Fall 2009

WIMS WORLD

Director's Message

In December, I had the opportunity to attend the Annual Meeting in Washington of all the NSF Engineering Research Centers and to give the swan song presentation for our WIMS ERC. In preparing for the talk, I was informed that a "swan song" is "a beautiful legendary song sung only once by a swan in its lifetime, as it is dying." So perhaps this was not quite the proper term for this talk. After ten years of NSF funding, we are changing, not dying, and hopefully it will be a change not unlike what a caterpillar undergoes as it spins itself into a cocoon and then emerges as a beautiful butterfly. In my talk, I reflected on past accomplishments and then looked ahead at the potential for even better things to come. Nearly 150 doctoral students have graduated from our ERC so far, generating over 300 journal articles, 700 conference papers (many of them plenary), and 54 patents. Over 2,700 pre-college students (51% underrepresented minorities and 43% women) have taken our WIMS short courses, with over 60% going on to major in engineering or science in college. Eight start-up companies have spun out of the ERC, creating jobs and taking WIMS technology into products that will change the way people live. I titled the swan song "A Ten-Year Fantastic Voyage," and it certainly has been that so perhaps we haven't done badly, even as a caterpillar.

Looking forward, I outlined our plans for the future and the things that will help us get there. Our goal is to expand work at the system level, demonstrating solutions to important problems in health care, the environment, infrastructure security, and energy systems. To do that we will need to become even more interdisciplinary than in the past, so we recently began a series of "focus-group" meetings with leading faculty in health care and environmental science. They have been uniformly enthusiastic about collaborating. It doesn't hurt either that the University of Michigan recently acquired an entirely new campus (formerly owned by Pfizer) that will be devoted to translational research, especially in health care and the environment. Expanding interdisciplinary collaborations is key to future funding, and supporting the infrastructure needed to realize fully-functional microsystems will require a lot of funding.

In order to deliver working prototypes, we must field breakthrough chips for sensing, actuation, and energy scavenging that are synergistic with continuing progress in micropower circuitry. To help enable this, the University recently created the Robert H. Lurie Nanofabrication Facility (LNF). Using funding derived entirely from alumni gifts, 5,000sf of new cleanroom, over 38,000sf of supporting infrastructure, and a full set of advanced process equipment have been added to our existing facility, including twenty high-temperature, oxidation/diffusion/CVD furnaces; two four-chamber AM P5000 cluster tools; one Hitachi metal etcher and high-resolution imaging SEM; two STS Pegasus deep reactive ion etchers; an STS advanced oxide etcher; one JEOL JBX-6300FX electron-beam lithography system; and EVG 510 and 520IS wafer bonders.

With these expanded collaborations and new facilities, we are well positioned for success but it still won't be easy. The real challenge, of course, is not in *establishing* complex organizations like the LNF or a WIMS Institute but in *running* them. And trying to run them on "soft" money just isn't viable. That's why an endowment is needed to help smooth out the dipsy-doodles in extramural funding. It would also reduce the tremendous stress on our faculty, who are responsible for bringing in a great deal more of the real costs of research than their overseas counterparts. This makes research here less stable, contracts more expensive, and technology transfer less effective. I keep wondering what life would be like if the University had talked the State into matching alumni donations to the LNF. If they had, the resulting endowment would cover most of its operating costs. Sadly that didn't happen. Nothing worth doing is ever easy and I'm confident we will succeed in this new balancing act just as we have in the past, but every so often I feel a bit like Punxsutawney Phil and want to crawl back into my cocoon!

The Robert H. Lurie Nanofabrication Facility at the University of Michigan: A Commitment to Continued Excellence in Microsystems and Nanotechnology.

Ken Wise

Director, Engineering Research Center
for Wireless Integrated MicroSystem

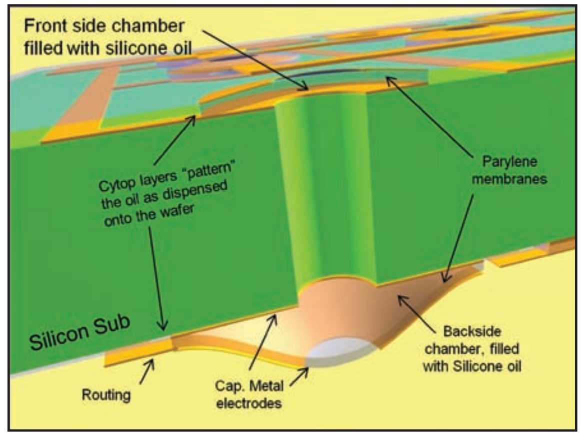
Research Highlights

Electrostatically Driven Micro-Hydraulic Actuator Arrays

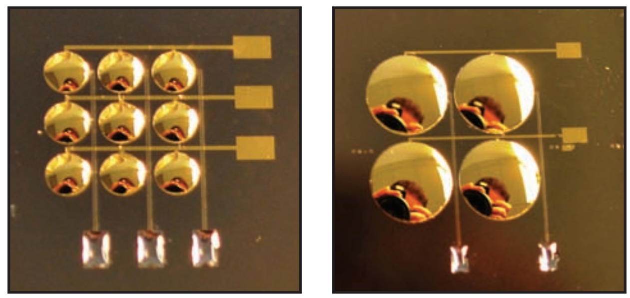
Mahdi Sadeghi, Hanseup S. Kim, and Khalil Najafi

High-force, large-deflection actuators are critical for devices such as valves and pumps used in micro-fluidic systems, for surface bump manipulation in tactile displays, and for micro-airfoil control. However, existing transduction methods such as piezoelectric, electro-magnetic, or electrostatic are limited in their ability to provide such actuation in low-power integrated microsystems.

We have now demonstrated an all-electric individually addressable micro-hydraulic actuator array that meets these goals using hydraulic amplification and electrostatic control. A novel high-yield, wafer-level fabrication technique allows bubble-free encapsulation of a liquid that acts both as an hydraulic fluid and as a capacitor dielectric (top image.) The fabricated microsystem consists of 2 × 2, 3 × 3, and 4 × 4 arrays of actuator cells (bottom image.) A curved electrode capacitive actuator with a diameter of 2.2mm driven at 200V produces 30μm deflection on the front side at 14kPa of pressure, which corresponds to a 11mN force generated by the capacitive actuator on the back side. Actuation occurs from DC to 15Hz. This architecture offers considerable performance advantages over the previously introduced micro-piston hydraulic actuator array, and the liquid-encapsulating fabrication technology is transferrable to other MEMS applications. ■



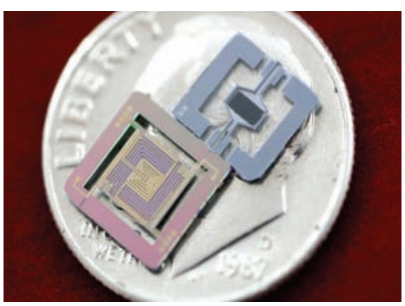
Schematic cross section of the hydraulic actuator.



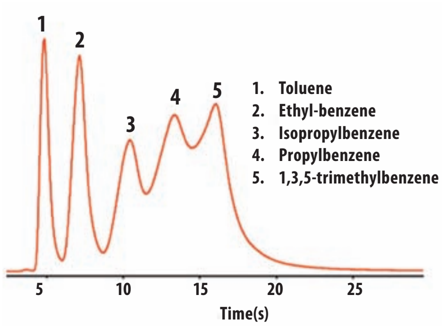
Fabricated arrays of liquid-encapsulated actuators.

First Separations From Released Orion MicroColumns

Shaelah M. Reidy, Katharine Beach, Robert Gordenker, and Kensall D. Wise



A 10cm Orion microcolumn and single-bed CNT-loaded preconcentrator on a U.S. dime.



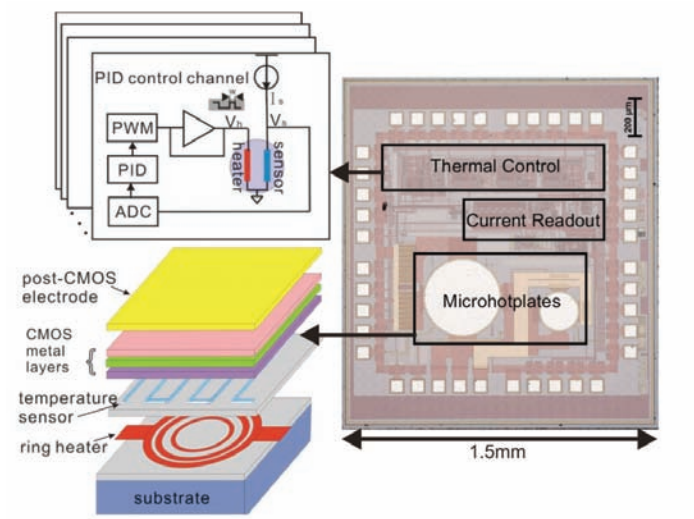
Analyte separations from a 10cm-long Orion column.

The first Orion CVD-sealed and released microcolumns have recently been fabricated, coated, and successfully used to separate gaseous mixtures. The Orion micro gas chromatography system is being developed by the WIMS ERC to explore the scaling limits in such systems. The very low mass of these columns allows high-speed temperature programming and their high thermal isolation substantially reduces their operating power. Suspended from the chip rim by their fluidic connections, the columns are semicircular in cross section with a silicon-and-dielectric upper surface and 12μm-thick, single-crystal, silicon walls. With channels typically 90μm deep and 120μm wide, both 10cm- and 25cm-long columns have been fabricated. The overall chip areas are 50mm^2 and 80mm^2, respectively. A non-polar stationary phase was deposited by initially filling the columns with polydimethylsiloxane dissolved in a 1:1 mixture of petane:dichloromethane and subsequently vacuum drying them in place. The solution concentration determines the stationary phase thickness, which is typically about 0.1μm. A five-compound separation has been achieved in 16 seconds as shown. ■

Electrochemical Microsystem Array for Functional Proteomics

Xiaowen Liu, Lin Li, and Andrew J. Mason

With the completion of the Human Genome Project and the sequencing of several other scientifically important genomes, emphasis has shifted to determining the structure and function of the gene products, i.e., the proteins. The goal of this multidisciplinary project is to develop an integrated microsystem platform that incorporates a protein-based bio-interface array into a continuous-use, cost-effective, electrochemical characterization system suitable for functional proteomics research. To achieve this goal, we have synergistically explored four technical challenges: 1) the development of novel nanostructured bio-interfaces appropriate for integration on the surface of a microelectronics chip; 2) the design of high-performance integrated circuits for multiple electrochemical assays; 3) the design of circuits, structures, and packaging for on-chip thermal control of individual bio-interface sites; and 4) the development of microfabrication techniques enabling a miniaturized, multi-protein, array-on-chip platform that incorporates fluid handling. Electrode arrays on silicon have been fabricated and functionalized with nanostructured enzyme and membrane protein interfaces. A new multi-channel electrochemical impedance spectroscopy circuit, with on-chip AC stimulus generator, has been implemented and provides a resolution of ~100fA and current range up to 100nA. An instrumentation circuit capable of multiple DC electrochemical techniques, including cyclic voltammetry and chronoamperometry, has also been implemented. Microhotplate arrays with thermal control circuitry have been realized in standard CMOS and verified to control the temperature of individual on-chip electrodes within the biological testing range. Several packaging options are now being explored to integrate all the elements of this microsystem platform and permit rapid functional characterization of a wide range of proteins. ■

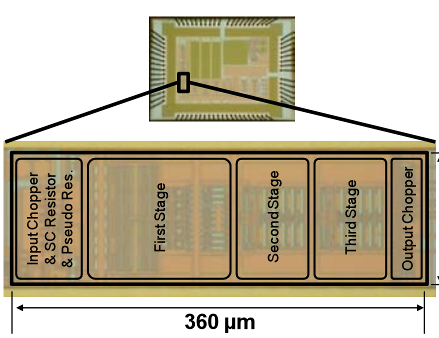


Prototype thermal control microsystem chip with block diagram of the thermoelectric control system and cross section of CMOS microhotplate layers.

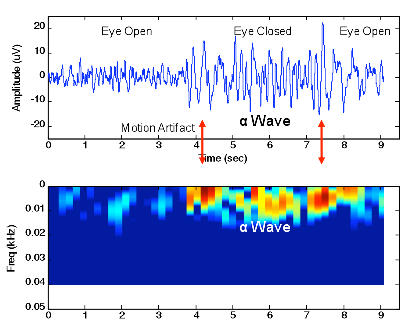
A 1μW 85nV/√Hz Pseudo Open-Loop Preamplifier With Programmable Band-Pass Filter for Neural Interface System

Sun-Il Chang and Euisik Yoon

With advances in CMOS technology, significant progress has been realized in implementing multichannel, implantable neural systems that will potentially enable us to diagnose disease and establish a direct interface between the brain and external electronic devices. However, chronic monitoring of brain activities, such as neural spikes, EEG, ECoG, etc., is still a challenge, especially in wireless ambulatory systems, due to stringent constraints in power, noise, and area. To overcome these obstacles, we have designed an energy-efficient, pseudo open-loop amplifier with embedded programmable band-pass filters for neural interface systems. The implemented amplifier consumes 400nA at 2.5V. The measured thermal noise level is 85nV/√Hz, while the input-referred noise is 1.69μVrms from 0.3Hz to 1kHz. The amplifier has a noise efficiency factor of 2.43, the lowest for all differential topologies reported to date. By programming the switched-capacitor frequency and bias current, we can control the bandwidth of the preamplifier from 138mHz to 2.2kHz to meet various application requirements. The entire preamplifier including band-pass filters has been realized in a small area of 0.043mm^2 using 0.25μm CMOS technology. We have successfully recorded and distinguished waveforms from an EEG electrode monitoring eye activity. ■



Microphotograph of the fabricated preamplifier.



In-vivo EEG measurement: waveform and its spectrogram.

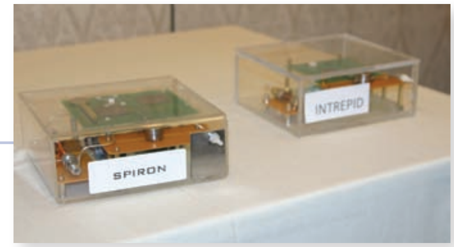
Recent Events

Industrial Advisory Board Meeting

On October 20–21, WIMS hosted its Industrial Advisory Board meeting at the Four Points Sheraton in Ann Arbor. Once again, members of industry had the opportunity to talk with WIMS students about their projects during the poster sessions. In addition to meeting the research faculty and students, the IAB had the opportunity to meet with U-M faculty serving administrative roles. During the Round Table, participants discussed the structure the WIMS ERC will take after graduation from the NSF and how members can engage with the expanded Institute. At the IAB banquet, Khalil Najafi, Electrical and Computer Engineering Division Chair, University of Michigan, discussed the division's future plans. Another highlight of the evening was the presentation of the WIMS Student Leadership Council's (SLC) Outstanding Leadership Award, which was given to Tzeno Galchev, by current SLC President, Angelique Johnson. ■

Robert Gordenker and Gholamhassan R. Lahiji.

Graduate student Heidi Zipperian discussing her poster with her father Dr. Thomas E. Zipperian, IAB member from Sandia National Labs.



Demo showing the SPIRON and INTREPID.

Professor Ken Wise with his team: Sister Mary Elizabeth Merriam, Angelique Johnson, and Razi-ul Haque.

Tzeno Galchev receives SLC Outstanding Leadership Award presented to him by SLC President, Angelique Johnson.

Faculty and Student Awards

Ted Kennedy Family Team Excellence Award

The endowment for the Ted Kennedy Family Faculty Team Excellence Award was established by Ted and Emily Kennedy of Ann Arbor. The award recognizes team collaboration on an extraordinary piece of work. Mr. Kennedy was President of the Engineering Class of 1942, and went on to work as an aeronautical engineer at Pratt & Whitney. After serving in the U.S. Navy during World War II, he and his father founded the Trenton Corporation, which was known for its innovations in anticorrosion materials and processes for gas pipeline and distribution systems. This year's award will be given to WIMS ERC Professors Michael P. Flynn, Yogesh B. Gianchandani, Khalil Najafi, Dennis M. Sylvester, Kensall D. Wise, and Edward T. Zellers, for their collaborative efforts in establishing the University of Michigan as a world-renowned research center in the area of microelectromechancial systems and integrated microsystems. The award recognizes the team's myriad research efforts derived from the ERC's two testbed microsystems: 1) The family of implantable neural prostheses for disorders such as deafness, paralysis, epilepsy, and Parkinson's disease; and 2) the wristwatch-size environmental monitor for pressure, temperature, humidity, radiation-level, and air quality. The award will be presented at the University of Michigan's annual College of Engineering Faculty Honors Dinner Dance on Saturday, March 27, in the Michigan League Ballroom. ■

Michael P. Flynn

Yogesh B. Gianchandani

Khalil Najafi

Dennis M. Sylvester

Kensall D. Wise

Edward T. Zellers

Education Highlights

Tech Day

The new Nanotechnology and Integrated Microsystems Student Association (NIMSA), formally the WIMS ERC student group, took part in the November 14 Tech Day on U-M's North Campus. Tech Day is an annual event organized by engineering students to introduce high school students and their families to the College of Engineering. Ali Besharitian and Jeff Gregory were on hand to answer the attendees' questions, hand out WIMS ERC rebranded chocolate bars, and show off the fun and exciting world of MEMS and wireless sensors. The EECS atrium was packed with roaming groups of students and their families who were especially interested in the work on cochlear implants and environmental monitoring with the micro gas chromatograph. ■

The EECS atrium during a momentary lull in traffic.

Ali discusses the work going on at the ERC while Jeff wades into the stream of people to lure in more attendees with chocolate.

Visitors show strong interest in the many ERC projects.

Ali explains the ERC to interested parents.

Jeff and Ali show off their new t-shirts.

Personnel Focus

Wen Li received her Ph.D. degree (2008) and M.S. degree (2004) in Electrical Engineering from the California Institute of Technology. Before that, she studied at Tsinghua University, Beijing, P. R. China, and earned her M.S. degree in Microelectronics (2003) and B.S. degree in Material Science and Engineering (2001). She joined Michigan State University in 2009, and is currently an Assistant Professor in the Department of Electrical and Computer Engineering. Her research interests lie in MEMS/NEMS technologies and systems, biomimetic devices and systems, microfluidic and lab-on-chip systems, and microsystem integration and packaging technologies. Prior to arriving at MSU, she conducted five years of research at Caltech on intraocular retinal prostheses, during which she took the lead in developing an implantable MEMS coil for wireless power and data transfer as well as a wafer-level integration technique for hybrid system assembly. She also contributed to the development of micro-electrode arrays for high-density neural stimulating and recording.

Dr. Li recently joined the WIMS ERC and is currently working on a collaborative project related to the integration and miniaturization of a prototype micro gas chromatograph system for the Environmental Monitoring Testbed. With support from her students, Dr. Li has committed to designing and fabricating a microfluidic detector cell for a μGC detector that consists of a nanoscale chemiresistor array with on-chip baseline-drift compensation circuitry. In addition, she is supporting the Pre-College Program in the Center by actively involving herself in the Youth Engineering Summer Camps at MSU. In summer 2009, she designed and taught a short bioMEMS-based experimental WIMS course for Teens and Women in Engineering. ■

Presentations and Publications

Conference Presentations/Papers

Center for Neuro-Electronics Research Flanders Kickoff Symposium, Leuven, Belgium, October 2009
K. D. Wise, "Neural Interfaces: Current Capabilities and Continuing Challenges," (Invited)

Annual Society of Neuroscience Meeting, Chicago, IL, October 2009
J. L. Skousen, B. D. Winslow, Sr. M. E. Merriam, O. Srivannavit, G. E. Perlin, K. D. Wise, and P. A. Tresco, "Microelectrodes With Reduced Surface Area Show Reduced Glial Encapsulation and Neuronal Loss"

B. D. Winslow, Sr. M. E. Merriam, G. E. Perlin, O. Srivannavit, K. D. Wise, and P. A. Tresco, "Chronic Microelectrode Implantation is Accompanied by Decreased Neurogenesis in the Dentate Gyrus"

S. S. Kellis, P. A. House, K. E. Thomson, R. B. Brown, and B. E. Greger, "Neuroprosthetic Application of Human Neocortical Electrical Activity Recorded on Nonpenetrating Microwire Arrays"

The 8th IEEE Conference on Sensors, Christchurch, New Zealand, October 2009
R. K. Franklin, S. Joo, S. Negi, F. Solzbacher, and R. B. Brown, "A Comparison of Fabrication Methods for Iridium Oxide Reference Electrodes"

IEEE International Conference on Computer Design, Lake Tahoe, CA, October 2009
R. Gandikota, D. Blaauw, and D. M. Sylvester, "Interconnect Performance Corners Considering Crosstalk Noise," pp. 231–237.

17th IFIP International Conference on Very Large Scale Integration, Florianopolis, Brazil, October 2009
A. Ghosh and R. B. Brown, "Low-Power Operation of Integrated Circuits in the Presence of Process Variation"

S. S. Kellis and R. B. Brown, "Embedded System to Perform Motor Decode in a Neural Prosthetic Application"

Proc. 5th Conference of NanoUtah, Salt Lake City, UT, October 2009
H. Kim, K. Najafi, and J. W. Park, "Micro Hydraulic Piston Arrays for Hydraulic Actuator Array for Pneumatic-Less Portable Large-Scale Microfluidic Systems"

IEEE/SEM Nano-Conference, Eaglecrest Resort, Ypsilanti, MI, November 2009
K. D. Wise, "Wireless Integrated Microsystems Based on Nanotechnology," (Invited)

Mini Symposium, The Society for Neuroscience, Chicago, IL, November 2009
S. E. Shore, Invited Discussant in "Ringing Ears: The Neuroscience of Tinnitus"

IEEE BioCAS Conference, Beijing, China, November 2009
Y. Huang and A. J. Mason, "A Redox-Enzyme-Based Electrochemical Biosensor With a CMOS Integrated Bipotentiostat"

Industrial Liaison's Report

WIMS ERC 10-Year Celebration
May 18–19, 2010

Our Industrial Advisory Board meeting was held in October, and we attended the NSF Engineering Research Center annual meeting in December. As this was our tenth year as an NSF ERC we had the opportunity to present to the meeting attendees an overview of our accomplishments and a peek into our future plans. The ERC has made tremendous strides in developing microsystems, including environmental monitoring systems (micropower radios, antennas, gas chromatography, Narda nodes, micropower controllers) and biomedical systems (cardiovascular stents, cochlear prosthesis, cortical microsystems). However, I believe that the biggest long-term impact to industry is the nearly 150 doctoral students we have graduated. Many graduates are already in industry applying the skills they acquired in the ERC to solving their company's challenges and producing new product. The ERC, as it evolves into an Institute, will continue to train students to be able to meet the changing needs of industry. This includes the technical knowledge and the skills to lead a team to meet the product goals required by the market place. Included in the technical skills is the realization that the "more than Moore" era requires a systems outlook and interdisciplinary teamwork on engineered systems to achieve success.

Today, the ERC has the technical staff, the facilities, and the administrative staff to efficiently and effectively address the needs of our academic researchers and industrial collaborators. Tomorrow, the Institute will continue to emphasize collaboration with our industrial partners to focus on the systems outlook and interdisciplinary teamwork to have engineered systems in the market. Importantly, the WIMS Institute will continue to drive core research and the development and application of microsystems to address both the short-term needs of our partners and the critical long-term priorities of our nation. It is through collaboration that we will be able to succeed in meeting the separate goals of both industry and academia, as well as the mutual goal of training new students.

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

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. ■

Joseph M. Giachino
Associate Director, Industry

X. Liu, L. Li, and A. J. Mason, "Thermal Control Microsystem for Protein Characterization and Sensing"

International Conference on Miniaturized Systems for Chemistry and Life Sciences (MicroTAS'09), Jeju, Korea, November 2009
J. Chung, T. Bersano-Begey, K. Pienta, and E. Yoon, "Clonal Culture and Chemodrug Assay of Heterogeneous Cells (PC3 Prostate Carcinoma Cells) Using Microfluidic Single Cell Array Chips," pp. 21–23.

Y.-J. Kim, T. Bersano-Begey, X. Lou, J. Chung, and E. Yoon, "Microfluidic Array Chip for Analysis of Pairwise Cell Interaction by Temporal Stimulation of Secreted Factors Using Chamber Isolation," pp. 1772–1774.

IEEE International Conference on Computer-Aided Design, San Jose, CA, November 2009
C. Zhuo, D. Blaauw, and D. M. Sylvester, "Post-Fabrication Measurement-Driven Oxide Breakdown Reliability Prediction and Management"

SERDP-ESTCP Partners in Environmental Technology Technical Symposium and Workshop, Washington, DC, December 2009
H. Chang, S. K. Kim, T. Sukaew, E. T. Zellers, D. R. Burris, and H. J. Reisinger, "A Microfabricated Gas Chromatograph for Sub-ppb Determinations of TCE in Vapor Intrusion Applications"

NSF ERC Annual Meeting, Washington, DC, December 2009
K. D. Wise, "The WIMS ERC: A Ten-Year Fantastic Voyage"

IEEE Circuits and Systems for Medical and Environmental Applications Workshop, Merida, Mexico, December 2009
E. Yoon and S. I. Chang, "Low-Power Area-Efficient Analog Front-End for Neural Interfaces"

PowerMEMS, Washington, DC, December 2009
E. Romero, M. R. Neuman, and R. O. Warrington, "Kinetic Energy Harvester for Body Motion"

Journal Articles

A. Basu and Y. B. Gianchandani, "Scanning Probe Thermochemical Patterning in the Context of Nano Scale Lithography," *Nature Nanotechnology, News and Views* (Invited Article), vol. 4, pp. 622–623, DOI:10.1038/nnano.2009.287, October 2009.

J. Lee, J. Kang, S. Park, J. Seo, J. Anders, J. Guilhereme, and M. P. Flynn, "A 2.5 mW 80dB DR 36 dB SNDR 22 MS/s Logarithmic Pipeline ADC," *IEEE Journal of Solid State Circuits*, vol. 44 (10), pp. 2755–2765, October 2009.

C. Yang, S. R. Jadhav, R. M. Worden, and A. J. Mason, "Compact Low-Power Impedance-to-Digital Converter for Sensor Array Microsystems," *IEEE Journal of Solid State Circuits*, vol. 44 (10), pp. 2844–2855, October 2009.

T. Li, A. Barnett, K. L. Rogers, and Y. B. Gianchandani, "A Blood Sampling Microsystem for Pharmacokinetic Applications: Design, Fabrication, and Initial Results," *Lab-on-a-Chip*, DOI: 10.1039/b910508e, October 2009.

D. Rairigh, G. Warnell, C. Xu, E. T. Zellers, and A. J. Mason, "CMOS Baseline Tracking and Cancellation Instrumentation for Nanoparticle-Coated Chemiresistors," *IEEE Transactions on Biomedical Circuits and Systems*, vol. 3 (5), pp. 267–276, October 2009.

M. T. Richardson and Y. B. Gianchandani, "Wireless Monitoring of Workpiece Material Transitions and Debris Accumulation in Micro-Electro-Discharge Machining," *IEEE/ASME Journal of Microelectromechanical Systems*, accepted for future publication, October 2009.

A. M. Sodagar, K. D. Wise, and K. Najafi, "A Wireless Implantable Microsystem for Multi-Channel Neural Recording," *IEEE Journal of Microwave Theory and Techniques*, vol. 57, pp. 2565–2773, October 2009.

C. Yang and A. Mason, "Fully Integrated 7-Order Frequency Range Quadrature Sinusoid Signal Generator," *IEEE Trans. Instrumentation Measurement*, vol. 58 (10), pp. 3481–3489, October 2009.

S. Tawfick, K. P. O'Brien, and A. J. Hart, "Flexible High Conductivity Carbon Nanotube Interconnects Made by Rolling and Printing," *Small,* vol. 5 (21), pp. 2467–2473, November 2009.

A. Basu and Y. B. Gianchandani, "A Programmable Array for Contact-Free Manipulation of Floating Droplets on Featureless Substrates by the Modulation of Surface Tension," *Journal of Microelectromechanical Systems,* vol. 18 (6), pp. 1163–1172, December 2009.

H. L. Lee, S. I. Chang, and E. Yoon, "Dual-Mode Capacitive Proximity Sensor for Robot Application: Implementation of Tactile and Proximity Sensing Capability on a Single Polymer Platform Using Shared Electrodes," *IEEE Sensors Journal*, vol. 9, pp. 1748–1755, December 2009.

E. Romero, R. O. Warrington, and M. R. Neuman, "Energy Scavenging Sources for Biomedical Sensors," *Physiological Measurement*, vol. 30, pp. R35–R62, December 2009.

K.-S. Yun, D. Lee, H.-S. Kim, and E. Yoon, "Multifunctional Microwell Plate for On-Chip Cell and Microbead-Based Bioassays," *Sensors and Actuators B: Chemical*, vol. 143 (1), pp. 387–394, December 2009.

Doctoral Dissertations

Allan T. Evans, "Valve-Regulated Implantable Intrathecal Drug Delivery for Chronic Pain Management"
University of Michigan, 2009
Postgraduate Position: Founder/Director, Globe Shares, Brighton, MI
Advisor: Professor Yogesh B. Gianchandani

Naveen K. Gupta, "A Motionless Gas Micropump Using Thermal Transpiration in Bulk Nanoporous Materials"
University of Michigan, 2009
Postgraduate Position: Research Fellow, University of Michigan
Advisor: Professor Yogesh B. Gianchandani

(Continued on page 8)

Doctoral Dissertations

(Continued from page 7)

Chun C. Lee, "Improving Accuracy and Energy Efficiency of Pipeline Analog-to-Digital Converters"
University of Michigan, 2009
Postgraduate Position: Analog Design Engineer, Intel Corporation, Hillsboro, OR
Advisor: Professor Michael P. Flynn

Mikhail Pinelis, "A High-Throughput Method for *In Vitro* Generation and Studies of Oxygen Microgradients"
University of Michigan, 2009
Postgraduate Position: President and CEO, MEMS Invester Journal, Inc., Oak Park, MI
Advisor: Professors Michel M. Marharbiz and Kensall D. Wise

R. Andrew Swartz, "Collocation of Sensing, Computing, and Actuation in Low-Power Wireless Nodes for Smart Structure Applications in Civil and Mechanical Systems"
University of Michigan, 2009
Postgraduate Position: Assistant Professor, MTU
Advisor: Professor Jerome P. Lynch

Seminar Series

*** October 6, 2009**
Dennis Desheng Meng
Assistant Professor
Michigan Technological University
"Micro Fuel Cell: The Challenges and Opportunities of a Platform For and Beyond PowerMEMS"

*** October 27, 2009**
Arno Aarts
Micro System Integration - IMEC and University of Leuven, Belgium
"Out-of-Plane Integration Technique for Biomedical Microprobe Arrays"

***December 3, 2009**
Yongmin Kim
Professor of Bioengineering and Electrical Engineering
University of Washington
"Engineering the 21st Century Healthcare"

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