Winter 2009

WIMS WORLD

Director's Message

A few years ago as I was browsing through a local coin store, I happened across a piece of Continental currency. The bill had seen a lot of history, and I bought it, even though it looked like it had had a hard life. During the past few months, I've thought about that six-dollar bill often, and the saying "Not worth a Continental!" keeps coming to mind. The Second Continental Congress authorized the United Colonies to start printing "Continental Currency" in 1775. They couldn't very well use the British pound, there being a rather high probability that the British wouldn't honor the promissory notes authorized and printed by their rebellious colonies, so they did the next best thing. They used Spanish dollars (pesos) instead, and the "$" sign we use to signify the dollar today is generally thought to have been born as a shorthand "P"-over-"S" standing for "Spanish Peso." For most colonists, taking those bills was an ultimate act of patriotism and faith because although Congress had authorized their printing, no one with any money had authorized Congress. And for a while they looked like a bad bargain. By 1778, Jonathan Carver would write (in *Travels Through America*) that "The Congress paper dollars are now used for papering rooms, lighting pipes, and other conveniences." Fortunately, they were a gamble that paid off. The Revolutionary generation wasn't afraid to bet on the future.

For the 233 years since that bill was printed, we have been blessed by the institutions those founding fathers created. There have been struggles, of course, but the Constitution has served us well, and in times of crisis, leaders have always emerged to make things right again. Lincoln did it during the Civil War, and Roosevelt did it during the Great Depression (although my parents might have disagreed at the time). The past few months have seen continued upheaval in our economy. Like the Spanish Flu of 1918, it may have started in the United States, but has now spread worldwide. But as columnist Thomas Friedman recently noted, "All eyes are on Washington to pull the world out of its economic tailspin. At no time in the past 50 years have we ever felt weaker, and at no time in the last 50 years has the world ever seen us as more important." That seems to make me feel a little better somehow, and yet I have a nagging worry that simply throwing money at the problem may not be the best solution either. But I really hope it works, because our great-grandchildren will still be paying for it. One thing it has done is taught me to think in big numbers. I used to think a million was a lot; now I hear the T-word a lot and a billion doesn't look like much at all. The national debt was about \$2T in 1985, had doubled by 1992, and hit \$6T in 2001. Then it really took off. I don't think anyone is quite sure what it is now, it having fulfilled all the requirements of a moving target. But most of it we owe to ourselves and I guess it's still less than the GNP, so maybe it's not so bad after all. A quote from Shakespeare's *Richard III* comes to mind: "Now is the winter of our discontent made glorious summer by this son of York!" Let's hope the administration's stimulus package indeed gives rise to a glorious summer, this year or next.

The United Colonies, Six DOLLARS. "This Bill entitles the Bearer to receive SIX Spanish milled DOLLARS, or the Value thereof in Gold or Silver, according to a Resolution of CONGRESS, passed at Philadelphia November 29, 1775." Individually numbered and signed.

The real problem, of course, is more the lack of faith that now permeates society rather than the shenanigans of the scoundrels that ran some of our financial institutions. That lack of faith has punished the good companies right along with the bad. We all need to recognize that this financial mess is something we can overcome, just as previous generations overcame their problems. We look back at the "Revolutionary Generation" and at the "Greatest Generation" that endured the Great Depression with respect and gratitude, but fail to recognize that perhaps we ourselves now have the (uncomfortable) opportunity to join them. The things that will get us out of this mess are education, innovation, and creating products people need. This may be the worst of times but it can also be the best of times, if we emerge more focused on the things that really matter. Someone observed recently that this may not be the best time to be transitioning the WIMS ERC to self-sufficiency, but I think it may be a very good time indeed. There is no

(Continued on page 5)

Research Highlights

A Micromachined Quartz and Steel Pressure Sensor Operating Up to 1,000°C and 2,000 Torr

Scott A. Wright and Yogesh B. Gianchandani

High-temperature pressure sensors have uses in numerous industrial sectors including gas turbine engines, coal boilers, internal combustion engines, and oil/gas exploration machinery. These environments require durable sensors, making sensors without moving parts and without intermediate transduction steps advantageous. To meet these challenges, microdischarge-based pressure sensors have been developed. These sensors operate by measuring the change, with pressure, in the spatial current distribution of pulsed DC microdischarges. They are well-suited for high-temperature operation because of the inherently high temperatures of the ions and electrons in the microdischarges, and they are designed to allow for unequal expansion of electrodes and substrate during high-temperature operation. These sensors use three-dimensional arrays of horizontal bulk metal electrodes embedded in quartz substrates (see Figure 1) with electrode diameters of 1–2mm and inter-electrode spacing of 50–100μm. Two cathodes are used, and the current components are denoted as I_1 in the proximal cathode and I_2 in the distal cathode. The sensor output is the differential current, expressed as a fraction of the total peak current, $(I_1–I_2)/(I_1+I_2)$. The sensors operate from 10–2,000 Torr, at temperatures as high as 1,000°C (see Figure 2). The maximum measured sensitivity is 5,420ppm/Torr, while the temperature coefficient of sensitivity is as low as -550ppm/K. These sensors demonstrate sensitivities more than 50x greater than traditional piezoresistive sensors. These high sensitivities, along with wide ranges of temperature operation, increase the number of applications in which microscale sensors can be utilized. ■

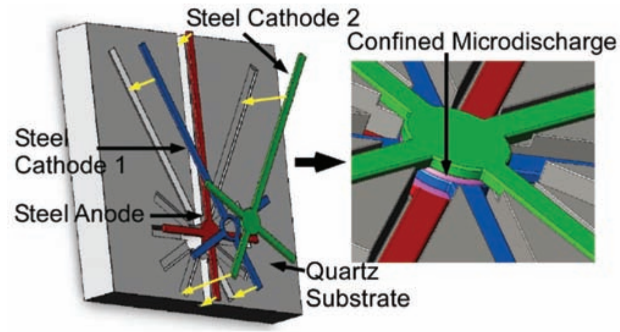


Figure 1 – Sensor schematic.

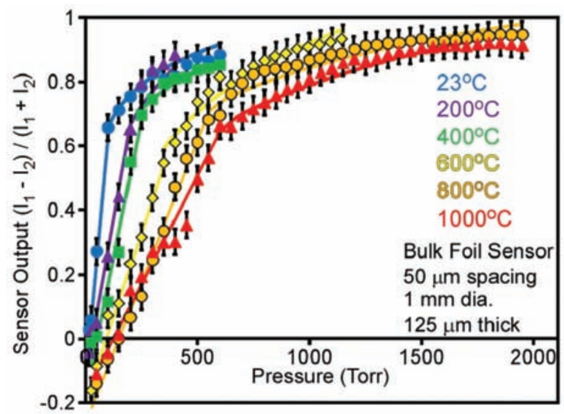


Figure 2 – Change in microdischarge current distribution with pressure (output) in a high-temperature pressure sensor.

A New Process for Implantable Silicon-Glass Microsystems

Razi-ul Haque and Kensall D. Wise

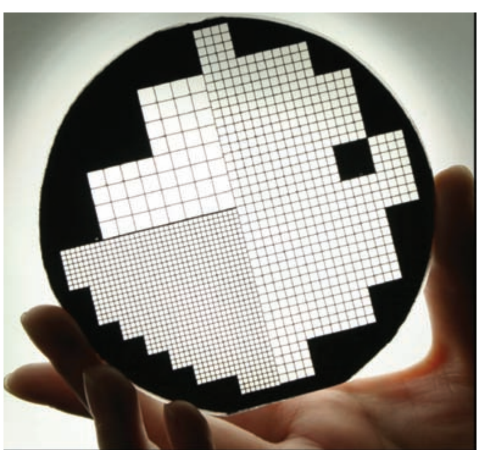


Figure 1 – A 100mm glass-in-silicon wafer with silicon feedthroughs.

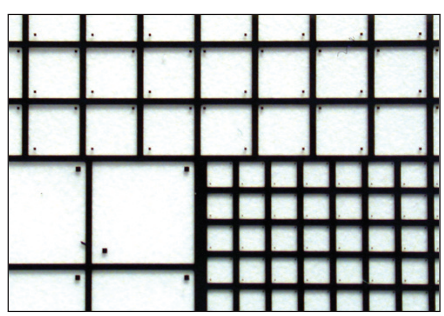


Figure 2 – The smallest die shown in the close-up are 1mm x 1mm in size.

A new process has been developed for fabricating silicon-glass microsystems such as the implantable intraocular pressure sensor now being pursued by the WIMS ERC. The process allows the realization of glass die of arbitrary two-dimensional shape containing silicon (or metal) feedthroughs as small as 20μm in diameter. Shaping glass and producing feedthroughs in it are both long-standing problems in MEMS. This process overcomes them by recessing a silicon wafer to a depth equal to the final glass thickness desired using a deep dry etch. With the silicon recessed, a glass wafer is anodically bonded to it and then heated above its transition temperature. The glass flows into and fills the silicon cavities. After cooling, the wafer is planarized using lapping followed by a chemical-mechanical polish to form a glass-in-silicon wafer (see Figure 1). The wafer can be anodically bonded to a second wafer containing, for example, silicon regions defined by a boron etch-stop. A final anisotropic silicon etch then performs die separation, producing completed devices (see Figure 2). ■

Human Neocortical Electrical Activity Recorded on Non-Penetrating Microwire Arrays: Applicability for Neuroprostheses

Spencer S. Kellis, Paul A. House, Kyle E. Thomson, Richard B. Brown, and Bradley Greger

This study was designed to investigate whether a non-penetrating microwire device can serve as a brain machine interface (BMI) for a motor neural prosthesis. These devices offer higher spatial and temporal resolution than standard electroencephalography or electrocorticography electrode arrays without penetrating the neocortex. A male patient (P1) requiring extraoperative electrocorticographic monitoring for medically refractory epilepsy gave informed consent to be enrolled in an Institutional Review Board approved protocol. Two 16-channel, nonpenetrating microwire arrays with 1mm interelectrode spacing were implanted; one over the upper extremity primary motor cortex and the other more inferiorly along the precentral gyrus. The patient performed repetitive motor tasks involving movement of the hand and arm on the opposite side of (contralateral to) the hemisphere in which the arrays were implanted. Trial-averaged spectrograms were generated during movement in the ipsilateral versus the contralateral directions (see Figure 1), with the percent change between the two (normalized difference of average power in the gamma-band [30–80Hz], -500ms to 0ms) shown in Figure 2. A substantial increase in gamma band power was noted to occur before movement onset in the contralateral direction, with much less gamma band power being seen related to movement in the ipsilateral direction. These results indicate potential for non-penetrating microwire arrays to serve as a non-invasive recording platform for the WIMS Biomedical Testbed with the third-generation WIMS microcontroller and signal processing electronics. ■

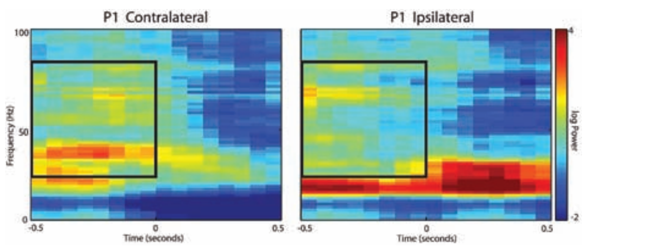


Figure 1 – Spectrograms from two non-penetrating microwire arrays demonstrating increased power in the gamma band during the planning phase for movement in the contralateral (left subgraph) versus the ipsilateral (right subgraph) direction. These spectrograms are aligned at the 0-sec tick to an outward reach movement. The inlaid boxed area represents an outline of the gamma band for the planning stage evaluated in Figure 2.

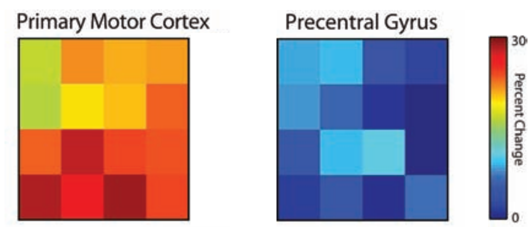
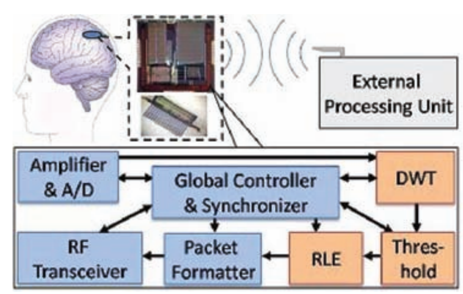


Figure 2 – Comparison of the percent change in average gamma band power during planning for movement in the contralateral direction versus the ipsilateral direction. The left subgraph shows results from the array over the primary motor cortex. The right subgraph shows results from the array located more inferiorly along the precentral gyrus.

A Neural Signal Processor for Wireless Implants

Awais M. Kamboh and Andrew J. Mason

Brain machine interfaces have been recognized as a powerful tool in helping patients with neural disorders. Wireless transmission of potentially hundreds of signals to extracranial processing units must address three major limitations: bandwidth, implant area, and power consumption. For example, without compression, a 32-channel system with a sampling rate of 25KHz per channel and 10-bits of data precision generates data at 8Mbps. Current state-of-the-art wireless transceivers for biomedical applications are not capable of providing the required data bandwidth, necessitating signal compression before transmission. The hardware required for signal compression within the implant must meet three performance standards. First, it must be area efficient, to enable minimally invasive surgical procedures; second, it must be power efficient, to avoid any temperature-induced damage to surrounding tissues. And third, superior energy efficiency is also required, to enable longer periods of operation with little available power.



Block diagram of the neural data compression engine (orange blocks) and its position within an implantable neural recording system.

To address this threefold challenge, we are developing a system that enables very-high-data compression of neural recording while maintaining high signal fidelity. The compression engine employs lossy, as well as lossless, compressions using Discrete Wavelet Transform (DWT), programmable thresholds, and Run Length Encoding (RLE) hardware blocks to pseudo-simultaneously process data from multiple channels (see Figure). Operation of the overall implanted system can be programmed to maximize the tradeoff between application demands and the required spike reconstruction quality. For a prototype 32-channel design, a typical compressor setting results in a data rate of less than 370Kbps, providing a compression of more than 20 times relative to 8Mbps for unprocessed data. The DWT block has been designed, fabricated, and tested to work with excellent match between simulated and experimental results. In 0.5μm CMOS, the DWT block requires only 3.84mm^2 of area to process 32 channels of data at 4 levels of decomposition in real time at a 25KHz sampling frequency per channel, while consuming only 3mW of power. The overall compression engine is designed to fit within 5.75mm^2. The small size and low power consumption of the system makes it highly suitable for implantable high-density microelectrode array devices. ■

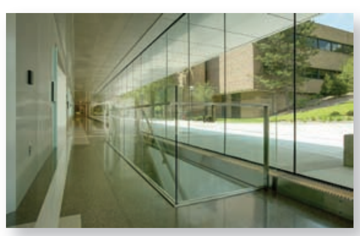
Recent Events

Michigan at ISSCC!

Michigan faculty, students, alumni, and friends relaxed together after a full day at *ISSCC09* in San Francisco, California, this past February. It was a time to relax, renew acquaintances, forge new relationships, and even do a little business. The event was hosted by the following WIMS and EECS faculty: Professors David Blaauw, Michael Flynn, John Hayes, Khalil Najafi, Marios Papaefthymiou, Dennis Sylvester, David Wentzloff, Ken Wise, and Euisik Yoon. ■

Special Feature

Lurie Nanofabrication Facility Wins Special Construction Award



The Lurie Nanofabrication Facility (LNF) was selected as one of the 12 most outstanding construction projects by *CAM Magazine*, the official publication of the Construction Association of Michigan, and will be featured in the Fall 2009 issue. The LNF is a newly expanded, 12,000sf, Class 100/10 cleanroom for MEMS, microsystems, and nanotechnology. The new facility provides expanded silicon processing from 100mm to 150mm wafers, improved cleanroom and safety systems, and upgraded equipment for the fabrication of microsystems, nanotechnology, and organic devices. Twenty new diffusion/oxidation/CVD furnaces have been purchased along with two Applied Materials P5000 cluster tools (for CVD and dry etch), a STS Pegasus DRIE, an AFM, a new parylene reactor, a CNT growth system, wafer bonders, and additional evaporation and sputtering systems. Detailed information concerning LNF equipment is available at **www.lnf.umich.edu**.

Education Highlights

DAPCEP Spring Program Blooms and Grows

The Center has hosted Detroit Area Pre-College Engineering Program (DAPCEP) seventh- and eighth-grade students for five weeks during spring for eight years, under the auspices of the WIMS SuperStar Challenge program. For Spring 2009, the program expanded to middle-school students from Ypsilanti Public Schools (YPS) supporting the U-M College of Engineering's partnership with YPS.

Consistent with the DAPCEP mission and goals (www.dapcep.org), the WIMS SuperStar Challenge program comprises four objectives:

- Provide weekly learning experiences in engineering, with special focus on WIMS technical educational content and applications;
- Improve participants' technical, analytical, and problem-solving skills;
- Present University of Michigan students as successful role models; and
- Provide information on career opportunities in engineering.

Over the long term, the program — along with comparable pre-college programs around the country—is intended to increase the number of well-prepared students who select engineering, science, or math majors in college and aspire to professional careers in those disciplines.

Students in WIMS SuperStar Challenge Program with mentors.

Implemented during five Saturday sessions totaling approximately 20 instructional hours overall, the WIMS SuperStar Challenge program curriculum contains (1) instruction for science, mathematics, and engineering motivated with (2) hands-on experiments that incorporate concepts for construction, system operation, programming, physical science, microfabrication, wireless communication, sensing, actuation, control, and microsystems. The first Saturday is devoted to flexible adaptable construction of electrically powered LEGO™ robots to introduce microsystems,

(Continued on page 7)

Director's Message *(Continued from page 1)*

question that WIMS is going to be key in solving many of the important problems that will confront us in this century. In WIMS, we have the opportunity to lead and should never lose sight of the fact that we can, must, and will do just that. But to do it, we need to approach things differently than in the past. This isn't business as usual. It will take a whole new approach to research, and that's what we are working on. ■

Ken Wise

Director, Engineering Research Center for
Wireless Integrated MicroSystems

Personnel Focus

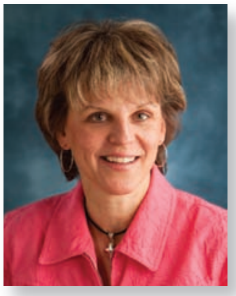
John Hart holds Ph.D. (2006) and S.M. (2002) degrees from the Massachusetts Institute of Technology, and a B.S.E (2000) degree from the University of Michigan, all in Mechanical Engineering. He joined the faculty at the University of Michigan in September 2007. He is currently Assistant Professor of Mechanical Engineering, and he holds a courtesy appointment in the School of Art and Design.

Hart directs the Mechanosynthesis Group (http://www.mechanosynthesis.com), and the group's research currently focuses on synthesis, properties, and applications of nanostructures and nanomaterials. Their work ranges from fundamental studies of synthesis and structure, to development of novel material and device applications, to creation of production techniques that realize these applications at commercial scales. Many of the group's current projects utilize carbon nanotubes (CNTs), which are seamless cylinders of graphitic carbon that have exceptional mechanical stiffness and strength, high electrical and thermal conductivities, and unique chemical and optical functionalities. Hart and his students are working to integrate CNTs as functional elements in many ongoing WIMS projects, for example, for enhanced passive gas preconcentration in the μGC and for reduction of recording impedance on neural probe arrays. Lastly, they are designing next-generation MEMS structures using three-dimensional assemblies of tightly packed CNTs.

John received the 2006 MIT Senturia Prize for best doctoral thesis in micro/nano technology, as well as graduate fellowships from the Fannie and John Hertz Foundation, National Science Foundation, and MIT Martin Foundation. In 2008, John was recognized with a DARPA Young Faculty Award, an R&D100 Award, and the Holcim Next Generation Award for Sustainable Construction. John is also known widely for his nanobliss (http://www.nanobliss.com) gallery of images of small-scale structures; this effort to communicate nanotechnology to broad audiences has been featured in hundreds of magazines, newspapers, and online media outlets worldwide. ■

Awards

Barbara Rice Received 2009 Distinguished Research Administrator Award



Barbara Rice, Research Administrator for SSEL, WIMS, LNF, and NNIN, was the recipient of the University of Michigan's *2009 Distinguished Research Administrator Award*. The award "honors staff members for their exceptional contributions to the University's mission through the demonstration of superlative service to the research community in a manner exemplifying the highest goals of research administration." Barb has certainly done all of that and has made tremendous contributions to the WIMS ERC, the SSEL, LNF, and NNIN over the past several years. The award was presented at a ceremony and reception held on May 7, 2009, in the Vandenberg Room of the Michigan League, where she received heartfelt congratulations from her colleagues for her many years of service. ■

Peggy Henderson Retires

On Friday, April 17, graduate students, staff, and faculty gathered at a retirement party for WIMS Education Coordinator, Peggy Henderson, to give her their well wishes and goodbyes, ending her eight years of service with the WIMS ERC. Building on her background as a K–6 teacher, Peggy played an important role in the ERC's pre-college educational programs and summer-based research experiences for undergraduates (REU) program. She also contributed to many of the Center's publications, including annual reports and *WIMS World*. During her time here, Peggy especially enjoyed working with our graduate students, often commenting about the tremendous talents she saw in them. She and her husband, Ken, moved back to Utah, to be close to family. She set a great example and she will be missed. ■

Peggy Henderson and WIMS graduate students.

Industrial Liaison's Report

Fall Industrial Advisory Board Meeting
October 20–21, 2009

I do not know if the purported curse "May you live in interesting times" has been in force on the global economy, but it has been a most interesting time to be sure. The impact has been felt by all segments of the global economy. The initial reaction has been to curtail expenditures and to weather the storm. This has been especially true in many high-tech companies that have laid off thousands of employees. Recently, *EE Times* reported (March 9, 2009) that 27 high-tech companies have laid off more than 1,000 employees since September 2008. In the midst of this severe downturn is the knowledge that at some point the economy will turn around. The companies that will be able to benefit the most from the upturn will be those that have the foresight to invest now for the future. Most people recognize that one of the keys to turning the economy around is innovation. The ERC is an engine of innovation. It is not only the intellectual property that we have generated but the ERC has also assisted in putting that intellectual property into product. We have done this through our spin-offs and in helping our member companies develop new products using technology developed in the ERC. The availability of the Lurie Nanofabrication Facility (LNF) allows companies to customize the ERC technology for their product. Utilizing the research engineer program benefits available to ERC members makes for a most efficient and cost-effective technology transfer process. The ERC is here to assist our members to position themselves to be at the front of the upturn. As we started with a proverb let us conclude with one: "Vision without action is a daydream. Action without vision is a nightmare." The ERC can help develop a vision (technology, intellectual property) and provide the necessary tools (people, facilities) to implement the vision. I encourage you to bring new challenges to the WIMS ERC so that we can collaborate in bringing new products to the marketplace.

If you, or one of your colleagues, is interested in giving a seminar, please contact me to schedule a date at (734) 615-3096 or giachino@eecs.umich.edu.

As always, please visit the Center when in the Ann Arbor area, so we can share our latest technical developments and have you tour our Lurie Nanofabrication Facility. ■

Joseph M. Giachino
Associate Director, Industry

Presentations and Publications

Conference Presentations/Papers

IEEE International Conference on Micro Electro Mechanical Systems (MEMS), Sorrento, Italy, January 2009

A. T. Evans, S. Chiravuri, and Y. B. Gianchandani, "Transdermal Power Transfer for Implanted Drug Delivery Devices Using a Smart Needle and Refill Port," pp. 252–255

S. R. Green and Y. B. Gianchandani, "A Batch-Patterned Self-Expanding Biliary Stent With Conformal Magnetic PDMS Layer and Topologically Matched Wireless Magnetoelastic Sensor," pp. 212–215

H. Kim and K. Najafi, "An Electrically Driven, Large-Deflection, High-Force, Micro Piston Hydraulic Actuator Array for Large-Scale Microfluidic Systems," pp. 483–486

S. H. Lee, J. Y. Cho, S. W. Lee, M. F. Zaman, F. Ayazi, and K. Najafi, "A Low-Power Oven-Controlled Vacuum Package Technology for High-Performance MEMS," pp. 753–756

G. E. Perlin and K. D. Wise, "Ultra-Compact Integration of Fully Implantable Neural Microsystems," pp. 228–231

S. Wright and Y. B. Gianchandani, "A Micromachined Quartz and Steel Pressure Sensor Operating Up to 1000°C and 2000Torr," pp. 841–844

IEEE International Solid-State Circuits Conference (ISSCC), San Francisco, California, February 2009

Y. S. Lin, D. Sylvester, and D. Blaauw, "A 150pW Program-and-Hold Timer for Ultra-Low-Power Sensor Platforms," pp. 326–328

S. Naraghi, M. Courcy, and M. P. Flynn, "A 9b 14uW 0.06mm^2 PPM ADC in 90nm Digital CMOS," pp. 168–170

D. Sylvester, "Device Sizing for Variability in Energy Constrained Systems," Low Voltage Design Forum

K. D. Wise, "Wireless Implantable Microsystems: Electronic Interfaces to the Nervous System"

BME Seminar, University of Texas, Department of Biomedical Engineering, Austin, Texas, April 2009

Y. B. Gianchandani, "Hybrid Microtechnologies for Medical Instrumentation"

Journal Articles

S. R. Green and Y. B. Gianchandani, "Wireless Magnetoelastic Monitoring of Biliary Stents," *IEEE/ASME J. Microelectromechanical Systems*, vol. 18. no. 1, pp. 64–78, February 2009.

S. A. Wright and Y. B. Gianchandani, "Discharge-Based Pressure Sensors for High Temperature Applications Using Three-Dimensional and Planar Microstructures," *IEEE/ASME J. Microelectromechanical Systems*, in press.

Q. Zhong, W. H. Steinecker, and E. T. Zellers, "Characterization of a High-Performance Portable GC With a Chemiresistor Array Detector," *Analyst*, vol. 134, issue 2, pp. 283–293, February 2009.

Doctoral Dissertations

Tushar Bansal, "Microtechnology for Spatial and Temporal Control of Gene Expression in Developing Embryos and Cells"
University of Michigan, 2009
Advisor: Professors Michel Maharbiz and Euisik Yoon

Scott Green, "Wireless Magnetoelastic Monitoring of Biliary Stents"
University of Michigan, 2009
Postgraduate Position: Postdoctoral Researcher for Professor Gianchandani
Advisor: Professor Yogesh B. Gianchandani

Tao Li, "Ultrasonic Batch Mode Micromachining and Its Application to Piezoelectric Sensors for Fine Needle Aspiration Biopsy"
University of Michigan, 2009
Postgraduate Position: Postdoctoral Researcher for Professor Gianchandani
Advisor: Professor Yogesh B. Gianchandani

Mark Richardson, "High Resolution Lithography-Compatible Micro-Electro-Discharge Machining of Bulk Metal Foils for Micro-Electro-Mechanical Systems"
University of Michigan, 2009
Postgraduate Position: Postdoctoral Research Fellow
Advisor: Professor Yogesh B. Gianchandani

Education Highlights

(Continued from page 5)

wireless communication, sensors, programming, and control algorithms. The second session is devoted to biomedical, microprobe electrode arrays with dual application as sensors for health-care monitoring and as actuators for delivering health-care treatments. The third Saturday is focused on computer concepts, starting with the binary number system and logic, leading to digital functions, electronic gates, and a decoder as a subcomponent of a microprobe array. The fourth Saturday session includes a nanocamp that provides an opportunity for each student to complete a fabrication process, specifically writing a pattern on a wafer, followed by a chemical etch process. The student takes home the patterned wafer as a memento. To complement the fabrication experience, the fourth session entails activities with nano products, magic sand, and memory-shaped alloys. The fifth and final Saturday session is mainly devoted to the Closing Ceremony, including preparation for that event; many parents attend the event, which is another important program accomplishment. Niloufar Ghafouri, graduate student and Chair of the WIMS Student Leader-ship Council Education Committee, was Program Coordinator for Spring 2009.

Although such programs are often classified as Center or university outreach to benefit K–12 students, the WIMS Superstar Challenge program has the additional objective of training our WIMS graduate students, undergraduate students, and post-docs. While serving as role models and mentors to the school-age children, our own students and staff play a crucial part in providing individual attention and transfering the program instructional and experimental technical content to the students. Mentor benefits include experiences in scheduling, planning, management, supervision, and leadership. Other mentors to be recognized are members of the National Society of Black Engineers (NSBE) and the Society of Women Engineers (SWE); each organization generously organizes volunteers to be mentors in the WIMS SuperStar Challenge program, and we appreciate their support and contribution. ■

Seminar Series

***January 21, 2009**
Shahzrad Naraghi
Graduate Student, University of Michigan
"A Pulse-Position Modulation Analog to Digital Converter in 90nm CMOS Technology"

Andrew Gross
Graduate Student, University of Michigan
"A Design and Implementation of a Micro Thermoelectric Cooler"

***April 1, 2009**
John S. Suehle
Leader, CMOS and Novel Devices Group
Semiconductor Electronics Division NIST
"Overview of Metrology Development at NIST for Micro and Nano Technologies"

***April 8, 2009**
Professor Shantanu Chakrabartty
Department of Electrical and Computer Engineering
Michigan State University
"Operating Below the Sub-Microwatt Barrier – Explorations in Analog Computing"

***April 15, 2009**
Professor Sunil Bhave
Assistant Professor
Electrical and Computer Engineering
Cornell University
"Micro (and Nano) Mechanical Signal Processors"

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