Spring 2008

WIMS WORLD

Director's Message

This past spring was marked by a number of important events. One was the semi-annual meeting of our Industrial Advisory Board. For the first time in a spring meeting, we weren't trying to dovetail it into an NSF site visit, and the reduced stress led to better interactions and a more enjoyable experience for us, and I hope for the IAB. Their support for our plans to transform the ERC into an Institute was appreciated, as were their suggestions on how to do it. Then in June, it was time for our biennial sensor meeting at Hilton Head—the *2008 Solid-State Sensors, Actuators, and Microsystems Workshop*. The term "workshop" was coined to underscore the interactive nature of this meeting, but part of me has always wished it had remained a "conference." Somehow, workshops seem less important, and this is one of the most important meetings in the MEMS field.

The Michigan contingent at Hilton Head 2008.

Like its twelve predecessors, this *Hilton Head* was very enjoyable. I couldn't help but think back to my first trip down there to check out the Island as a location for these meetings. It was beastly hot, and I didn't find out until later that it was breaking records. All I knew is that when I went outside, my glasses steamed up and stayed steamed! It was between there and Mackinac Island, but when I found out that there were only two flights a day into Pellston, my enthusiasm for the latter dampened considerably. And when Tom Poteat said he was willing to do local arrangements if the meeting were on Hilton Head, Hilton Head it was, and so it has remained!

Good papers were presented at the meeting this year, but most of all, I enjoyed the opportunity to see old friends. Chip Spangler, a former student, did a great job as General Chair, and Michigan had thirty-three past and present students there, almost ten percent of the meeting. No less than thirteen of them were mine, and with each one, I have special memories. After four or five years of study at my side, they become real colleagues and, usually, lifelong friends.

In the early days of my career, I took satisfaction in doing things that had never been done before—in research results. Finding funding for new projects can be challenging, but finding really good projects is harder still—a bit like finding diamonds on the beach. They need to be things that are well worth doing, things that can be done with the available facilities, and things that can be done in a reasonable amount of time. They should be application driven, but it shouldn't be obvious at the outset how to do them. And it doesn't hurt to have an edge over the competition. It's not very satisfying to come in second.

These days, I find I take more satisfaction in people than in the research results they produce. It's fun to watch as they develop the confidence to try new things, the ability to focus on the relevant issues, and the tenacity to overcome unanticipated obstacles. All those elements are part of successful research. At Michigan, we have always tried to make sure that the processes and structures we develop are well engineered, consistent with moving them at some point to products. In any emerging field, a fine line exists between exploring new frontiers and designing microstructures that, while they might work in prototypes, would be totally impractical in high-volume manufacturing. I guess that's the engineer in me talking, certainly not the scientist. But I find that what is more important to me now are the students themselves. I hope my students find as much enjoyment in their careers as I have in mine. I've gotten to be a teacher, and I've gotten to be an engineer. One is about helping young people learn and the other is about taking science and using it to improve the quality of life. Thinking back, I really have been lucky indeed. ■

Ken D. Wise

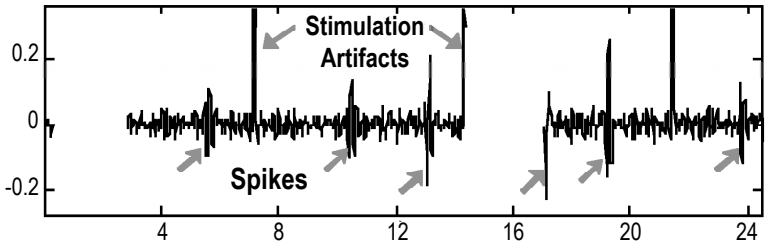
Director, Engineering Research Center for
Wireless Integrated MicroSystems

Research Highlights

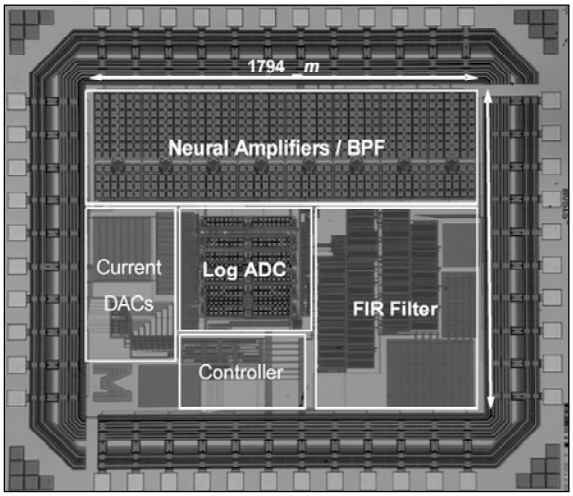
A Multi-Channel Programmable Closed-Loop Deep-Brain Stimulator With Low-Noise Neural Amplifier and Logarithmic ADC

Jongwoo Lee, Hyo-Gyuem Rhew, Daryl R. Kipke, and Michael P. Flynn

Parkinson's disease is a progressive disorder of the central nervous system, affecting more than three million people in the United States. Deep-Brain Stimulation (DBS) is an emerging therapeutic technology for hypokinetic neurological disorders, such as Parkinson's disease. In order to achieve the most effective treatment results, the stimulation parameters should be adjusted based on the individual patient's condition, which can be achieved by a neuro-physiological feedback algorithm.



Recorded neural signal from the cortex of a rat's brain.



Closed-loop DBS die micrograph.

A single-chip, closed-loop DBS device, which senses a tremor in neural activities, has been proposed for the self-configuration of stimulation parameters. Thanks to a novel architecture, the prototype system incorporates more functionality, yet consumes less power and area compared to other systems. Eight front-end, low-noise neural amplifiers are multiplexed to a single high-dynamic-range logarithmic, pipeline ADC. Instead of an analog filter, an on-chip digital filter separates the low-frequency neural field potential signal from the neural spike energy. To alleviate disease symptoms, 64 DAC stimulator channels generate independent, bi-phasic, stimulation current signals. An on-chip controller sets the stimulation pulse amplitude, duration, and repetition rate, spanning the effective range of parameters for clinical usage. Recently, this closed-loop DBS chip was presented at the *2008 Symposium on VLSI Circuits* and reported to *IEEE Spectrum*. ■

The Phoenix Processor: A 30pW Platform for Sensing Applications

Mingoo Seok, Scott Hanson, Yu-Shiang Lin, Zhiyoong Foo, Daeyeon Kim, Yoonmyung Lee, Nurrachman Liu, Dennis M. Sylvester, and David Blaauw

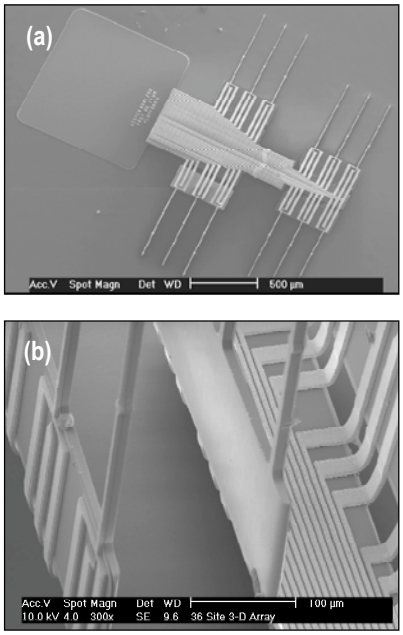
An integrated platform for sensor applications, dubbed the "Phoenix Processor," has been designed in a 0.18μm process with a square area of 915μm, making on-die battery integration feasible. The Phoenix Processor uses a comprehensive sleep strategy with a unique power gating approach, an event-driven CPU with compact ISA, a custom low-leakage memory cell, as well as data memory compression, and adaptive leakage management. The potential applications of the Phoenix Processor include implantable medical systems that require ultra-low power consumption and small-form factors. Prototype chip measurements show that this novel platform consumes 29.6pW in sleep mode, which is the lowest energy consumption ever published in a system of this size, and 2.8pJ/cycle in active mode. It operates at 0.5V. ■

The Phoenix Processor on a penny.

A Folding Assembly Structure for 3-D Neural Implants

Sister Mary Elizabeth Merriam and Kensall D. Wise

Novel structures and associated processes have been devised as alternatives to previous three-dimensional neural implant devices. Whereas previous designs required the time-consuming insertion of individual two-dimensional probes into a mounting platform and interconnect lead bonding, the folding assembly structure (FAST) integrates the individual probes and their corresponding platform directly at the device layout level. This structural development promises decreased lateral platform size and vertical rise, reduced assembly time, and increased yield. Several variations of FAST designs have been fabricated and assembled for proof-of-concept, including the 36-site, 4-probe array shown. The number of electrode sites and shanks, as well as their dimensions, may be varied as the application requires. The leads are routed from the individual electrode sites to the probe back-end and then across the foldable interconnect leads to the platform, eliminating the first stage of interconnect bonds. If an active fabrication process is used, circuitry may be incorporated directly on the probe back-end or on the platform. Similarly, hybrid chips may be incorporated and interconnected using tab or wire bonding or an integrated cable fabricated as part of the platform structure. ■



A 3-D electrode array prototype (a) before and (b) after folding assembly.

Shock Protection and Vibration Analysis for MEMS

Sang Won Yoon, Sangwoo Lee, Noel C. Perkins, and Khalil Najafi

Mechanical vibration and shock have critical impact on the performance and reliability of MEMS. This project aims to analyze vibration and shock effects on MEMS and to develop effective protection methods. The developed technologies should be compatible with conventional microfabrication techniques. First, we conceptualized, fabricated, and characterized two novel shock-protection technologies, termed "nonlinear spring" and "soft coating shock stops". In our tests, these technologies reduced impact force generated between a device mass and its shock stops, as well as limited excessive travel of device mass. Moreover, the technologies were demonstrated to be readily integrated with MEMS devices with minor design/fabrication modifications. Multiple high-g (>2500g) shock tests were conducted using >70 test devices. The test results showed that both novel technologies provide superior device-survival rate (nonlinear spring: 88%, soft coating: 92%) compared to standard hard shock stops (4%). Second, we demonstrated that differentially operating MEMS tuning fork gyroscopes, which are known to be immune to external vibration, can generate unwanted vibration-induced errors in certain situations. We selected two commonly used designs (Type-A and Type-B) and compared their vibration characteristics. Simulations were conducted using MATLAB and SIMULINK, and the results reveal that Type-B (drive mass anchored) is less sensitive to vibrations (>99% reduction) than Type-A (sense mass anchored). ■

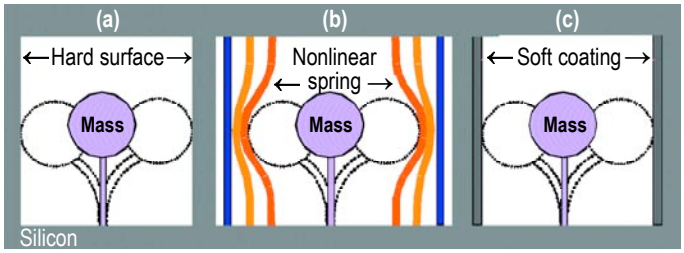


Figure 1 – Conceptual view of novel shock-protection technolo - gies: (a) Conventional hard shock stops, (b) nonlinear spring shock stops, (c) soft coating shock stops.

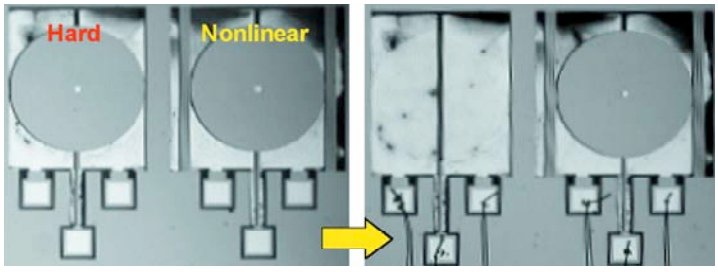


Figure 2 – Shock test results showing that the device having hard stops was damaged but the device having nonlinear spring shock stops survived.

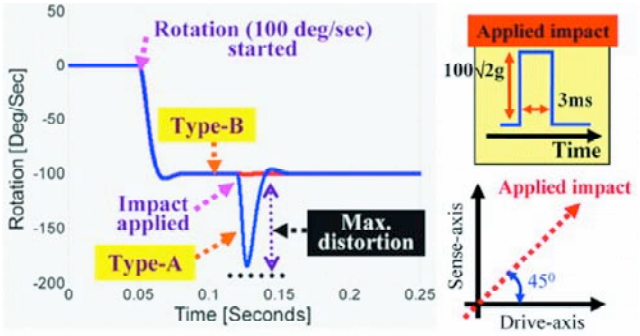


Figure 3 – Outputs of two tuning fork gyroscope designs after experiencing an impact-like vibration.

Education Highlights

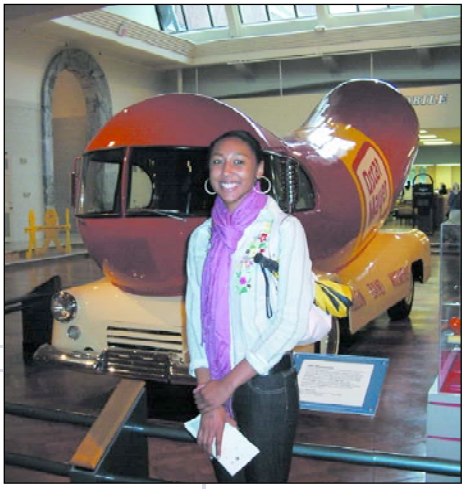
Research Experiences for Undergraduates (REU) and WIMS Undergraduate Research (WUGR) Students Worked Hard to Complete Summer Projects

For the past six summers, the WIMS ERC has invited undergraduate students, both minority and non-minority, to participate in a research opportunity with the Center's outstanding graduate students and renowned faculty.

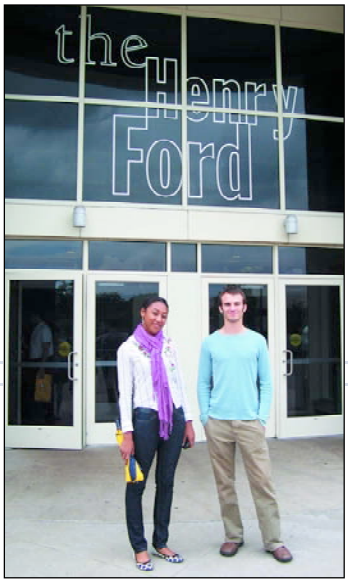
This summer, the Center hosted two Research Experiences for Undergraduates (REU) students: one male from the University of California-Berkeley and one female from Spelman College, an all-women's college in Atlanta, Georgia. Also participating were four University of Michigan male students in the WIMS Undergraduate Research (WUGR) Program. Each student was mentored by an upper-level graduate student who assigned specific research needed to enhance the mentor's work towards his/her Ph.D.

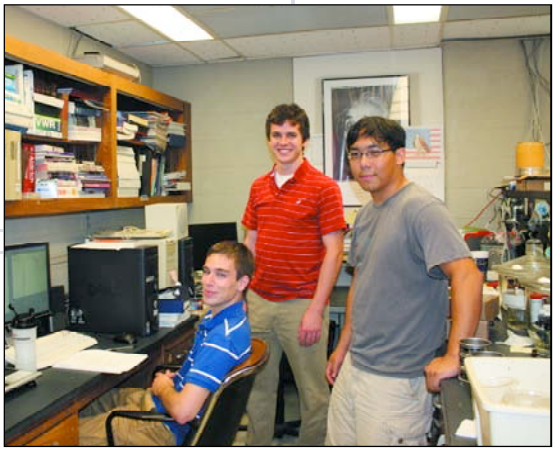
The REU students were provided a salary stipend along with room and board. For eight weeks, they conducted research and attended instructional sessions with the aim of: (1) improving clarity and style of written reports; (2) understanding ethical responsibilities through case study discussions involving possible problems in personal and professional situations; and (3) preparing for graduate school, including career opportunities after graduation, choices of schools, application requirements, and financial aid. The WUGR students were given the option of attending these sessions, but they could opt out because the subjects are already included in the typical U-M curriculum.

Both groups toured the new state-of-the-art Lurie Nanofabrication Facility and saw the future of research capabilities in such a facility. Also, they were invited to the Henry Ford Museum where they witnessed the growth of innovation, technology, and fabrication throughout the past century.



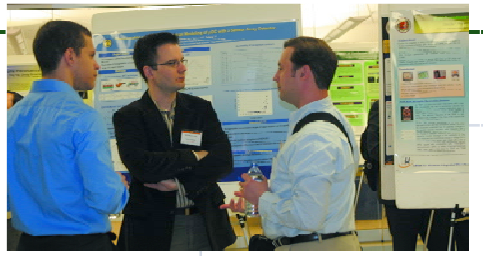
Both groups were required to document their research by writing a project description, a progress report, and a final report. They also prepared and presented a slide presentation at the Closing Symposium. After the symposium, and to celebrate their hard work, they spent some fun time together at a closing activity comprising dinner, putt-putt golf, and ice cream sundaes. The final day was spent packing, saying good-bye to new friends, and returning home. ■





Recent Events

Industrial Advisory Board Meeting



The WIMS ERC hosted its semi-annual IAB Meeting at the Lurie Engineering Center on the University of Michigan's North Campus, May 20–21, 2008. WIMS ERC Deputy Director Khalil Najafi presented ERC goals, research highlights, and framework for expansion as we graduate from the NSF program. The thrust leaders apprised participants of the latest advances in their areas of research. Special presentations included John Janik of Stryker Instruments sharing Stryker's experience in building a partnership with WIMS. John's presentation emphasized that both organizations need to contribute so that each can benefit and prosper from the relationship.

Poster sessions took place in the EECS building's new atrium, and included demonstrations of both the gas chromatography system and the cochlear testbed. Center staff demonstrated the micro gas chromatograph's peak detection using innovative WIMS hardware and software. For the cochlear testbed, researchers demonstrated the reception of data from the WIMS processor to an ASIC chip, which then activated cochlear stimulation sites. IAB members toured the Lurie Nanofabrication Facility (LNF) including the new 37,000-square-foot addition. ■

Center Staff Member Participated in World-Class Sailing Event

Sunday morning, the skipper steering through large quartering seas at high speed. Note the wake behind the boat!

Robert Gordenker, WIMS ERC's Technical Director for the Environmental Monitoring Testbed, is also the owner of a racing sailboat, *Time Machine*, that has been competing in races all over the Great Lakes including one of the premiere events, the BYC Port Huron to Mackinac Race. *Time Machine* competed, for the 10th year, in the 2008 "Mac Race," as it is fondly known, and it was one for the record books.

Time Machine is a J/35 class racing boat, a class nationally recognized for close racing and a class inducted into the Sailing Hall of Fame. *Time Machine* carries a crew of ten, all of them amateurs and all of them friends.

The 2008 Mac Race was very special. *Time Machine* has never been within sight of Mackinac Island on Sunday. This year, they finished before sunset on Sunday. The record fast time resulted from plenty of wind from the southwest that turned towards the northwest as they sailed farther up the lake. *Time Machine* started the race at 1:00 p.m. on Saturday in light-but-building following breeze and completed the last 50 miles on a close-hauled course (sailing as close to an into-wind direction as possible) with 10- to 12-foot waves washing over the decks every few minutes. It was wet and wild!

Time Machine crossed the finish line in 4th place, just 15 seconds behind the 3rd place boat. However, an International Jury awarded the team 11:00 minutes of redress to compensate for time spent rushing to the aid of a fellow competitor during the early morning hours of Sunday. Subsequently, the team was scored in 2nd place, just 2 seconds ahead of the 3rd place boat.

Time Machine was also entered as part of a three-boat team, North Cape Yacht Club, in the Doyle Yacht Club Challenge. The combined scores of the three boats earned a 1st place. Each of the boats and the club were awarded a coveted 1st place flag!

More details… See http://tmsailing.blogspot.com ■

Special Feature

The WIMS ERC Welcomes Professor Euisik Yoon!

Dr. Euisik Yoon recently joined the faculty of the Department of Electrical Engineering and Computer Science at the University of Michigan and the WIMS ERC. He received the B.S. and M.S. degrees in Electrical Engineering from Seoul National University in 1982 and 1984, respectively, and the Ph.D. degree in Electrical Engineering from the University of Michigan in 1990. He then joined National Semiconductor's Fairchild Research Center in Santa Clara, CA, where he explored deep submicron CMOS integration and advanced gate dielectrics. From 1994 to 1996, he was employed at Silicon Graphics, Inc., in Mountain View, CA, working on the design of the MIPS microprocessor R4300i and the RCP 3-D graphic coprocessor. In 1996, he joined the Korea Advanced Institute of Science and Technology (KAIST) in Daejon, Korea, where he directed the National Research Laboratory for 3-D Microstructures. During 2000–2001, he was on sabbatical at Agilent Laboratories in Palo Alto, CA. In 2005, he joined the Department of Electrical and Computer Engineering at the University of Minnesota, where he served as Director of the Nano/MicroSystems Applications Center. His current research interests are in BioMEMS, microfluidic cell assay chips, wireless neural probes, and CMOS image sensors.

Dr. Yoon was the co-recipient of Student Paper Awards at the *1999* and *2000 IEEE International Microwave Symposium* for his work on MEMS inductors and RF MEMS switches. He has served on many technical program committees, including those of the *International Conference on Solid-State Sensors, Actuators, and Microsystems;* the *IEEE International Electron Devices Meeting (IEDM)*; the *IEEE MicroElectroMechanical Systems Conference*; and the *IEEE International Solid-State Circuits Conference*. He was general chair of the *International Symposium on Bio Micro & Nanosystems* in 2005, and is currently serving on the *IEEE IEDM* executive committee. He is the author of over 150 technical papers and is a major addition to U-M's microelectronics/MEMS faculty. He will serve as leader of the Biomedical Sensors and Subsystems Thrust in the WIMS ERC. ■

Industrial Liaison's Report

Industrial Advisory Board Meeting
October 21–22, 2008

Those who attended the May 2008 Industrial Advisory Board meeting had the opportunity to tour our new fabrication facility, the Robert H. Lurie Nanofabrication Facility (LNF). The LNF is a superb facility for work in solid-state electronics and microsystems, and the Center is most fortunate to have such a facility. The real benefit of the facility is that it allows us to train outstanding students to become exceptional engineers. Our primary product continues to be our students. Fortunately, one of the major supporters of science and technology training is the National Science Foundation (NSF). The NSF promotes scientific progress by awarding competitive grants to institutions for research and education. Through centers such as ours, the NSF helps support programs that develop an interest in engineering among K–12 students. These students are the life blood of a sustainable technical resource base for our future. As our members are aware, the NSF is a major resource for training our graduate engineers as well. We could not succeed, however, without the support of our industrial membership. While our members' fees go toward augmenting the monies from the NSF and other government agencies, their support is more valuable than just funds. Our members provide relevant input for our research, they provide internships for our students, and they provide employment for our graduates.

I recently had the opportunity, along with senior graduate student, Rebecca Veeneman, to visit Washington, D.C., to emphasize to Congress the need to continue supporting scientific research and education. As part of the visit, we participated in the 14th Annual Coalition for National Science Funding Exhibition and Reception on Capitol Hill. This event allowed a large number of congressional representatives and staffers to see the impact that NSF funding has had on the country. Earth is truly becoming flat, and if we do not have new people entering the field, we are in danger of flatlining. When you see your elected representatives, remind them to support funding for science education. This funding is essential in keeping your company, region, and country in the global economic race. It will take all of us—the government, industry, and academia—to keep the future bright.

Dr. Kathie L. Olsen, Deputy Director and Chief Operating Officer of the National Science Foundation, talks with Rebecca A. Veeneman, a WIMS ERC graduate student attending the NSF Exhibition.

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

NSF-NNIN Workshop on Nanotechnology as an Enabler for Ocean Observatories, Seattle, WA, April 2008

K. D. Wise, "Integrated Sensors, MEMS, and Microsystems: Revolution in the Gathering of Information"

IEEE International Conference on Technologies for Homeland Security, Boston, MA, May 2008

C. K. Eun and Y. B. Gianchandani, "Exploring RF Transmissions From Discharge-Based Micromachined Radiation Detectors," pp. 18–23

ECE Distinguished Seminar Series (Inaugural Lecture), University of Cincinnati, OH, May 2008

K. D. Wise, "Wireless Integrated MicroSystems: Coming Revolution in the Gathering of Information"

Solid-State Sensor, Actuator and Microsystems Workshop (Hilton Head), Hilton Head Island, SC, June 2008

A. E. Aktakka, H. Kim, and K. Najafi, "Mechanical Energy Scavenging From Flying Insects," pp. 382–383

M. P. Chang and M. M. Maharbiz, "Electrostatically Actuated Reconfigurable Elastomer Microfluidics," pp. 122–125

C. K. Eun and Y. B. Gianchandani, "A Micromachined Wireless Gamma Radiation Detector Using Bulk Metal Conversion Layers," pp. 308–311

S. R. Green and Y. B. Gianchandani, "Wireless Biliary Stent System With Wishbone-Array Resonant Magnetoelastic (WARM) Sensor and Conformal Magnetic Layer," pp. 158–161

H. Sato, C. Berry, and M. M. Maharbiz, "Flight Control of 10 Gram Insects by Implanted Neural Stimulators," pp. 90–91

G. Serrano, S. M. Reidy, K. D. Wise, and E. T. Zellers, "DRIE-Si Gas Chromatography Columns: Efficiency and Thermal Stability of Stationary Phases for Comprehensive Two-Dimensional (GC x GC) Separations," pp. 260–263

K. Takahata and Y. B. Gianchandani, "A Cavity-less Micromachined Capacitive Pressure Sensor for Wireless Operation in Liquid Ambient," pp. 300–303

R. Veeneman and E. T. Zellers, "A Micro-Preconcentrator/Focuser for a Micro Gas Chromatograph: Device and Materials Characterization," pp. 252–255

K. Visvanathan, N. K. Gupta, M. M. Maharbiz, and Y. B. Gianchandani, "Flight Initiation and Directional Control of Beetles by Microthermal Stimulation," pp. 126–129

S. Wright and Y. B. Gianchandani, "Microdischarge-Based Pressure Sensors for Operation at 1000 C," pp. 332–335

AIHce 2008 Conference, Minneapolis, MN, June 2008

S. K. Kim, Q. Zhong, and E. T. Zellers, "Breath Biomarker Determinations With a Novel Portable Gas Chromatograph"

IEEE Symposium on VLSI Circuits, Honolulu, HI, June 2008

M. Seok, S. Hanson, Y. Lin, Z. Foo, D. Kim, Y. Lee, N. Liu, D. Sylvester, and D. Blaauw, "The Phoenix Processor: A 30pW Platform for Sensor Applications"

International Joint IEEE NEWCAS-TAISA Conference, Montreal, Canada, June 2008

D. A. Ortiz and N. G. Santiago, "Impact of Source Code Optimizations on Power Consumption of Embedded Systems," pp. 133–136

Doctoral Dissertations

Chao Yang, "Impedance Extraction Microsystem for Nanostructured Electrochemical Sensor Arrays"
Michigan State University, 2008
Postgraduate Position: Marvell, Santa Clara, CA
Advisor: Professor Andrew J. Mason

Khalil Najafi Named New ECE Chair

Following a national search, the WIMS ERC Deputy Director, Professor Khalil Najafi, was selected by U-M Engineering Dean Dave Munson as the next chair of the Electrical and Computer Engineering (ECE) Division and co-chair of Electrical Engineering and Computer Science (EECS) Department. Professor Najafi is the Schlumberger Professor of Engineering and holds appointments in the EECS and Biomedical Engineering Departments. He received his Ph.D. from the University of Michigan and has served in several administrative roles since then. He served as the Director of the Solid-State Electronics Laboratory (SSEL) from 1998 to 2005, has been serving as the Deputy Director of the WIMS ERC since its launch in 2000, and has served as the Director of NSF National Nanotechnology Infrastructure Network (NNIN) at Michigan since 2004. His research focuses on MEMS sensors and actuators, integrated circuits, biomedical integrated microsystems, packaging, and MEMS fabrication technologies. He has been active in the MEMS/Microsystems community in both conference organizations and has served on the editorial board of many journals. Professor Najafi begins his tenure as chair starting September 2008 for a five-year appointment. The ECE Division and EECS Department have been two of the largest and most active entities in the College of Engineering and combined represent one of the leading programs of its type world-wide. We congratulate Professor Najafi on his appointment and wish him success as he assumes the leadership of ECE and EECS during the next five years. ■

Faculty/Student Awards

Ruba Borno and **Tzeno Galchev**, electrical engineering graduate students, have gained invaluable in-sight into what it takes to commercialize research. Partnering with U-M MBA student Rishiraj Das, they have developed a business plan that they have used to enter and win several competitions. Recent wins include first place in both the Colorado Cleantech Venture Challenge and the Michigan FuturTech Quick Pitch competitions.

Additionally, they were awarded three separate prizes at the Michigan Business Challenge: runner-up to the Pryor-Hale Award for Best Business; the Williamson Award for Outstanding Business and Engineering Team; and the Erb Award for Sustainability. ■

Seminar Series

***April 2, 2008**
Professor Tal Carmon
Department of Electrical Engineering and Computer Science, University of Michigan
"Nonlinear Opto-Mechanics Using Radiation Pressure in Micro-Cavities"

***April 9, 2008**
Professor John A. Hart
Department of Mechanical Engineering, University of Michigan
"Making Massive Crowds of Nanotubes: Growth Mechanisms, Microstructures, and Composite Materials"

***April 16, 2008**
Professor Jingkuang Chen
Department of Electrical and Computer Engineering, University of New Mexico
"A Panoramic Ultrasonic Internal Imager and Related Minimally Invasive CMUT Arrays for Medical Imaging and Treatment"

***May 7, 2008**
Professor Qiao Lin
Department of Mechanical Engineering, Columbia University
"Microelectromechanical Systems for Thermal Characterization and Manipulation of Biomolecules"

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