



WIMS WORLD

University of Michigan • Michigan State University • Michigan Technological University

DIRECTOR'S MESSAGE

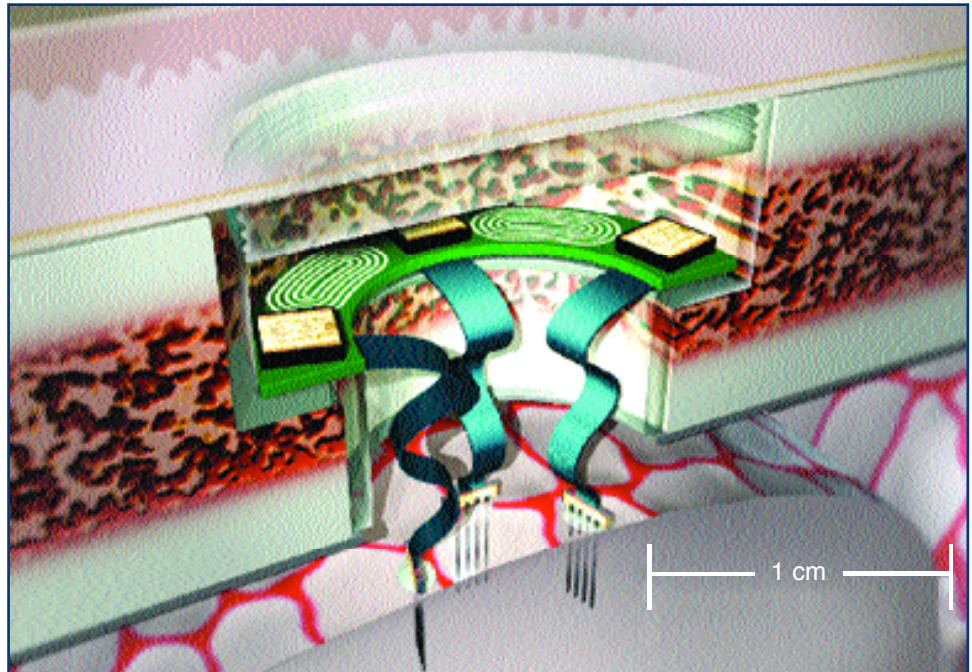


As I write this, the fourth year of our WIMS ERC has just begun. When we started, the Center's ten-year expected life looked endless; now it looks all too finite. But I believe we are making a substantial impact. When we started, we selected two testbeds to guide our system-integration activities, representing the spectrum of needs that characterize microsystems.

The first testbed is a family of neural prostheses, targeted at some of man's most debilitating disorders. We started with a cochlear implant for the profoundly deaf before moving to central nervous system (CNS) implants. CNS implants have developed even faster than we hoped, partly due to the Center's results. Prototypes can now be built that will allow us—for the first time—to see if properly-engineered microsystems can be useful in treating these disorders. The first human implants now appear much closer at hand (see illustration). An invited paper addressing this topic, will be in the January issue of the *Proceedings of the IEEE*, a special issue on BioMEMS.

The second testbed is our environmental monitor, a wristwatch-size microsystem aimed at precise measurement of pressure, temperature, humidity, gas composition, and other variables. This testbed is an extension of some unfinished business. When I left Stanford in 1972, I most regretted leaving the project that was developing a single-wafer gas chromatograph. Ever since, I have considered it a great approach to gas sensing, albeit one requiring the integration of a full

microsystem. Since beginning work on the environmental monitor three years ago, we have shown that my enthusiasm was not misplaced. When we started, Sandia was the only major player in this area with a dictionary-size system undergoing application trials. But today, propelled by needs made obvious by 9/11, this area is becoming hotly competitive. It is the focus of a new Defense Advance Research Projects Agency (DARPA) program, spurred by the ERC's activities and closely mirroring our specifications.



In an NIH-funded collaborative project with Professor Andrew Schwartz at the University of Pittsburgh, this electronic interface to the nervous system was implanted in the motor cortex of a monkey. The 96-channel sensing system has enabled the animal to feed itself using signals recorded from the cortex to drive a robotic arm. The work has tremendous implications for restoring function to quadriplegics and was recently reported at the Annual Conference for the Society for Neuroscience.

As with the neural prostheses, delivery time lines are accelerating, creating increasingly difficult challenges in research and in balancing educational needs against those demanded by critical societal issues. An invited paper on our recent microsystem work, with the environmental monitor as an example, will be presented at the *IEEE International Solid-State Circuits Conference* in February.

One of the highlights this summer was a retreat held at the Shanty Creek Resort near Traverse City. ERC faculty,

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MichiganEngineering

SUMMER 2003 1

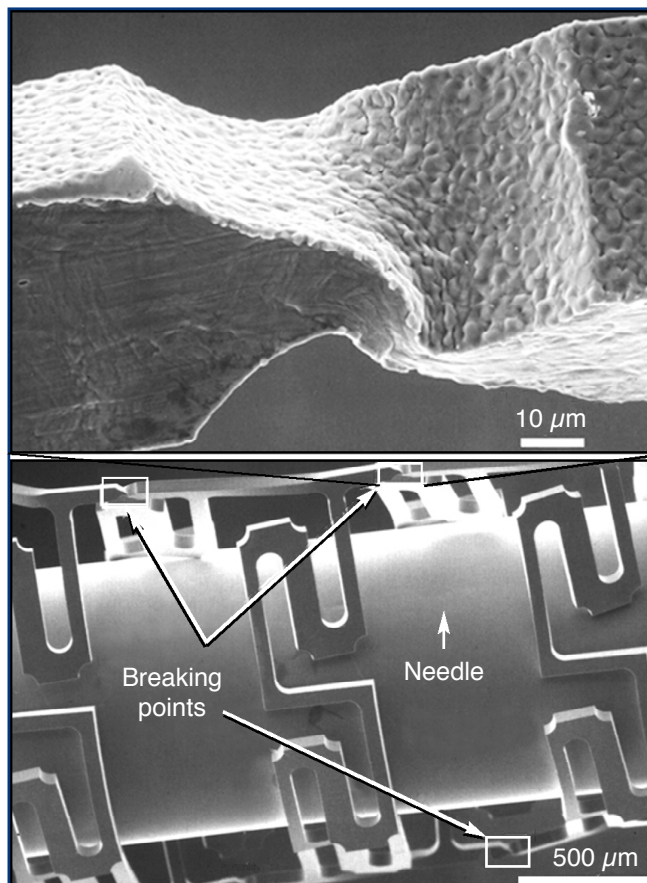
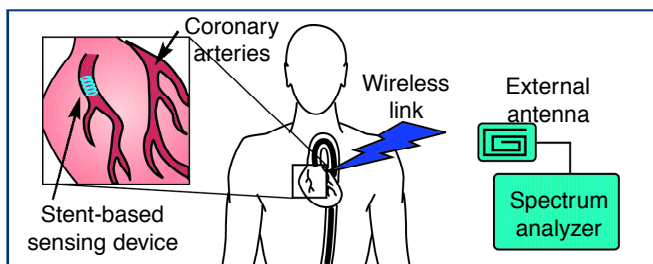
RESEARCH HIGHLIGHTS

UNIVERSITY OF MICHIGAN'S STENTENNA WIRELESSLY MONITORS ARTERIAL BLOOD FLOW

A commercial stent is a stainless steel mechanical device used to enlarge coronary blood vessels that have been reduced by plaque accumulating along the vessel wall. Once inside the vessel, the stent's mesh walls are expanded by an internal balloon allowing blood to flow freely.

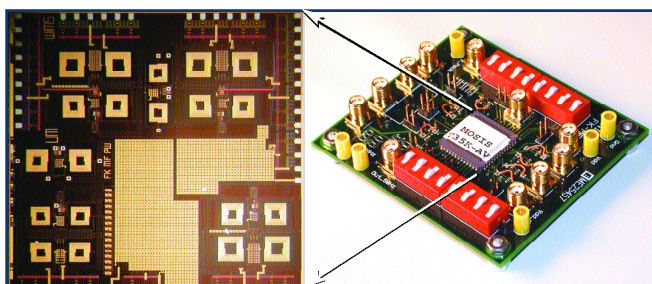
The University of Michigan (UM) has expanded this technology to produce a stent that also works as an antenna: a stentenna. Lighter, more cost effective, and more precise than commercial stents, UM's stentenna works as an electrical inductor, in addition to its regular mechanical tasks. This stentenna, coupled with two pressure sensors, has become a fully-implantable integrated system that wirelessly monitors arterial blood flow (see illustration).

In order to function as an antenna, the stentenna must form a helical coil when it expands. However, the helical coil is not robust enough for deployment. To counter this, researchers created breakable links in the design. When the stent is contracted, the links provide the needed mechanical strength; during expansion, stress concentrations fracture the links allowing the helical coil to form.



In order for a stentenna (bottom) to function as an antenna, stress concentrations fracture during expansion. These fractures are breakable links (top)

INTEGRATED CIRCUIT IMPROVES PERFORMANCE BY GAINING POWER IN STANDBY MODE



Tested in the printed circuit board (right), Fatih Kocer's new integrated circuit (left) proved fully functional with a low-power 900MHz transceiver and a 2.3GHz wireless temperature sensor.

Unlike conventional radio-frequency (RF) systems, this integrated circuit accumulates energy while in standby mode, which increases the transmission range and reduces the transmit power of the chip. This module also stores more energy for a given capacitor size and has a simpler telemetry circuit because the voltage stored on the capacitor is much larger than the received voltage amplitude, due to voltage multiplication.

In the past, Schmitt triggers have been used to extract reference clocks for modules, but they are usually very power hungry at high frequencies and are generally prone to jitter. However, this module extracts the clock from the

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WIMS ERC EXHIBITORS PRESENT RESEARCH AT TRANSDUCERS 2003 CONFERENCE

The 13th International Conference on Solid-State Sensors, Actuators, and Microsystems (Transducers '03) was held in Boston, Mass. on June 8–12, 2003. This premier conference is the largest in the field of MEMS/microsystems, and was attended by 1,100 researchers from around the world. Highly successful, it highlighted research in several areas, most significantly in chemical and biomedical microsystems and in micro-fabrication technologies. University of Michigan researchers presented 23 out of the 464 papers presented from 25 different countries. Papers from Michigan covered several areas, including solid-state sensors and actuators and biomedical microsystems.

The WIMS ERC was part of a large group of exhibitors who set up booths showing their technologies, books, and other related material to attendees. The WIMS booth provided information on our educational, industrial, and research programs.



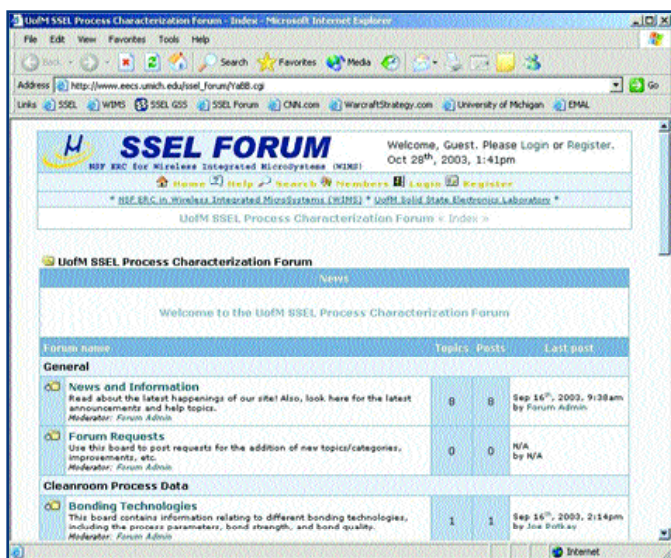
WIMS graduate students, Brian Stark (left) and Gary O'Brien (middle), explaining WIMS exhibit to conference attendee.



Some of the WIMS researchers and Michigan alumni that attended the Transducers 2003 Conference.

RECENT EVENTS

NEW STUDENT WEB SITE SHARING SSEL PROCESSES AND CHARACTERIZATION DATA



The new SSEL processes forum facilitating data sharing, www.eecs.umich.edu/ssel_forum/YaBB.cgi.

A new Web site intended to facilitate sharing of clean-room related processes and information was designed by the WIMS Student Leadership Council. The SSEL Forum allows information sharing among students and research groups. Also, the amount of information lost when a student graduates will be decreased because information can be stored on the Web. The forum can be found at www.eecs.umich.edu/ssel_forum/YaBB.cgi.

The site—created at the request of WIMS students and staff—is geared for University of Michigan, Michigan State University, and Michigan Technological University students, and for industrial members of the WIMS ERC, but may be used by anyone. It contains a list of initial categories related to different processes in the cleanroom and useful information on bonder characterization data, a 50 μ m thick PR9260 process, glass etching processes and more. Please visit the site and send feedback to forumAdmin@wimserc.org.

~Joseph A. Potkay



STUDENT LEADERSHIP

STUDENT LEADERSHIP COUNCIL CONTINUES TO STRENGTHEN PROGRAMS

Working hard, the Student Leadership Committee (SLC) has continued to improve relations between the WIMS ERC and its students, industry, and community.

The social committee held an information day on north campus, where hundreds of students visited a booth collecting information on the Center, its research, and how they could become involved in WIMS. Also, several movie nights served to provide a brief break from research, increase collaboration, and build friendships between students.

The education area continued to work on the Ann Arbor Hands-On Museum exhibit, which explains and demonstrates how the cochlea works and the benefits of micromachined cochlear implants, such as the one being developed in our Center.

Our industrial committee created a resume booklet and a brochure on the Center. The brochure explains the Center and its research, while the resume booklet highlights students interested in internships or full-time positions. The resume booklet was distributed to ERC member companies.

To honor outstanding WIMS students, the SLC gave out two different awards at the Fall 2003 Industrial Advisory Board Meeting. The first award—presented to Andrew DeHennis—acknowledges one student who went out of his or her way to help others and to improve the lab. The second award—presented to almost 20 students—recognizes those who showed outstanding service over the past year. Congratulations everyone!

~The WIMS SLC officers



T.J. Harpster (left) presents Andy DeHennis (right) with the Outstanding Leadership Award.

EDUCATION HIGHLIGHTS

FIRST FEMALE ASTRONAUT ENCOURAGES GIRLS TO PURSUE ENGINEERING FIELDS

About 1,000 middle school girls and their families participated in the Sally Ride Festival, sponsored by the Women in Science and Engineering program, on Saturday, September 20, 2003. Sally Ride, the first American female astronaut in space, created these festivals to support and encourage girls interested in the fields of science and math to choose engineering as a future career.

At the festival, a WIMS exhibit illustrated science, technology, and math concepts utilizing LEGO Mindstorm kits, often used by the Center's Outreach Summer Programs. Also, several WIMS personnel presented a workshop for parents and educators.



Festival participants observing WIMS display.

INTRODUCTION TO MEMS COURSE IS REACHING STUDENTS INTERNATIONALLY

University of Michigan's (UM) EECS 414 (Introduction to MEMS) class is reaching an even broader spectrum of students. Most off-campus students enrolled are at Michigan State University, Michigan Technological University, or Western Michigan University, but this fall two students from the Delphi Mexico Technological Center in Jaurez, Mexico and one student from General Dynamics Land Systems here in Michigan have enrolled.

Virtually the whole class is presented to students online. Mid-term evaluations indicate that students are happy with both content and format of the course. Next term, UM's Center for Professional Development will offer EECS 514 (Advanced MEMS Devices and Technologies) and ME 553 (MicroElectroMechanical Systems) to off-campus students as well.

WIMS EDUCATIONAL PROGRAMS ARE EXPANDING DUE TO INCREASING POPULARITY

WIMS pre-college engineering summer programs are expanding next summer to accommodate growing interest of middle school students and their parents. Next year, sixth and seventh grade students will be involved in a new program called LEGO Robotics to WIMS. This one-week commuter program will examine pre-algebra, integrated math and physics, Visual Basic programming, and will include a WIMS lecture and lab.

Overwhelming Success of Programs

At the closing ceremonies of this last summer's Detroit Area Pre-College Engineering Program (DAP-CEP), Dr. Lee June, vice president of Student Affairs and assistant provost for Academic Student Services and Multicultural Issues at Michigan State University (MSU), remarked, "I have been to a number of DAPCEP student presentations in the past, but this year was by far the most impressive show of talents and technical skills demonstrated by the students."

Students impressed their audience with their final WIMS projects illustrating what they learned from courses



WIMS graduate student, David Lemmerhirt, illustrates complexities of his research to visiting WIMS for TEENS students.

REU PROGRAM HOSTED 11 STUDENTS

During this past summer, the Research Experiences for Undergraduates (REU) program hosted eleven students from across the Americas. Five students came from Hampton University, University of Florida, University of Puerto Rico, and Southern University at Baton Rouge while the remaining six were from within the Center.

In the past, all REU students visited University of Michigan's campus, but this year, the REU program placed students at all three Center universities—University of Michigan, Michigan State University, and Michigan Technological University.

The focus of this program is giving undergraduate students research experience. Directed by a faculty advisor, undergraduate students are given a research project by a graduate student mentor. The project is part of the graduate student's research, but the undergraduate is given full responsibility of the project.

All classes and meetings were held via video conferencing so that all participants could be actively involved. Through their classes, field trips, and workshops, students learn necessary written and oral skills for engineering while increasing their awareness of numerous ethical issues surrounding engineering.

they attended while living in the resident halls at MSU for three weeks.

Women in Engineering (WiE) and WIMS for TEENS also experienced similar success. WiE was lengthened to two weeks based on feedback from 2002 participants. WIMS for TEENS proved to be a great program, introducing participants to cutting-edge technology, new computer programs, and the world of engineering.

What It's All About

Throughout June and July, three different residential summer programs are offered at MSU, including DAPCEP, WIMS for TEENS, and Women in Engineering. The overall objectives of the programs are to develop students' interest in science, technology, and engineering careers; provide access to WIMS; create cooperative learning opportunities; introduce students to new multimedia instruction; and prepare students for success in their classes.

Participants in the past have stated that they learned the importance of teamwork, how to deal with communication issues, and how to cope with the stress of completing projects in a certain time frame. Thus, students learn what it is like to be an engineer. A booklet of the WIMS pre-college summer programs will be available mid-November. To request a hard copy, please email kima@egr.msu.edu or download the summer program information from www.egr.msu.edu/dpo.



DIRECTOR'S MESSAGE

(Continued from page 1)

staff, students, and their families from the three participating universities, gathered for two-and-a-half days of plenary talks, breakout sessions, and fun. One of the more important, perhaps surprising, results came from a session considering new research directions for the coming decade. What do we want to be the very best in? The recommendation was to continue what we are doing—emphasizing engineered microsystems and using the previously mentioned testbeds. There is no question that testbeds are a real stretch within the university environment, but I was delighted to see the strong feeling that it is a worthwhile stretch.

While the decisions made at the retreat will be helpful in moving forward, the opportunities to get to know each other better may have been even more important. We had a lovely summer here in Michigan, with bright sunshine every day but two. Unfortunately, those two days were the days of the retreat. We could still see Lake Bellaire—sometimes—but the greatest attraction was watching the rain come off the roof. We're not talking about dripping here, we're talking Niagara. It forced some very creative thinking by our staff. The water balloon toss still had to be outside, but the frisbee toss and the soccer match took on a lethality all their own when moved indoors. Friday afternoon, my wife and I finally broke and took a drive, just to get into the beautiful countryside. All I remember is that the rain was horizontal, and the bank thermometer we passed said 58°F, the high for the day. But as someone said, we all got a lot better acquainted being sequestered

together. There's a good lesson in there someplace. I'm still trying to find it.

Ken D. Wise

Director, Engineering Research Center for
Wireless Integrated MicroSystems

PERSONNEL FOCUS



Jin Zheng was awarded the Matt Wolfe Outstanding Graduate Research Assistant Award, October 2003, by the Department of Electrical and Computer Engineering at Michigan Technological University for her research efforts developing porous silicon process technologies supporting the Environmental Monitoring Testbed.



University of Michigan Assistant Professor, **Mingyan Liu**, wins the National Science Foundation's (NSF) Faculty Early Career Development (CAREER) Award for her "Capacity-Driven Design of Large-Scale Wireless Sensor Networks" research. One of the NSF's most prestigious awards, the CAREER award is given to junior faculty that combine outstanding research and education. Liu's research is developing design methodology for large-scale wireless sensor networks used for data-gathering, with fundamental capacity limit studies as guidelines.

INDUSTRIAL LIAISON'S REPORT



On October 15, 2003, we held our Industrial Advisory Board (IAB) meeting allowing students, faculty, and members to discuss the technical advances and economic achievements during the summer. Many of our member companies, including Sensicore, Discera and ISSYS, reported substantial new government contracts, obtaining additional funding from investors, and introducing new products. Because these companies originated from work done at the University of Michigan, we are especially proud of their commercial success. We look forward to helping all our members improve their bottom line by providing leading-edge technology and well-trained technical leaders.

To further help our members, we have distributed copies of our second annual WIMS resume booklet. The booklet contains resumes of WIMS students—both graduate and

undergraduate—who are interested in internships and full-time employment. It is also available in the **Members Only** section of our Web site, www.wimserc.org. Contact information is available in the booklet; however, if the Center can assist in arranging interviews or answering any questions, please contact me.

The Center is also scheduling visits allowing students and faculty to become familiar with our member company facilities in order to discuss projects in detail and become more aware of company needs. Please contact me if you are interested in visiting a particular facility or discussing certain projects or technology. As always, please stop at the Center whenever you are in Ann Arbor.

Joseph M. Giachino

Associate Director Industry

INTEGRATED CIRCUIT*(Continued from page 2)*

RF power signal, eliminating this problem. When locked to a 450 MHz signal, the measured phase noise of the internal oscillator is much more stable, operating at 102dBc/Hz at 100kHz offset corresponding to a figure merit of 181dBc/Hz.

The design for the chip was fabricated in the five metal TSMC 0.25 μ m CMOS process with low voltage transistors and a thick top metal. The active area of the design—excluding the storage capacitor—is 1mm². Packaged in a 52 pin ceramic leadless chip carrier package, the chip incorporated electrostatic discharge protection.

SEMINAR SERIES**July 1, 2003**

Jing Wang
University of Michigan
Self-Aligned 1.14GHz Vibrating Radial-Mode Disk Resonator

Mustafa Demirci
University of Michigan
Mechanically Corner-Coupled Square Microresonator Array for Reduced Series Motional Resistance

July 8, 2003

Professor Leo Kempel
Michigan State University
Enabling Materials for Antenna Miniaturization

July 15, 2003

Professor Kukjin Chun
Seoul National University
MEMS for Infogence System

July 21, 2003

Leland Spangler, Ph.D.
Aspen Technologies
Colorado Springs, CO
Challenges in the Assembly of Microsystem Packages

July 24, 2003

Prof. Kevin Pipe
Massachusetts Institute of Technology
Internal and External Heat Exchange in Electronic and Optoelectronic Devices

August 26, 2003

Professor Greg Nellis
University of Wisconsin-Madison
Mixed Gas Joule-Thomson Refrigeration Cycles

September 23, 2003

Asst. Professor Katsuo Kurabayashi
University of Michigan
PDMS-on-Silicon Microsystem

September 30, 2003

Eric Dishman
Intel Corporation
Hillsboro, OR
Proactive Computing Research for Home Healthcare and Aging-in-Place

PRESENTATIONS/PUBLICATIONS

IEEE International Conference on Solid-State Sensors and Actuators Conference (Transducers 2003), Boston MA, June 2003

A. DeHennis and K. Wise, "An All-Capacitive Sensing Chip for Temperature, Absolute Pressure, and Relative Humidity"

A. Ucok, J. Giachino, and K. Najafi, "Compact, Modular Assembly and Packaging of Multi-Substrate Microsystems"

B. Stark and K. Najafi, "An Integrated Process for Post-Packaging Release and Vacuum Sealing of Electroplated Nickel Packages"

C. Zhang, L. Bernal, P. Washabaugh, and K. Najafi, "Micro Combustion-Thermionic Power Generation: Feasibility, Design and Initial Results"

D. Lemmerhirt and K. Wise, "Air-Isolated Through-Wafer Interconnects for Microsystem Applications"

G. O'Brien, D. Monk, and K. Najafi, "Angular Accelerometer with Dual Anchor Support"

G. Rebeiz, "RF MEMS/Switches: Status of the Technology"

H. Kim and K. Najafi, "Wafer Bonding Using Parylene and Wafer-Level Transfer of Free-Standing Parylene Membranes"

H. Kim, K. Najafi, P. Washabaugh, and L. Bernal, "Large-Deflection Out-of-Plane Electrostatic Buckled-Electrode Actuators"

H. Kulah, J. Chae, and K. Najafi, "Noise Analysis and Characterization of a Sigma-Delta Capacitive Silicon Mic-accelerometer"

J. Chae, H. Kulah, and K. Najafi, "A Monolithic Three-Axis Silicon Capacitive Accelerometer with Micro-G Resolution"

J. Wang, Z. Ren, and C. Nguyen, "Self-Aligned 1.14-GHz Vibrating Radial-Mode Disk Resonators"

L. Que, C. Wilson, J. de la Rode, and Y. Gianchandani, "A Water Spectroscopy Microsystem with Integrated Discharge Source, Dispersion Optics, and Sample Delivery"

M. Agah, J. Potkay, J. Driscoll, R. Sacks, M. Kaviani, and K. Wise, "Thermal Behavior of High-Performance Temperature-Programmed Microfabricated Gas Chromatography Columns"

M. Demirci, M. Abdelmoneum, and C. Nguyen, "Mechanically Corner-Coupled Square Microresonator Array for Reduced Series Motional Resistance"

P. Bhatti, B. Arcand, J. Wang, N. Butala, C. Friedrich, and K. Wise, "A High-Density Electrode Array for a Cochlear Prosthesis"

S. McNamara and Y. Gianchandani, "A Micromachined Knudsen Pump for On-Chip Vacuum"

W. Steinecker, M. Rowe, A. Matzger, and E. Zellers, "Chemiresistor Array with Nanocluster Interfaces as a Micro-GC Detector"

W. Tian, H. Chan, S. Pang, C. Lu, and E. Zellers, "High Sensitivity Three-Stage Microfabricated Preconcentrator-Focuser for Micro Gas Chromatograph"

Y. Yao, M. Gulari, J. Hetke, and K. Wise, "A Self-Testing Multiplexed CMOS Stimulating Probe for a 1024-Site Neural Prosthesis"

25th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Cancun, Mexico, 2003

K. Takahata, A. DeHennis, K. Wise and Y. Gianchandani, "Stentenna: A Micromachined Antenna Stent for Wireless Monitoring of Implantable Microsensors"

R. Olsson, D. Buhl, M. Gulari, G. Buzsaki, and K. Wise, "A Silicon Microelectrode Array for Simultaneous Recording and Stimulation in the Brain of Behaving Animals"

R. Vetter, R. Olsson, J. Hetke, J. Williams, D. Pellinen, K. Wise, and D. Kipke, "Silicon-Substrate Intracortical Microelectrode Arrays with Integrated Electronics for Chronic Cortical Recording"

S. Nickles, D. Pellinen, J. Kitagawa, R. Bradley, D. Kipke, K. Najafi, "Long Term In Vitro Monitoring of Polyimide Microprobe Electrical Properties"

ASME IMECE 2003, Washington, D.C., 2003, A. Astle, L. Bernal, P. Washabaugh, H. Kim, K. Najafi, "Dynamic Modeling and Design of a High Frequency Micro Vacuum Pump"



15th Biennial University/Government/Industry Microelectronics Symposium, Boise, ID, 2003, S. Martin, T. Strong, F. Gebara, K. Kraver, G. Keeler, and R. Brown, "Integrated Microtransducers and Micro-electronics for Environmental Monitoring"

American Society for Engineering Education National Conference, Nashville, TN, 2003, M. McCorquodale and R. Brown, "Academic and Professional Resources for Student-Led Technology Ventures"

European Solid-State Circuits Conference, Estoril, Portugal, 2003, R. Rao, J. Burns and R. Brown, "Circuit Techniques for Gate and Sub-Threshold Leakage Minimization in Future CMOS Technologies"

IEEE International Conference on Electronic Circuits and Systems, Sharjah, United Arab Emirates, 2003, M. McCorquodale, M. Ding, and R. Brown, "Top-Down and Bottom-Up Approaches to Stable Clock Synthesis"

IEEE MTT-Radio Frequency Integrated Circuits (RFIC) Conference, Philadelphia, PA, 2003, J. Wang, Z. Ren and C. Nguyen, "Self-Aligned 1.14-GHz Vibrating Micromechanical Disk Resonator"

IFIP VLSI-SoC International Conference, Darmstadt, Germany, 2003, M. McCorquodale, E. Marsman, R. Senger, F. Gebara, and R. Brown, "Microsystem and SoC Design with UMIPS"

International Symposium on Low Power Electronics and Design, Seoul, Korea, 2003, R. Rao, J. Burns, A. Devgan, and R. Brown, "Efficient Techniques for Gate Leakage Estimation"

Radio Frequency Integrated Circuits Symposium, Philadelphia, PA, 2003, M. McCorquodale, M. Ding, and R. Brown, "A CMOS Voltage-to-Frequency Linearizing Preprocessor for Parallel Plate RF MEMS Varactors"

SIGDA Ph.D. Forum at the 40th Design Automation Conference, Anaheim, CA, 2003, P. Mohseni and K. Najafi, "Bi-Directional Wireless Microsystems for Biomedical In-Vivo Recording Applications"

DOCTORAL DISSERTATIONS

John R. Clark
"VHF and UHF Micromechanical Disk Resonators for Wireless Communications"
University of Michigan, 2003
Current Position: Discera Inc., MI
Advisor: Professor Clark T.-C. Nguyen

Chunbo Zhang
"Combustion-Based Micro-Power Generation: Thermoelectric and Thermionic Approaches"
University of Michigan, 2003
Current Position: Honeywell Corp., MN
Advisor: Professor Khalil Najafi

SUMMER 2003 Schedules of upcoming seminars as well as a listing of publications are available at www.wimserc.org.

The Regents of the University of Michigan
David A. Brandon
Laurence B. Detch
Daniel D. Horning
Olivia P. Maynard
Rebecca McGowan
Andrea Fischer Newman
S. Martin Taylor
Katherine E. White
Mary Sue Coleman (ex officio)

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