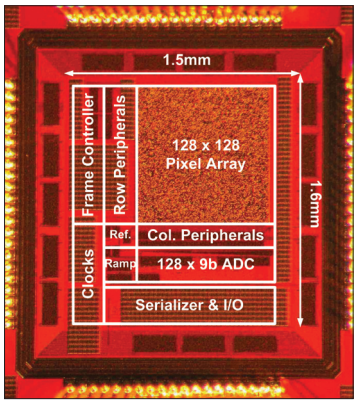
1mm³ device photograph.



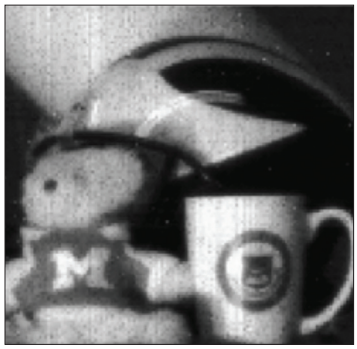
1mm³ device architecture.

Low Power Motion Detection Without DSPs

Dennis Sylvester, David Blaauw, and Gyouho Kim



CMOS visual motion sensor die photo.



Sample 128x128 image from CMOS image sensor.

Visual monitoring and imaging with integrated CMOS image sensors can open up a variety of new applications for wireless sensor nodes, ranging from surveillance to *in vivo* molecular imaging. In particular, the ability to detect motion can enable more intelligent power management through on-demand duty cycling and reduced data retention requirement. Conventional motion detection schemes use digital signal processing (DSP), which requires a dedicated computational unit and memory, with large power and area overhead for miniaturized battery-limited sensor nodes.

In an effort to avoid DSP, several designs have been proposed, in which the previous pixel value is stored on an in-pixel capacitor until the end of the next integration cycle for immediate frame differencing. However, these designs still consume mWs of power, and are limited to frame differencing of only two consecutive frames, reducing sensitivity to slow moving objects, in contrast, more sophisticated DSP approaches operate on multiple frames.

We have developed a 128×128 resolution CMOS image sensor with ultra-low power in-pixel motion detection capability. By using a dual supply design, sub-threshold biasing of analog amplifiers, and smart clocking of the digital blocks, the sensor consumes merely 467nW while performing motion detection at 5 frames per second (fps), marking two orders of magnitude reduction over prior art. Spatial aggregation of pixels and temporal averaging during pixel integration are implemented to minimize blindspots and increase sensitivity to slow motion. With these techniques, motions as slow as 3cm/sec at a distance of 5m can be detected. Full-frame still images with 38.5dB dynamic range are captured at 6.4fps while consuming 16μW. ■

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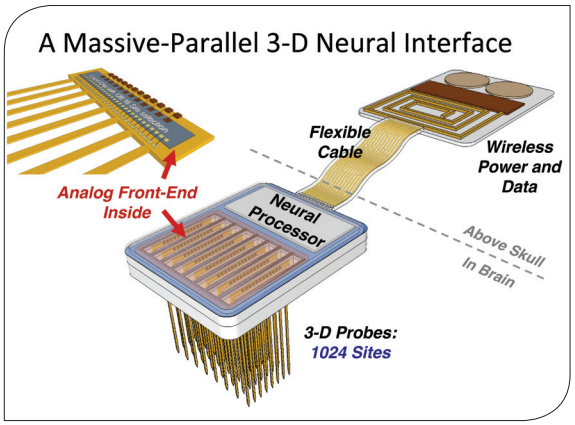
Interface Circuits for Neural Recording Electrodes

Khaled Al-Ashmouny, Sun Il Chang, and Euisik Yoon

The study of brain dynamics has tremendously improved over the past five decades due to the progress in neural recording techniques. In addition to developing algorithms of spike detection and spike sorting, the ability to record massive parallel neural activities has been a crucial tool for many complex neuroscientific studies. Similar to Moore's law, the number of simultaneously recorded channels actually doubles every 7 years, which implies that recording a few thousand channels will become feasible in the next decades. Nonetheless, a leap in the number of simultaneously accessible channels has remained as an unmet need due to many limitations, including recording integrated circuits.



Pictorial view of neural interface circuitry.

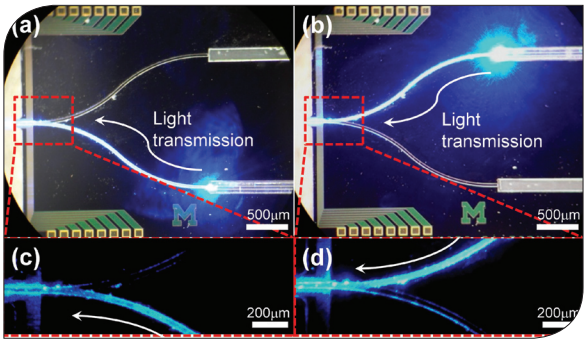
We report an analog front-end prototype designed in 0.25μm CMOS process for hybrid integration into neural recording microsystems. For scaling towards massive parallel neural recording, the prototype has investigated some critical circuit challenges in power, area, interface, and modularity. We achieved extremely low power consumption of 4μW, optimized energy efficiency using moderate inversion in low-noise amplifiers (K of 5.98 or NEF of 2.9), and minimized asynchronous interface (only 2 per 16 channels) for command and data capturing. We also implemented adaptable operations including programmable-gain amplification, power-scalable sampling (up to 50 kS/s/channel), wide configuration range (9-bit) for programmable gain and bandwidth, and 5-bit site selection capability (selecting 16 out of 128 sites). The implemented front-end module has achieved a reduction in noise-energy-area product by a factor of up to 25 times compared to reported state-of-the-art analog front-end approaches. ■

Neural Probes Integrated With Optical Mixer/Splitter Waveguides and Multiple Stimulation Sites

Maesoon Im, Il-Joo Cho, Fan Wu, Kensall D. Wise, and Euisik Yoon

Neural probes have enabled neuroscientists to monitor neural activities as well as to stimulate neurons electrically. In recent times, optical stimulation has drawn much attention because it has high temporal and spatial resolution [3-6], and at low power it does not damage neurons.

We are working on a new neural probe scheme incorporating various optical waveguides for optogenetic applications. A photodefinable polymer (SU-8) has been patterned to form optical mixer and splitter waveguides for advanced optical functions with multiple light sources and easy delivery of light to multiple shanks, respectively. Also, multiple stimulation sites have been implemented by step-wise patterning in a single waveguide. Iridium electrodes have been integrated for recording of neural signals from optically stimulated neurons. Single-mode optical fibers have been coupled in grooves etched in the probe body. We have successfully demonstrated transmission of light (blue), 473nm, through the waveguides that are integrated on the fabricated devices.

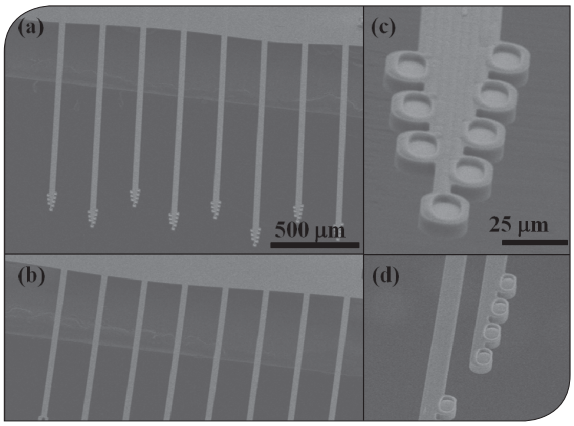


Light transmission through the optical mixer waveguides integrated on the fabricated neural probe: (a, b) bright field microscope images; (c, d) magnified dark field images.

The fabricated probes cannot only illuminate different wavelengths on the given stimulation sites but also synchronously stimulate multiple sites with precise distance control between the optical stimulation sites and electrical recording sites. The light intensity is sufficient to optically stimulate genetically targeted neurons. Additionally, electrical recording has been verified with the commercialized data acquisition system. The fabricated neural probes with optical stimulation capabilities are expected to be utilized in a variety of neuroscience research projects. ■

Optical neural probes on a U.S. penny.

WIMS² Student Wins Outstanding Paper Award



SEM images of the fabricated probes with two different designs in (a) and (b), and their respective magnified view in (c) and (d).

WIMS² doctoral student Fan Wu received an Outstanding Oral Paper Award at the *17th International Conference on Solid-State Sensors, Actuators and Microsystems (Transducers '13)* for the paper entitled "A Multi-shank Silk-backed Parylene Neural Probe for Reliable Chronic Recording." The authors were Lee Tien, Fujun Chen, Prof. David Kaplan, Prof. Joshua Berke, and his advisor, Prof. Euisik Yoon. Tien and Kaplan are with the Department of Biomedical Engineering at Tufts University; Chen and Burke are with the Department of Psychology at the University of Michigan.

The researchers designed and obtained the first *in vivo* recording of a biodegradable silk-backed neural probe. "Many chronic brain implants would benefit from a neural probe with many densely configured electrodes with stable recording quality," stated Mr. Wu. "We presented a novel strategy to scale up the number of electrodes with minimized risk of proportionally increasing the adverse foreign body reactions."

A flexible parylene probe with 64 electrodes was fabricated with biocompatible silk fibroin. The silk was patterned to provide the required mechanical stiffness and sharpened tip for proper insertion. The silk support degraded at a controlled rate after implantation was complete, leaving behind ultra-small and flexible electrodes for chronic recording. The technology provides additional freedom in the size and shape and construction of any type of implanted medical device. The probes were tested in rats and provided stable results over a period of six weeks.

The work is funded by the Microsystems Technology Office, DARPA, and the NSF Graduate Research Fellowship Program. ■

WIMS² Students Win Best Poster Award

Doctoral students Zhengzheng Wu, Vikram Thakar, Adam Peczalski, and their advisor Prof. Mina Rais-Zadeh received a Best Poster Award at the *17th International Conference on Solid-State Sensors, Actuators and Microsystems (Transducers '13)* for their paper entitled "A Low Phase-Noise Pierce Oscillator Using a Piezoelectric-on-Silica Micromechanical Resonator."

Fan Wu, Zhengzheng Wu, and Prof. Rais-Zadeh.

The award-winning paper reports on a high-performance electrical oscillator using a fused silica micro-electromechanical resonator. Fused silica, a high-purity transparent glass, is known for its excellent optical properties. The mechanical properties of silica such as extremely-low thermal conductivity, small thermal expansion coefficient, and low acoustic loss are exploited in this work to realize high-quality factor micromechanical resonators.

This research demonstrates fused silica resonators that are highly miniaturized and suitable for batch fabrication, and overcomes the challenge of transducing signals between electrical and mechanical domains using a thin layer of a piezoelectric aluminum nitride layer. The miniature silica resonator is interfaced directly to a custom designed integrated circuit using 180nm commercial CMOS process to realize a low-noise oscillator. This creates a state-of-the-art integrated MEMS frequency reference and results pave the way for realizing highly integrated silica-based MEMS.

This research, funded by DARPA and performed in collaboration with Prof. Khalil Najafi's group, is targeted at developing a precision master clock for a chip-scale Timing and Inertial Measurement Unit (TIMU). The goal of the TIMU program is deep integration of high-performance inertial sensors and timing reference units within a small (<10mm^3) microsystem, enabling advanced precision navigation, guidance, and control capabilities in GPS denied environments. ■

Other Michigan Awards at Transducers

There were two other WIMS² related awards at *Transducers*. Prof. Clark Nguyen who started his faculty career at WIMS before moving to UC Berkeley received a best paper/poster award and Prof. Haluk Külah a graduate of Prof. Najafi's group received a best presentation award. ■

Industrial Liaison Report

Dr. Andy Oliver

Industrial Liaison and Principal Staff Scientist

It has been a busy time at WIMS^2 since my last column. Much of our time has been spent organizing the *NSF Nano and Micro Manufacturing Workshop* which was held following the Spring 2013 IAB meeting. The workshop was a tremendous success thanks to the efforts of WIMS^2 faculty, students, staff, and members. Special thanks are due to John Janik, a long-term member of the Industrial Advisory Board, Kurt Peterson, Herbert Bennett, and Roger Grace of the Strategic Advisory Board who all contributed talks. Several WIMS^2 faculty spoke including Katsuo Karabayashi, John Hart, and Khalil Najafi. In addition, Yogesh Gianchandani served as the General Chair of the workshop and Karen Richardson, Joe Giachino, and myself were involved in planning and executing the workshop.

The workshop serves to emphasize the applications focus of the WIMS^2 Center. We believe that science and engineering can make much more of an impact when it is applied to real world problems. The workshop was an attempt to connect industrial people who have challenges and applications with academics who have new technology and solutions. It also served to educate both industry and academia why transitioning technology from universities to industry is not straightforward. Easing the transition is one function of the WIMS^2 Center because members have both formal (through licensing rights) and informal (access to university researchers) access to intellectual property and knowledge. The industrial liaison's office acts to further this technology transfer. Please contact us if we can be of assistance.

This workshop is part of our increased emphasis on outreach to the wider scientific and engineering community. Outreach increases the engagement of the Center, the faculty, and the University with researchers and industrial practitioners as a whole across the country and globe.

We have continued to update our website to act as a resource for our members. For example, we have streamlined the process for member companies to gain access to the IAB files (if you want access and did not receive a username and password please contact me). We have also been updating the lists of publications and patents.

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. ■

Jonathan Plummer Retires

Jonathan Plummer, the WIMS^2 webmaster, has retired after 7 years at WIMS and 36 years at the University. Jon has been responsible for all the recent updates on the website including all the interfaces with databases which keeps things working behind the scenes. He holds a Bachelors Degree in Business Administration specializing in IT management. Prior to joining WIMS^2 he was a University facility manager. He plans to spend more time traveling and performing music with *Sumkali*, a group that plays Indian classical, light classical, folk, and fusion music of both North and South India. We at WIMS^2 will greatly miss him. ■

Personnel Focus

Ms. **Lynette Bush** was hired in January as an administrative specialist for WIMS^2 and has already had several successes. As an initiation, she handled all the arrangements and registrations for the May *IAB* meeting as well as assisting at the *Nano and Micro Manufacturing Workshop.* She also arranged for the IEEE Sensors Technical Program Committee to meet in Ann Arbor and is helping with the visit of the National Chiao Tung University in August. She handles membership agreements and invoices for the Center and acts as point of contact for administrative matters. In addition to her other responsibilities, Lynette is active in planning and organizing Staff Works, Michigan's staff development conference. Before joining the Center, Lynette worked in the University Medical Center in the Department of Internal Medicine. Welcome aboard Lynette. ■

Strategic Advisory Board

An important part of WIMS^2 is the Strategic Advisory Board (SAB), which is composed of leaders in industry and government who advise the WIMS^2 leadership on how to improve the Center. Current members include Joe Giachino (Chair), Herbert Bennet, Patricia Glaza, Roger Grace, Kalyan Handique, Rajinder Khosla, and Kurt Peterson. The SAB attends the WIMS^2 Industrial Advisory Board (IAB) meetings, and meet with faculty, students, and industrial members. Additionally, they convene with the Center leadership in a closed meeting that allows for candid discussions of the perceived strengths and weaknesses of the Center. As the SAB has the opportunity to compare WIMS^2 with other research centers, they have the ability to offer beneficial insight to WIMS^2 leadership on a variety of ways to provide improved value to the industrial community. For example, one of the suggestions was to emphasize businesses, which was one of the catalysts that produced the *Workshop on Nano & Micro Manufacturing*. The SAB also acts as ambassadors for the Center by informing business associates about the ongoing research activities at WIMS^2. ■

Blaauw and Sylvester Named to List of Top ISSCC Authors

Prof. David Blaauw

Prof. Dennis Sylvester

Profs. **David Blaauw** and **Dennis Sylvester** have been named two of the top contributing authors to the *International Solid-State Circuits Conference (ISSCC*), which is the flagship conference of the Solid-State Circuits Society.

This honor came as part of *ISSCC's* 60th anniversary celebration. The *ISSCC* selected an elite group of 16 authors who either presented more than 30 papers at *ISSCC* during the course of the past 60 years, or who are among the top 10 contributors over the past 10 years.

At *ISSCC*, Profs. Blaauw and Sylvester have presented many of their groundbreaking research papers in the areas of ultra-low-power chip design and millimeter-scale computing. In addition to their conference papers, they have served as panelists in special sessions, presented invited talks, and their students have been winners in the 2009 and 2011 DAC/ISSCC Student Design Contest. Also, Prof. Sylvester received the Beatrice Winner award for editorial excellence at the *ISSCC* conference in the year 2000. ■

Wentzloff Receives NSF Career Award

Wireless Thrust Leader, David Wentzloff received an NSF Career Award for his project, "Ultra-Low Power Radios for Energy-Autonomous Applications". Prof. Wentzloff's work aims to improve the modeling of wireless channels for a wide range of applications through new wireless communication circuits and architectures, and development of ultra-low power radios for dense wireless environments — such as sensor networks. He conducts research in the area of low-power integrated circuits for wireless communication in energy-constrained and volume-constrained applications. Specifically, his research group focuses on three topics, synthesizable all-digital radios and radio building blocks, wireless body sensor networks, and radios and interfaces for the mm-scale class of computers. The Early Faculty Development (CAREER) Program Award is an award from the National Science Foundation (NSF). It is intended to support "junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education, and the integration of education and research." It is one of the most prestigious and sought after awards from the NSF. ■

Nano and Micro Manufacturing Workshop

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Sridhar Kota was the first plenary speaker. As the Assistant Director for Advanced Manufacturing at the White House Office of Science and Technology Policy, he played an instrumental role in launching the National Manufacturing Innovation Institute and the National Robotics Initiative. He pointed out that being the world's best in science is still vital to American success, but this alone is not sufficient to compete in a global economy. Prof. Kota, who has now returned to the University of Michigan as a professor, stressed that European governments often have joint industrial-government funded laboratories that perform advanced product development, and this might be an appropriate model for the United States.

Kurt Petersen, also a plenary speaker, is a member of the WIMS^2 Strategic Advisory Board, and a co-founder of six successful companies in MEMS technology stated that the intersection of the mobile and medical technologies will further accelerate the sales of MEMS devices. Dr. Petersen pointed out that while the U.S. has a nearly unique entrepreneurial infrastructure, competition from the rest of the world is rapidly gaining. In Dr. Petersen's view, more resources need to be invested in easing and simplifying the transition from R&D to production.

Two other invited speakers were Professor Emerita **Lynn Conway** from the University of Michigan who reflected on the emergence and impact of modern microelectronics and computing. The goal of her talk was to help the audience frame and envision the adventures, opportunities, and challenges that lie ahead in micro/nano engineering. Emeritus Prof. **Kensall Wise**, the Founding Director of WIMS, chronicled the advances in electronics and MEMS over the past 50 years. His conclusion was that pervasive microsystems that can run forever and can sense, interpret, and communicate wirelessly, locally, or globally will define a new generation of electronics.

Numerous speakers addressed industry needs. Dr. **John Janik** from Stryker, a WIMS^2 member company, talked about the applications of implanted nano and micro devices. Dr. **Herbert Bennett**, a member of the Strategic Advisory Board, addressed the need for standards in nano and micro devices. The role of technology clusters in technology development was summarized by Mr. **Roger Grace**, another member of the WIMS^2 Strategic Advisory Board.

The sessions on manufacturing processes covered a vast number of applications and manufacturing technologies. Included in the presentations were roll-to-roll nanofabrication, atomic layer deposition, self-assembly, photolithography and printing technologies. Speakers included Profs. **John Hart** and **Katsuo Kurabayashi** from WIMS^2 in addition to notables from 15 other institutions. Applications for these technologies range from displays, biomedicine, electronics, automotive, and energy. In addition to the oral presentations, there were two days of poster sessions with over 50 posters that presented additional manufacturing techniques and specific applications for micro and nano systems.

Unlike some forms of technology that require a relatively small amount of funding to move from concept to reality, nanoscale and microscale devices require highly specialized laboratories for their creation and fabrication. The workshop addressed the unique challenges that exist in moving from university nano and micro research to the manufacturing stage which included a presentation given by Prof. **Khalil Najafi** about the NSF National Nanotechnology Infrastructure Network (NNIN), an integrated network of 13 university micro/nanofabrication facilities.

The workshop held panel discussions on the future of manufacturing as well as the barriers to commercialization. Included were discussions on technology clusters, funding challenges, licensing technology from universities, and patenting considerations.

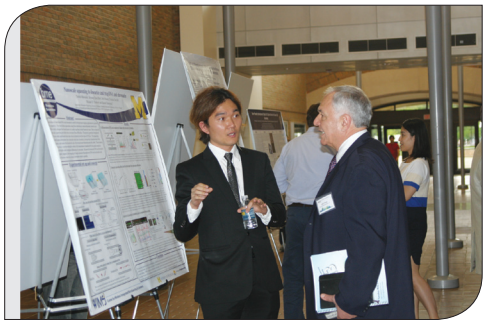
The General Chair of the meeting was Prof. **Yogesh Gianchandani**. **Karen Richardson** took care of the local arrangements while Profs. **Katsuo Kurabayashi** and **John Hart** co-chaired the Technical Program Committee. The Strategic Direction Committee was headed by **Joe Giachino** and **Andy Oliver** was the Industrial Chair.

This NSF workshop was co-sponsored by the Center for Wireless Integrated MicroSensing & Systems (WIMS^2), Freescale Semiconductor, and the Transducers Research Foundation. Additional financial support was provided by the Michigan Economic Development Corporation. Workshop marketing partners were Roger Grace Associates and the MEMS Industry Group. The exhibitors at the workshop included the Lurie Nanofabrication Facility, Olympus America Inc., Oxford Instruments, SMART Commercialization Center for Microsystems, Freescale Semiconductor, and the Center for Wireless MicroSensing & Systems (WIMS^2).

The proceedings are available from http://nano-microworkshop.com/proceedings/ as either a single pdf file or you can choose which of the nearly 70 poster or oral presentation slides to download individually. ■

Spring 2013 Industrial Advisory Board Meeting

The Spring *2013 Industrial Advisory Board Meeting* was held on May 21, 2013. The event was different than previous meetings because many of the participants were also involved in the *Workshop on Nano and Micro Manufacturing* that was held the next day. However, the general consensus was that many of the changes were positive including having a single poster session in conjunction with a walking lunch. Following the poster session for the industrial members, there was a student poster contest. The winner of the contest was Kee Scholten from the Zellers Group for a poster entitled "Microfabricated OptoFluidic Ring Resonators for Microscale Gas Chromatography." The co-authors on the poster were Karthik Reddy, Prof. Xudong Fan, and Prof. Ted Zellers. There were also meetings of the Industrial Advisory Board and the Strategic Advisory Board who provided feedback to the faculty. This year, the banquet was replaced with a very well attended evening reception at the Dearborn Inn. ■



The poster session at the Spring IAB meeting.

Micromachine Summit

WIMS^2 was well represented at the *19th Annual World Micromachine Summit* in Shanghai, China this past April. The chief U.S. delegate was Prof. Yogesh Gianchandani and the other U.S. delegate was Dr. Andy Oliver. The four-day meeting theme was "Smart City, Better Life Powered by Micro/Nano Technology" and it concentrated on the different ways that micro and nano sensors and actuators could improve urban life. This is a particular challenge for China and Shanghai in particular, which has grown from 13 to 23 million people in the last 20 years. At the workshop, all 17 of the attending delegations gave an overview of the status of their national research programs. Prof. Gianchandani gave an overview of federal initiatives from NSF and the White House. He noted that the U.S. research program is less centrally organized than many other countries and compared various countries R&D spending to the percentages of their populations who are involved in technology. He concluded despite a lack of increase in investment, the U.S. R&D effort is in fairly good shape, but that competition from Asian countries is rapidly increasing. Assistant U.S. Delegate Dr. Andy Oliver reviewed interaction models between industry and gave an overview of the WIMS^2 Industrial Program and how it promotes technology transfer. ■

WIMS^2 Director Prof. Yogesh Gianchandani's speech representing the United States at the World Micromachine Summit in Shanghai, China.

Transducers 2013 Conference

In June, WIMS^2 students and faculty presented papers at the *Transducers 2013 Conference*. Transducers, also known as the *International Conference on Solid-State Sensors, Actuators and Microsystems*, is one of the preeminent conferences on MEMS and Microsystems. At the workshop, one WIMS^2 paper received a best paper award and a second received a best poster award (see separate articles in page 5). As a service to our members, these papers are now on the WIMS^2 website. Topics include: a PZT Microvibratory Stage, a MicroPump for Gas Chromatographs, Multi-Layer Microsystems, Birdbath Gyroscopes, Quality Factors of MicroResonators, MicroJet Arrays, Electrostatic Actuators, A Fieldable Gas Chromatograph, Carbon Nanotube UV Sensors, Neural Probes, a Optofluidic Red Blood Cell Measuring System, Vapor Detection Using Optofluidic Ring Resonators, Micromechanical Pierce Oscillators, Mechanical Gas MicroPumps, and a Directional Air Flow Sensor.

The four-day conference was held in Barcelona, Spain and the faculty and students enjoyed the warm Mediterranean climate and the Catalonia cuisine. In addition to the current students and faculty, several Michigan alumni also attended the conference. ■

Prof. Chris Roberts from the University of Hong Kong, Seow Yuen Yee, Khalil Najafi, Ning Gulari (an alumnus), and John Clark (an alum).

The traditional Michigan conference dinner.

2013 ISSCC

There were several newsworthy events at the *2013 ISSCC (International Solid State Circuits Conference)*. First, Profs. David Blaauw and Dennis Sylvester received an award for being two of the top 10 contributors to the *ISSCC* conference in the past 10 years (see separate article). Also, students and faculty from Michigan presented 10 papers including an invited talk by Prof. Dennis Sylvester on, "An Energy-Centric Design Approach to Achieve Nanowatt Microsystems."

In addition, WIMS^2 Prof. Mike Flynn organized a session for students nearing their graduation, called "You're Hired – The Top 25 Interview Questions for Circuit Designers." The wildly successful session was attended by 1000 people.

Furthermore, Prof. Flynn organized and co-hosted the *5th Annual University of Michigan Alumni and Friends Mixer* at *ISSCC (International Solid-State Circuits Conference)*. It was a great success as old and new friends gathered to discuss the day, catch up with friends, and simply relax together. Alumni in the area are always invited, and several came to reconnect with their Maize and Blue colleagues.

"It's so nice to be able to unwind and connect with people in a relaxed setting," said Prof. Michael Flynn, the event organizer. "Many of these people have known each other for years; it's a great time to catch up." ■

IEEE SENSORS 2013

WIMS^2 is planning a presence at the *2013 IEEE Sensors Conference* in Baltimore, MD. WIMS^2 Director, Prof. Yogesh Gianchandani, is also serving as the Technical Program Chair and is working on creating a larger industrial presence at this conference. One of his initiatives is an industrial panel whose topic is wearable electronics for both medical and physical fitness purposes. The conference will be held from November 3–6 and early and advanced registration ends on August 9 and September 22, respectively. ■

www.ieee-sensors2013.org

WIMS^2 Faculty Promotions

Prof. Becky Peterson

Dr. Becky Peterson, a research scientist in Prof. Najafi's group since 2009, will start her tenure track faculty career at Michigan in the fall. "I'm very excited to have this opportunity," Becky said. "I'm looking forward to starting a research group in the areas of novel electronic materials and wafer scale materials integration. I'm also interested in thin film transistors, energy harvesting, and sensors, as well as continuing my collaborations with Prof. Najafi and the rest of the faculty at WIMS^2." Prior to coming to WIMS^2, Dr. Peterson was a post-doctoral research fellow at the Cavendish Laboratory, Department of Physics, and a Associate Lecturer in Engineering at Newnham College both at the University of Cambridge in the UK. She also has industrial experience at Guidant Corporation (now Boston Scientific) designing integrated circuits for implanted medical devices. Her PhD is from Princeton and her thesis concerned heteroepitaxy and wafer bonding for strained-silicon MOSFETs. Her awards include two best paper awards in 2012, an NSF Graduate Research Fellowship, an Association of Princeton Graduate Alumni Teaching Award, an American Association of University Women Engineering Fellowship, and an Automatic RF Techniques Group Microwave Measurement Student Fellowship. Congratulations Professor Peterson!!! ■

Assoc. Prof. David Wentzloff

Assoc. Prof. Tal Carmon

Two WIMS^2 faculty members, **Tal Carmon** and **David Wentzloff**, have been promoted to Associate Professor with tenure.

Tal joined WIMS in 2007 as an assistant professor. Since then he has established himself as an internationally recognized leader in optomechanics, which is the coupling of light to the oscillation modes of mechanical systems. He developed the technique of Brillouin scattering for driving high-frequency optomechanical oscillation in optical microcavities. This has enabled record-high frequencies to be achieved and also enabled for the first time optical cooling of such a mechanical system. Tal received an AFOSR Young Investigator Award. He teaches courses in the area of Photonics, Lasers, and Photonic MEMS, and introduced web-based visualization and simulation tools into the curriculum. He is a member of the High Frequency MEMS Thrust.

David joined WIMS in 2007 as an assistant professor. He has made important contributions to a number of key problems in wireless connectivity for sensors and computing. These contributions dramatically reduce the size and improve the energy efficiency of sensing systems and computing nodes. He is also a pioneer in the implementation of RF and analog circuits with digital gates. Dave has excelled as a teacher and mentor of undergraduate and graduate students, and was named HKN Professor of the Year in 2010. He received a DARPA Young Faculty Award and and NSF CAREER Award, and has graduated 6 PhD students. In 2012, he became thrust leader of the WIMS^2 Wireless Thrust. ■

Optofluidics 2013

Profs. Sherman Fan and Katsuo Kurabayashi have both been invited to speak at *Optofluidics 2013* in Hong Kong. This conference aims to discuss the latest progress in the fields of optofluidics and related research. Prof. Fan will talk about his work in multi dimensional gas chromatography and Prof. Kurabayashi will talk about his work constructing microfluidic devices to analyze cells. ■

Doctoral Dissertations

Khaled AlAshmouny, January 2013
"Analog Front-End Circuits for Massive Parallel 3-D Neural Microsystems"
Chair: Prof. Euisik Yoon

Sun-Il Chang, January 2013
"Nano-Watt Modular Integrated Circuit for Wireless Neural Interface"
Chair: Prof. Euisik Yoon

Seunghyun Oh, January 2013
"Energy-Efficient Reactive Radio Design in Body Area Networks"
Chair: Prof. David Wentzloff

Yonghyun Shim, February 2013
"Fully Integrated High-Performance MEMS Lumped Element Filters for Reconfigurable Radios"
Chair: Prof. Mina Rais-Zadeh

Erwin Hendarto, March 2013
"Applications of Marangoni Forces in Actuating Solid Phase Objects"
Chair: Prof. Yogesh Gianchandani

Ali Besharatian, April 2013
"A Scalable Modular Multistage Peristaltic Electrostatic Gas Micropump"
Chair: Prof. Khalil Najafi

Kuo-Ken Huang, May 2013
"Crystal-Less RF Communication Integrated Circuits for Wireless Sensor Networks"
Chair: Prof. David Wentzloff

Matthew Tomes, June 2013
"Brillouin Optomechanics"
Chair: Prof. Tal Carmon

ZhiYoong Foo, July 2013
"Custom Silicon for Low-Cost Information Dissemination Among Illiterate People Groups"
Chair: Prof. David Blaauw

Seow Yuen Yee, August 2013
"Design and Development of Ultrasonic Jet Array (UJA) for Micro Propulsion Applications"
Chair: Prof. Khalil Najafi ■

Journal Articles

(From January 2013 – July 2013)

D. Fick, R. Dreslinski, B. Giridhar, G. Kim, S. Seo, M. Fojtik, S. Satpathy, Y. Lee, D. Kim, N. Liu, M. Wieckowski, G. Chen, T. Mudge, D. Blaauw, and D. Sylvester, "Centip3De: A Cluster-based NTC Architecture With 64 ARM Cortex-M3 Cores in 3D Stacked 130nm CMOS," *IEEE Journal of Solid-State Circuits*, pp. 104–117, January 2013.

M. Fojtik, D. Fick, Y. Kim, N. Pinckney, D. Harris, D. Blaauw, and D. Sylvester, "Bubble Razor: Eliminating Timing Margins in an ARM Cortex-M3 Processor in 45nm CMOS Using Architecturally Independent Error Detection and Correction," *IEEE Journal of Solid-State Circuits*, pp. 66–81, January 2013.

P. Gupta, Y. Agarwal, L. Dolecek, N. Dutt, R. Gupta, R. Kumar, S. Mitra, A. Nicolau, T. Simunic Rosing, M. B. Srivastava, S. Swanson, and D. Sylvester, "Underdesigned and Opportunistic Computing in Presence of Hardware Variability," *IEEE Transactions on Computer-Aided Design*, pp. 8–23, January 2013 (invited article).

E. Hendarto, T. Li, and Y. B. Gianchandani, "Investigation of Wine Glass Mode Resonance in 200-μm-Diameter Cenosphere-Derived Borosilicate Hemispherical Shells," *Journal of Micromechanics and Microengineering*, pp. 1–6, January 2013.

Y. Lee, G. Kim, S. Bang, Y. Kim, I. Lee, P. Dutta, D. Sylvester, and D. Blaauw, "A Modular 1mm3 Die-Stacked Sensing Platform With Low Power I2C Inter-die Communication and Multi-Modal Energy Harvesting," *IEEE Journal of Solid-State Circuits*, pp. 229–243, January 2013.

L. W. Tien, F. Wu, M. D. Tang-Schomer, E. Yoon, F. G. Omenetto, and D. L. Kaplan, "Silk as a Multifunctional Biomaterial for Reduced Glial Scarring Around Brain Penetrating Electrodes," *Advanced Functional Materials*, DOI: 10.1002/adfm.201203716, pp. 3185–3193, January 2013.

X. Luo and Y. B. Gianchandani, "A Pulsed High Voltage Generator Utilizing a Monolithic PZT Element and Evaluation of Nonlinear Piezoelectric Behavior in Transient Mode," *(JMEMS) IEEE/ASME Journal of Microelectromechanical Systems*, in press.

A. T. Zimmerman, J. P. Lynch, and F. Ferrese, (2013). "Market-Based Resource Allocation for Distributed Data Processing in Wireless Sensor Networks," *Transactions on Embedded Computing Systems*, ACM, pp. 1–28.

S. Green, R. Kwon, G. Elta, and Y. B. Gianchandani, "In Vivo and In Situ Evaluation of a Wireless Magnetoelastic Sensor Array for Plastic Biliary Stent Monitoring," *Biomedical Microdevices,* pp. 509–517, February 2013.

A. Viswanath, S. R. Green, J. Kosel, and Y. B. Gianchandani, "Metglas-Elgiloy Bi-Layer, Stent Cell Resonators for Wireless Monitoring of Viscosity and Mass Loading," *Journal of Micromechanics and Microengineering*, vol. 23, no. 2, pp. 1–9, February 2013.

J. K. Brown and D. D. Wentzloff, "A GSM-Based Clock-Harvesting Receiver With –87 dBm Sensitivity for Sensor Network Wake-Up," *IEEE Journal of Solid-State Circuits (JSSC)*, vol. 48, no. 3, pp. 661–669, March 2013.

G. Serrano, T. Sukaew, and E. T. Zellers, "Hybrid Preconcentrator/Focuser Module for Determinations of TNT Marker Compounds With a Micro-Scale Gas Chromatograph," *J. Chrom. A*, 1279, pp. 76–85, March 2013.

E. Hendarto and Y. B. Gianchandani, "Size Sorting of Floating Spheres Based on Marangoni Forces in Evaporating Droplets," *Journal of Micromechanics and Microengineering*, in press.

J. Tang, S. Green, and Y. B. Gianchandani, "Miniature Wireless Magnetoelastic Resonant Motor With Frequency Selectable Bi-Directional Rotation," *(JMEMS) IEEE/ASME Journal of Microelectromechanical Systems*, pp. 730–738, June 2013.

V. Thakar, Z. Wu, A. Peczalski, and M. Rais-Zadeh, "Piezoelectrically Transduced Temperature-Compensated Flexural-Mode Silicon Resonators," *IEEE/ASME Journal of Microelectromechanical Systems (JMEMS)*, vol. 22, no. 3, pp. 815–823, June 2013.

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(From January 2013 – July 2013)

R. Dreslinski, D. Fick, B. Giridhar, G. Kim, S. Seo, M. Fojtik, S. Satpathy, Y. Lee, D. Kim, N. Liu, M. Wieckowski, G. Chen, T. Mudge, D. Sylvester, and D. Blaauw, "Centip3De: A 64-Core, 3D Stacked, Near-Threshold System", *IEEE Micro*, vol. 33, no. 2, pp. 8–16, March/April 2013.

M. Fojtik, D. Kim, G. Chen, Y-S. Lin, D. Fick, J. Park, M. Seok, M-T. Chen, Z. Foo, D. Blaauw, and D. Sylvester, "A Millimeter-Scale Energy-Autonomous Sensor System With Stacked Battery and Solar Cells," accepted for publication in *IEEE Journal of Solid-State Circuits*.

V. J. Gokhale, O. A. Shenderova, G. E. McGuire, and M. Rais-Zadeh, "Infrared Absorption Properties of Carbon Nanotube/NanoDiamond Based Thin Film Coatings," *IEEE/ASME Journal of Microelectromechanical Systems (JMEMS)*, accepted, 2013.

Y. Lee, D. Yoon, Y. Kim, D. Blaauw, and D. Sylvester, "Circuit and System Design Guidelines for Ultra-Low Power Sensor Nodes," accepted for publication in *IPSJ Transactions on System LSI Design Methodology (T-SLDM)*, (Invited paper).

K. Scholten, K. Reddy, X. Fan, and E. T. Zellers, "Vapor Discrimination by Dual-Laser Optical Reflectance of a Single Thiolate-Monolayer-Protected Gold Nanoparticle Film", *Anal. Methods*, 5, pp. 4268–4272.

K. Scholten, L. Wright, and E. T. Zellers, "Vapor Discrimination With Single- and Multi-Transducer Arrays of Monolayer-Protected-Nanoparticle Coated Chemiresistors and Resonators," *IEEE Sensors Journal*, 13(6), pp. 2146–2154, 2013.

T. Sukaew and E. T. Zellers, "Evaluating the Dynamic Retention Capacities of Microfabricated Vapor Preconcentrators as a Function of Flow Rate," *Sensors and Actuators B,* 183, pp. 163–171, 2013.

C. Zhuo, D. Blaauw, and D. Sylvester, "A Statistical Framework for Post-Fabrication Oxide Breakdown Reliability Prediction and Management," *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems (TCAD)*, vol. 32, no. 4, pp. 630–643, April 2013. ■

Conference Publications

(From January 2013 – July 2013)

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

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

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

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

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.

M. Sadeghi, R. L. Peterson, and K. Najafi, "High-Speed Electrostatic Micro-Hydraulics for Sensing and Actuation," pp. 1191–1194.

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.

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

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.

F. Wu, L. Tien, F. Chen, D. Kapla, J. Berke, and E. Yoon, "A Multi-Shank Silk-Backed Parylene Neural Probe for Reliable Chronic Recording," pp. 888–891.

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

IEEE Radio Wireless Week, Austin, TX, January 2013

O. U. Khan and D. D. Wentzloff, "1.2 GS/s Hadamard Transform Front-End for Compressive Sensing in 65nm CMOS."

IEEE ISSCC (International Solid-State Circuits Conference), San Francisco, CA, February 2013

S. Bang, A. Wang, B. Giridhar, D. Blaauw, and D. Sylvester, "A Fully Integrated Successive-Approximation Switched-Capacitor DC-DC Converter With 31mV Output Voltage Resolution," pp. 370–371.

J. K. Brown, K.-K. Huang, E. Ansari, R. R. Rogel, Y. Lee, and D. D. Wentzloff, "An Ultra-low-power 9.8GHz Crystal-less UWB Transceiver With Digital Baseband Integrated in 0.18μm BiCMOS," pp. 442–443.

J. Choi, S. Park, J. Cho, and E. Yoon, "A 3.4μW CMOS Image Sensor With Embedded Feature-Extraction Algorithm for Motion-Triggered Object-of-Interest Imaging," Technical Digest, pp. 478–479.

D-W. Jee, D. Sylvester, D. Blaauw, and J-Y. Sim, "A 0.45V, 423nW, 3.2MHz Multiplying DLL With Leakage-Based Oscillator for Ultra-Low Power Sensor Platforms," pp. 188–189.

D. Jeon, Y. Kim, I. Lee, Z. Zhang, D. Blaauw, and D. Sylvester, "A 470mV 2.7mW Feature Extraction Accelerator for Micro Autonomous Vehicle Navigation in 28nm CMOS," pp. 166–167.

G. Kim, M. Barangi, Z. Foo, N. Pinckney, S. Bang, D. Blaauw, and D. Sylvester, "A 467nW CMOS Visual Motion Sensor With Temporal Averaging and Pixel Aggregration," pp. 480–481.

S-J. Kim, I. Kwon, D. Fick, M. Kim, Y-P. Chen, and D. Sylvester, "Razor-Lite: A Side-Channel Error Detection Register for Timing Margin Recovery in 45nm SOI CMOS," pp. 264–265.

S-K. Lee, S-H. Lee, D. Sylvester, D. Blaauw, and J-Y. Sim, "A 95fJ/b Current-Mode Transceiver for 10mm On-Chip Interconnect," pp. 262–263.

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Conference Publications

(From January 2013 – July 2013)

D. Sylvester, "An Energy-Centric Design Approach to Achieve Nanowatt Microsystems," (Invited) Sunday night panelist.

IEEE International Symposium on High Performance Computer Architecture (HPCA-19, Shenzhen, China, February 2013

N. Abeyratne, R. Das, Q. Li, K. Sewell, B. Giridhar, R. Dreslinski, D. Blaauw, and T. Mudge, "Scaling Towards Kilo-Core Processors With Asymmetric High Radix Topologies," pp. 496–507.

Proceedings of ASNE Day 2013, Arlington, VA, February 2013

M. Collette and J. P. Lynch, "Lifecycle Support for Naval Ships Based on Structural Health Monitoring: Data to Decisions Strategies."

Proceedings of SPIE: Smart Structures and Materials, San Diego, CA, March 2013

S. O'Connor, J. P. Lynch, and A. Gilbert, "Implementation of a Compressive Sampling Scheme for Wireless Sensors to Achieve Energy Efficiency in a Structural Health Monitoring System."

C. A. Peckens and J. P. Lynch, "Embedded Linear Classifiers on Wireless Sensor Networks for Damage Detection."

C. A. Peckens and J. P. Lynch, "Cochlea-inspired Sensing Node for Compressive Sensing."

G. van der Linden, A. Emami-Naeini, Y. Zhang, and J. P. Lynch, "Cyber-infrastructure Design and Implementation for Structural Health Monitoring."

IEEE International Symposium on Circuits and Systems, Beijing, China, May 2013

S. Bang, Y. Lee, I. Lee, Y. Kim, D. Blaauw, and D. Sylvester, "Fully Integrated Switched-Capacitor Based PMU With Adaptive Energy Harvesting Technique for Ultra-Low Power Sensing Applications," 2013.

Proceedings of the 9th IEEE International Conference on Distributed Computing in Sensor Systems, Boston, MA, May 2013

C. Lo, M. Liu, J. P. Lynch, and A. C. Gilbert, "Efficient Sensor Fault Detection Using Combinatorial Group Testing."

Proceedings of the 7th National Seismic Conference on Bridges and Highways, Oakland, CA, May 2013

A. A. Mosavi, I. Talebinejad, H. Sedarat, Y. Zhang, P. Hipley, E. Thometz, V. Jacob, and J. P. Lynch, "Using Field Measured Ambient-induced Vibration Responses for Finite Element Model Calibration of the Carquinez Bridge."

10th International Conference on Nanomechanical Sensing, Palo Alto, CA, May 2013

E. T. Zellers, "Analyzing Complex Vapor Mixtures With Micro/Nano-Sensing Systems: Plenty of Challenges Left," Keynote Address, pp. 25–29.

Proceedings of the 13th International Workshop on Computing in Civil Engineering, Los Angeles, CA, June 2013

Y. Zhang, S. O'Connor, J. P. Lynch, G. van der Linden, and A. Prakash, "Cyberinfrastructure Middleware and Analytical Tool Sets for Automated Mining of Massive Structural Health Monitoring Data Sets," (Invited Keynote Presentation).

Transducers, Barcelona, Spain, June 2013

E. E. Aktakka, R. L. Peterson, and K. Najafi, "A 6-DOF Piezoelectric Micro Vibratory Stage Based on Multi-Axis Distributed-Electrode Excitation of PZT/Si Unimorph T-Beams," pp. 1583–1586.

A. Besharatian, K. Kumar, R. L. Peterson, L. P. Bernal, and K. Najafi, "Valve-Only Pumping in Mechanical Gas Micropumps," pp. 2640–2643.

Z. Cao, Y. Yuan, G. He, R. L. Peterson, and K. Najafi, "Fabrication of Multi-Layer Vertically Stacked Fused Silica Microsystems," pp. 810–813.

J. Cho, J.-K. Woo, J. Yan, R. L. Peterson, and K. Najafi, "A High-Q Birdbath Resonator Gyroscope (BRG)," pp. 1847–1850.

W. Collin, G. Serrano, L. K. Wright, H. Chang, N. Nuñovero, and E. T. Zellers, "Fieldable Mems Gas Chromatograph for Rapid Determinations of Explosive Marker Compounds in Complex Mixtures," pp. 2763–2766.

M. De Volder, E. Meshot, S. Tawfick, and A. J. Hart, "Fabrication and Integration of Horizontally Aligned Carbon Nanotube–C60 Films for UV Sensors," pp. 2407–2410.

M. N. Gulari, M. Ghannad-Rezai, and N. Chronis, "A Compact, Optofluidic System for Measuring Red Blood Cell Concentration," pp. 2552–2555.

Y. Qin and Y. Gianchandani, "A Facile, Standardized Fabrication Approach and Scalable Architecture for a Micro Gas Chromatography System With Integrated Pump," pp. 2755–2758.

M. Sadeghi, R. L. Peterson, and K. Najafi, "A 2-D Directional Air Flow Sensor Array Made Using Stereolithography and MEMS Micro-Hydraulic Structures," pp. 722–725.

K. Scholten, K. Reddy, X. Fan, and E.T. Zellers, "Micro-Optofluidic Ring Resonator Structures for Selective Detection of Organic Vapors," pp. 850–853.

B. Shiari and K. Najafi, "Surface Effect Influence on the Quality Factor of Microresonators," pp. 1715–1718.

F. Wu, L. Tien, F. Chen, D. Kaplan, J. Berke, and E. Yoon, "A Multi-Shank Silk-Backed Parylene Neural Probe for Reliable Chronic Recording," pp. 888–891.

Z. Wu, A. Peczalski, V. A. Thakar, and M. Rais-Zadeh, "A Low-Phase-Noise Pierce Oscillator Using a Piezoelectric-on-Silica Micro-Mechanical Resonator," Best Poster Award, pp. 490–493.

S. Y. Yee, R. L. Peterson, L. P. Bernal, and K. Najafi, "High-Speed Air Microjet Arrays Produced Using Acoustic Streaming for Micro Propulsion," pp. 1595–1598.

S. Y. Yee, R. L. Peterson, L. P. Bernal, and K. Najafi, "Highly-Reliable Electrostatic Actuator Using Filleted Electrode Made With Photoresist Solvent Reflow," pp. 1617–1620.

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Conference Publications

(From January 2013 – July 2013)

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J. Cho, J. Choi, S.-J. Kim, J. Shin, S. Park, J. D. K. Kim, and E. Yoon, "A 5.9μm-Pixel 2D/3D Image Sensor With Background Suppression Over 100klx," pp. C6–C7.

I. Lee, S. Bang, D. Yoon, M. Choi, S. Jeong, D. Sylvester, and D. Blaauw, "A Ripple Voltage Sensing MPPT Circuit for Ultra-Low Power Microsystems."

N. Pinckney, M. Fojtik, B. Giridhar, D. Sylvester, and D. Blaauw, "Shortstop: An On-Chip Fast Supply Boosting Technique."

IEEE International Frequency Control Symposium, Prague, Czech Republic, July 2013

V. A. Thakar and M. Rais-Zadeh, "Optimization of Tether Geometry to Achieve Low Anchor Loss in Lamé Mode Resonator." ■

Other Publications

C. Peckens, M. B. Kane, Y. Zhang, and J. P. Lynch, (2013). "Introduction to Wireless Structural Monitoring Systems: Permanent Installation in Infrastructure Systems," in *Sensor Technologies for Civil Infrastructures: Performance Assessment & Health Monitoring* (ed. M. Wang, J. P. Lynch, and H. Sohn), Woodhead Publishing, London, in press.

M. B. Kane, C. Peckens, and J. P. Lynch (2013). "Introduction to Wireless Structural Monitoring Systems: Design and Selection," in *Sensor Technologies for Civil Infrastructures: Performance Assessment & Health Monitoring* (ed. M. Wang, J. P. Lynch, and H. Sohn), Woodhead Publishing, London, in press. ■

Brief Abstracts

V. Gokhale and M. Rais-Zadeh, "Thin Film Infrared Absorbers Using Carbon Nanotube Composites," Poster presented at *Micro and Nano Manufacturing Workshop*, Dearborn, MI, May 2013. ■

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ePack, Inc.
Fleetilla, LLC
InvenSense, Inc.
MESO, Inc.
PicoCal, Inc.
Sandia National Laboratories
Twisthink, Inc.

Strategic Partners

MEMS Industry Group
Roger Grace Associates

Patents Issued

A. M. Sastry and F. Albano, "Deposited Microarchitectured Battery and Manufacturing Method," U.S. Patent No. 8,231,998, issued July 2012.

G. E. Perlin, B. E. Casey, M. N. Gulari, and K. D. Wise, "Compact Multilevel Electrical Integration of Microsystems," U.S. Patent No. 8,255,061, issued August 2012.

A. Johnson and K. Wise, "Electrode Array and Method of Fabrication," U.S. Patent No. 8,283,569, issued October 2012.

S. Chiravuri, A. Evans, Y. B. Gianchandani, and J. M. Park, "Dual Drug Delivery Device," U.S. Patent No. 8,323,246, issued December 2012.

A. M. Sastry, K. A. Cook-Chennault, C. W. Wang, and F. Albano, "Vehicle Hybrid Energy System," U.S. Patent No. 8,381,849, issued February 2013.

J. P. Lynch, K. J. Loh, N. Kotov, "Passive Wireless Readout Mechanisms for Nanocomposite Thin Film Sensors," U.S. Patent No. 8,451,124, issued May 2013.

Y. B. Gianchandani , T. Li, and R. Y. Gianchandani, "In-situ Tissue Analysis Device and Method, " U.S. Patent No. 8,467,867, issued June 2013. ■

Seminar/Webinar Series

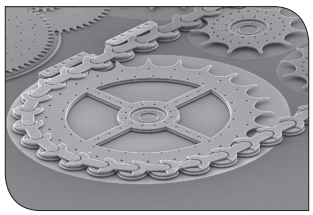
The WIMS^2 Center has restarted its popular series of webinars for the summer and fall. Last fall and winter, we had a series of technology experts present their work and we are excited to continue this popular offering. On **July 31** at **3 pm** in room **1200 EECS, Prof. Sherman Fan** discussed his work in novel micro gas chromatographs. WIMS^2 members are always welcome to attend webinars both in person and online. Typically, webinars are at 3 pm in the afternoon ET and last about an hour. They are either overviews of technology, or descriptions of current research. Technical presentations from an industrial viewpoint are also included. The webinar series will be announced on our website and through Linked_In. WIMS^2 members will also receive an email reminder. As always, WIMS^2 webinars are free to attend or download.

Last fall's webinars had about 1000 virtual and in person attendees and are available for download at http://wims2.org/media/webinars.html. Speakers included Prof. Ken Wise on Implanted Wireless Microsystems, Dr. Mike Daneman from Invensense on the Invensense's MEMS fabrication and packaging technology, Prof. Kazuo Sato from Aichi Institute of Technology on new developments in bulk anisotropic etching of silicon, Prof. Mina Rais-Zadeh on High Frequency Passive MEMS, Prof. Khalil Najafi on Biomimetic Hair Sensors, and Prof. Yuji Suzuki from the University of Tokyo on energy harvesting. ■

Past Seminars

March 28, 2013
Carl Arft, PhD/Seminar
Director, Technology Development
SiTime Corporation, Sunnyvale, CA
"State-of-the-Art Timing References Using MEMS Resonators"

May 21, 2013
Dr. Keith Ortiz/Seminar
Manager, MEMS Technologies Department
Sandia National Laboratories, Albuquerque, NM
"Overview of MEMS and Microsystems at Sandia National Laboratories"



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

Visit our new website at http://wims2.org

WIMS^2 Patents are Now Online

WIMS^2 is very pleased to announce that we have put our library of pending and issued patents on our website. Thanks to the hard work of our webmaster, Jonathan Plummer, our website has undergone a radical transformation over the past several months with lots of new content including project descriptions, upcoming events, seminars, publications, and webinars. We invite you to visit at http://wims2.org. We included the full pdf files of over 50 issued and 15 pending patents from the Center.

Horizons

Microsystems for the Next Generation

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