

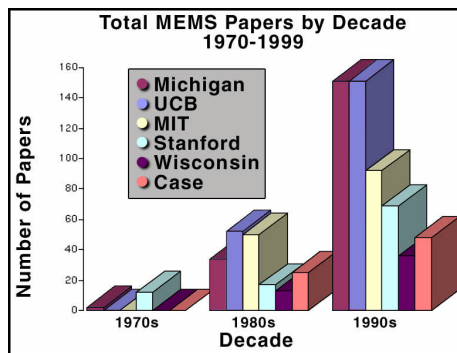
MESSAGE FROM THE DIRECTOR



As we move toward completing our first year, I'm grateful for the efforts of a very dedicated collection of faculty, students, and staff. A total of 65 research projects have been launched, involving all aspects of microsystems and blending expert-

ise from chemistry, public health, and medicine with that from many engineering departments. Perhaps most importantly, I think the group really enjoys working together, which is essential to the success of any multidisciplinary endeavor. On the educational front, we have defined innovative microsystems curricula at the undergraduate and graduate levels and are now co-developing the courses that will make them a reality. In this issue you will hear about a workshop held last month to engage secondary school teachers in defining ways WIMS can be used to more effectively teach science and attract more students to engineering careers. Twenty companies are now partnering with us in the Center, providing valuable guidance along with very concrete solutions to some key problems.

It was nice to see many old friends at the recent Transducers'01 meeting in Munich and interesting to see the enormous breadth of activity there. MEMS is clearly in a state of vigorous growth with many newcomers just starting in the field. I remember being impressed quite early in my career at the rapid rate of change in the microelectronics industry. Looking at



a list of the leading electronics companies from, say, 1950 onward, very few names stayed on the list decade after decade. Many pioneering companies fell by the wayside or went off to pursue other activities (e.g., RCA, Westinghouse, GE, Philco). Where will the leading microsystem centers be in 2010? We hope that Michigan is still on the list then,

and many more places that have important and growing microsystem programs.

In a recent count of MEMS papers presented to date at the three major MEMS conferences (Transducers, Hilton Head, and MEMS) and from the sensor sessions at ISSCC and IEDM by the above schools, Michigan is a close second to UC-Berkeley in having the most papers from any North American organization. And during the 1990s, no one contributed more papers than Michigan (UCB contributed the same number). These six schools each have a rich history of contributions and are still leading contributors as we move into the new century. The microsystems field owes them much. With the WIMS ERC, we hope to keep Michigan at the forefront of microsystems development throughout the coming decade and are grateful for the opportunities it gives us to work with our industrial

INDUSTRIAL LIAISON



The next Industrial Advisory Board (IAB) meeting will be held on October 30-31. We will report on the progress made in the research and educational programs of the Center and a poster competition will give IAB members and students an opportunity to discuss the projects in detail on a one-to-one basis.

As part of recent progress, we have followed the IAB's advice and obtained two System

Integrator Resident Engineers. Sandia National Laboratories and Ardesta are each placing an engineer at the Center to coordinate system integration. These engineers will work with the ERC Testbed Champions, researchers, and other engineering staff to insure that the testbed issues surface and are addressed, resolved, and documented in a timely manner. We continue to obtain new memberships - the latest being Delphi Automotive and Applied Micromedical Systems. By October we hope to have at least three additional members.

Keeping technology transfer to industry in mind, we are scheduling visits to our members' companies to ensure that we understand their needs and that they have a significant impact on our research.

Remember that members have online access to streaming video of the seminars and to student resumes.

If you have any suggestions on other member services you would like to see on our site, please contact me.

Joseph M. Giachino
Associate Director

and in 2020. But I still occasionally get comments like "Gee, it's nice to see Michigan getting into MEMS!" or "We recently went to a review at (wherever), and you guys are really right up there too." While such comments are well intended, they certainly don't reflect the field or its history. MEMS began, for me at least, in 1966, and all through the 1970s, 80s, and well into the 90s, the field in the US was academically led and centered in about six schools. It began at Stanford but within a decade had also started at Case, Michigan, Berkeley, MIT, and Wisconsin as well. This story is too long to recite here, but some of it is told in Simon Middelhoeke's article (Sensors and Actuators, A, 82, pp. 2-23, 2000). Today, there are many more players

and academic partners in this exciting area. I hope you enjoy the various items in this Newsletter describing our most recent activities.

Ken D. Wise

Director
Engineering Research Center for Wireless Integrated Microsystems

University of Michigan
Michigan State University
Michigan Technological University

TABLE OF CONTENTS

Message from the Director	1
Industrial Liaison	1
Recent Events	2
Personnel	2
Education Highlights	3
Research Highlights	4
SLC Report	5
Seminar Series	6
Publications	6



RECENT EVENTS

IAB/NSF MEETINGS

May 1-2, Industrial Advisory Board (IAB) Meeting

Representatives from our IAB were audience to a host of presentations, posters, and discussions by faculty and students at our semi-annual IAB Meeting. Presentations from faculty and students outlined the Center's major thrusts and all the associated work supporting those goals. A question and answer session followed each presentation. A poster competition, judged by the IAB, with awards provided by Deloitte & Touche, followed. After convening on the second day, IAB members provided the ERC with detailed feedback and critique. Insight from an outsiders perspective proved invaluable and helped us to prepare for the subsequent NSF site visit.

The **first year review** of the WIMS ERC was held on May 22-23, 2001. The Site Visit Review Team consisted of technical experts and educators from universities and industry as well as representatives from the NSF. Professors Wise and Najafi gave an overview of the vision and strategic plan for the Center while the six thrust leaders highlighted recent results. A poster session was held at which the ERC graduate students presented detailed results.

The Site Review Team's evaluation of the Center was very positive. Their report indicated that "The WIMS ERC has a clear vision of the pervasive impact of WIMS technology and has gotten

off to an excellent and aggressive start on many fronts. The Center has strong leadership and a cohesive team of researchers...Significant research progress has been made in all the research thrusts. There have also been enthusiastic efforts in education, outreach, and industrial collaboration activities." The committee stressed the importance of system integration in the testbeds, which is currently being strengthened with the addition of several resident engineers and members of technical staff. We are grateful to all of our IAB members and to the members of the Site Review Team for their help in guiding the Center.

ARDESTA SCHOLAR ANNOUNCED

This Scholarship sponsored by Ardesta, LLC, is given to a student working in the packaging area.

The first recipient is Timothy J. Harpster, who is working on thin-film coatings for the hermetic encapsulation of microsystems.

SCIENCE TEACHER WORKSHOP

June 26-27 - The Education Thrust of the ERC hosted a Science Teacher Workshop for Michigan area teachers to show how WIMS devices could be used to teach basic science principles. Teachers learned about current research and our Okemos H.S. pilot program. (see page 3)

TRANSDUCERS '01

The 11th International Conference on Solid-State Sensors and Actuators, *Transducers '01*, was

held in Munich, Germany on June 10-14, 2001. This is the premier and largest conference in the field of MEMS/Microsystems and was attended by approximately 930 researchers who presented and listened to the latest research results. A total of 414 papers were presented in four parallel oral and two poster sessions by researchers from 32 countries. Eighty-nine papers were contributed by researchers from the USA, and of this, 13 papers were contributed by students from the University of Michigan. Papers from Michigan covered several areas, including: biomedical microsystems, micro-packaging, power generation, RF MEMS, microfluidics and Bio-MEMS. In addition, four short courses were presented before the conference started. Professor Clark T.-C. Nguyen presented a short course in RF MEMS which was very well attended and Professor Khalil Najafi served as North American Chairman. The Conference was very successful and highlighted research in several areas. Of significance were a large number of papers in micropackaging, micropower generation, optical, RF, and Bio-MEMS, and a special session on "Microsystems Commercialization". The latter session was held on the last day of the conference and was launched from an invited talk by Dr. Janusz Bryzek, President and CEO of Transparent Optical, Inc. This special session was extremely well received, and the attendees felt that sessions like this were needed to encourage further commercialization in the area of MEMS. ~KN

PERSONNEL



Richard B. Brown was recently appointed Interim Chair of the EECS department by Dean Stephen Director.

Richard previously served as Associate Chair for the department's EE Division. He is also active nationally, having served on NSF, ASME, and DARPA advisory committees for emerging technologies and VLSI education. He continues to serve on the MOSIS Advanced Technology Advisory Committee and as the chair of the MOSIS Advisory Council for Education.



WIMS is proud to welcome Associate Professor, **Ann Marie Sastry** of the University of Michigan's Department of Mechanical

Engineering to the ERC, effective Spring 2001.

Ann Marie's research interests include: modeling of damage progression in nerves, process/structural modeling of polymeric composites, performance of porous composites, advanced battery systems for electric vehicles and modeling of RTM-fabricated composites. Her work on power sources will help the team currently developing the cochlear implant.



Paul Bergstrom has moved to Michigan Technological University and joined the WIMS ERC. Paul received his M.S.

and Ph.D. degrees from the University of Michigan in '93 and '96, respectively.

Paul currently has 20 refereed publications, 1 book chapter, and 2 patents issued. He also serves as reviewer for IEEE J. Micro Electro Mechanical Systems, Sensors and Actuators A: Physical,



The 11th International Conference on Solid-State Sensors and Actuators, Transducers '01, the premier and largest conference in the field of MEMS and Microsystems. LEFT: The WIMS ERC team takes a break from conference activities to pose for a group shot. Michigan students presented 13 of 89 papers submitted from the U.S.

Sensors and Actuators, B: Chemical, and the ASME J. Manufacturing Systems. Amongst his duties with the ERC, Paul will be codeveloping with professor Najafi the curriculum for a Microsystems Technology course to be offered at the three partnering universities. He will also act as coadvisor for the Enterprise Team at Michigan Technological University, a three year undergraduate design experience.



As we were going to press **Daryl R. Kipke**, formerly of Arizona State University, joined the ERC. His research mission - as he states - is "to

develop increasingly more sophisticated neural implant technologies and then to apply these technologies to advance strategic areas of basic and applied neuroscience and functional neurosurgery."

A graduate of the University of Michigan, (Ph.D. 1991), Kipke has since taught at Syracuse University and more recently was a tenured Associate Professor at ASU, where his primary research included a "BioMEMS effort to develop and characterize next-generation neural implants as well as more fundamental investigations of neuroprosthetic systems, neural plasticity, and biomaterials."

Daryl has received significant amounts of funding - both federal (NIH, NSF and DARPA) and private (Whitaker Foundation and Amercian Heart Association) - and was awarded both the NIH Career (1995) and NSF First (1995) awards. He has collaborated with several biomedical device companies and has also served as a U.S. delegate to U.S.-South Korea joint Bio-engineering Symposium (1998). Daryl also taught at all levels in the undergraduate and graduate Bioengineering Departments at ASU. ~LL

EDUCATION HIGHLIGHTS

SCIENCE TEACHER WORKSHOP

June 26-27, 2001 - Okemos H.S. and MSU students demonstrated the possibilities WIMS/MEMS technology can bring to Michigan area middle and high school basic science curricula. Teachers from Ann Arbor, Detroit/DAPCEP, Dearborn, Houghton/Hancock, and Okemos school districts were able to interact with Lego's Mindstorms robots and microcontrollers with the guidance of Okemos H.S. and MSU students who were on hand to assist.

The objectives of the workshop were (1) to inform a small group of middle and secondary school science teachers about pilot program efforts to transfer WIMS technology into secondary education through a variety of teaching/learning approaches (in classroom, laboratories, after school activities, enrichment activities, and research at local universities), and (2) to foster discussion among the teachers and WIMS staff about, where WIMS technology could be used to facilitate middle and high school basic science education. The need for this discussion was made evident during Director

Ken Wise's talk, when several teachers asked about curriculum introducing the WIMS/MEMS technology in the the secondary school classroom. With their advice for curriculum identification, a plan could be drawn up, describing how this technology could be introduced with the help of the ERC.

Participants were exposed to two days of presentations from the ERC Director, thrust leaders, partnering universities and Okemos H.S. students. Afterwards, small group discussions related to WIMS in schools gave the Education program a better idea of how WIMS/MEMS devices could be integrated into the school systems, advancing basic science education to further use 21st Century technology.

Expansion of the Okemos H.S. Pilot Program to other Michigan schools and perhaps throughout the U.S. will be an important theme in the next Science Teacher Workshop scheduled for Summer 2002. ~DA

ERC WILL OFFER NEW COURSE, INTRODUCTION TO MEMS

One of the main goals of the ERC educational program is to develop a sequence of courses

that form the core of a Masters program concentrating on MEMS and Microsystems. The first in a series of four MEMS/Microsystems courses will be offered in Fall 2001.

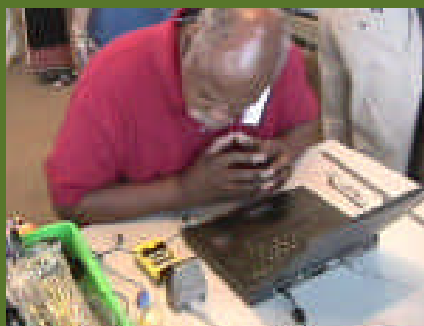
The introductory course is designed for those not familiar with MEMS, microfabrication technologies, integrated circuits, or non-electrical devices and systems. The course pre-requisites will allow students from many engineering or science disciplines, including mechanical, electrical, chemical, aerospace, biomedical, and materials engineering to enroll. The course will focus on fundamentals of micro-machining and microfabrication techniques, including planar thin-film process technologies, photolithographic, deposition and etching techniques, and other technologies that are central to MEMS fabrication. It will also pay special attention to teaching fundamentals necessary for the design and analysis of devices and systems in mechanical, electrical, fluidic, and thermal energy/signal domains, and will teach basic techniques for multi-domain analysis (e.g., electro-mechanical, electrothermal). Fundamentals of sensing and transduction mechanisms (i.e. conversion of non-electronic signals to electronic signals), including capacitive and piezoresistive techniques, and design and analysis of micromachined miniature sensors and actuators using these techniques will be covered. Many existing devices and their applications will be reviewed.

This course is being offered as a multi-institutional course in partnership with Michigan Technological University (MTU) and Michigan State University (MSU). The course is taught over the instructional networks of these universities. Students will have access, on-demand, to lecture materials, assignments, etc. via video streaming. The course will eventually be made available to other universities and companies through the internet.

For more information please contact Prof. Khalil Najafi at najafi@umich.edu.

Science Teachers from all over Michigan came to learn about WIMS and microcontrollers in the classroom at the Science Teacher Workshop: Elementary school to Ph. D., held at the University of Michigan in June. Top: Brandon Gregory, a high school student from the WIMS/Okemos H. S. Pilot Program, demonstrating the spring constant experiment he and his fellow classmates built in Prof. Aslam's lab at MSU.

Bottom: DAPCEP teacher Dana Robinson, really got into the experiment session with the laptop's and Lego Mindstorm robots.



RESEARCH HIGHLIGHTS

SENSORS

Micro-GC

Significant progress has been made toward development of a monolithic wireless microanalyzer for complex vapor mixtures (WIMS- μ GC). A critical component of the system is the integrated multi-adsorbent preconcentration/focusing module. Initial structures consist of high-aspect-ratio doped-Si "slat microheaters" 20-40 μ m wide and 100-400 μ m tall that will be packed with a few milligrams of graphitized carbon adsorbent microbeads or coated with similar quantities of nanocomposite adsorbent materials currently being developed. Modeling indicates heating to 300 °C will be possible in <3 sec at low power to desorb trapped vapors for subsequent high-speed separation and sensor-array detection. Alternative "post microheater" structures are also being evaluated.

Spiral and serpentine high-aspect-ratio channels are being developed for the separation stage of the μ GC. Initial structures have been fabricated by a deep RIE process with cross-sections ranging from 0.02-0.04 mm² and aspect ratios of 2:1 to 4:1. Each chip (~1.7 cm on a side) will contribute about 1-meter of length to the ultimate stacked column ensemble. For preliminary testing, 1-meter chips have been sealed with anodically bonded pyrex lids having capillary inlet and outlet ports for stationary phase deposition and evaluation of flow dynamics.

Arrays of interdigitated-electrode (chemiresistor) sensors employing monolayer-encapsulated metal (MenM) nanoclusters as chemically sensitive interfaces are being employed for the μ GC detector. An array of two Au-thiolate-MenM-coated chemiresistors has been fabricated, packaged in a low-dead-volume (~60- μ L) cell and evaluated as a detector for a conventional GC analyzer. Detection limits for 8 test vapors ranged from 100-700 parts-per trillion assuming a 0.5-L preconcentrated air sample.

The combination of response patterns and GC retention times provides unequivocal recognition of resolved vapors. ~EZ

WIRELESS

ERC Wireless Thrust researchers have demonstrated a bonded microplatform process, in which micromechanics are constructed on microplatforms that are then flipped and compression bonded onto transistor integrated circuit wafers to merge RF MEMS and transistor devices in nearly "single-chip" fashion. In this technology, microplatforms are held onto a carrier wafer via thin support struts before bonding. After platforms are bonded to specific locations on a circuit wafer, the MEMS carrier wafer is torn away from bonded platforms, breaking the support struts, and leaving bonded platforms (with mounted RF MEMS devices) together with the circuit wafer.

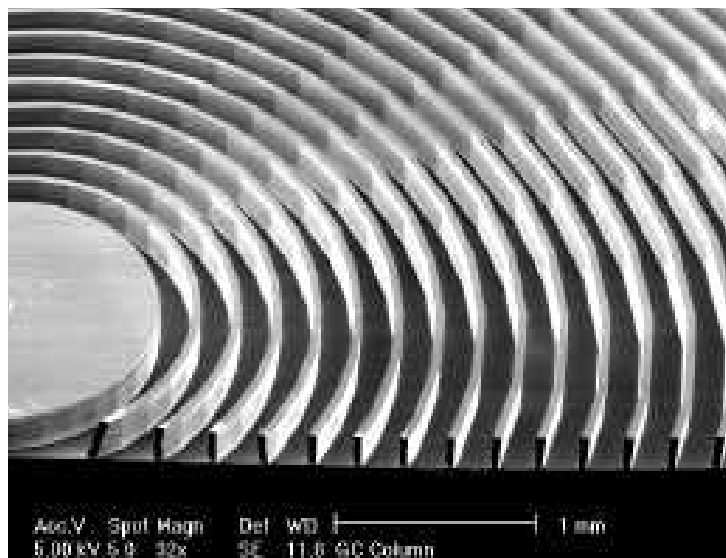
This technology can be highly economical for products where the area taken by micromechanics is much smaller than that taken by transistor circuits, since not all platforms need be bonded in a single bonding step; rather some platforms can be bonded and others left on the MEMS carrier to bond to another transistor circuits wafer. In this way, a single MEMS wafer might service ten or more transistor circuit wafers. ~CN

MICROPACKAGING

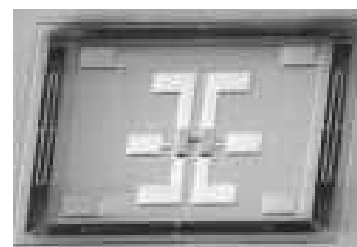
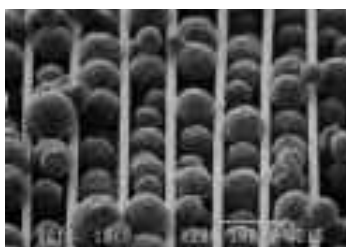
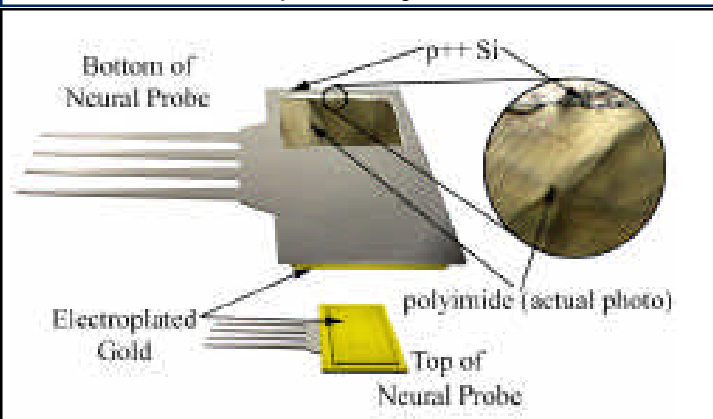
A new wafer-level hermetic packaging technology for protection of integrated circuits and sensors against harsh environments, including those in the body, has been developed. This technology utilizes electroplated gold, or other metals, to package and protect sensitive areas. The gold film is only a few microns thick, is formed using electroplating at room temperature, can withstand exposure to biological and salt solutions, and is biocompatible. In order to isolate this gold package from the integrated electronics it is protecting, a thick layer of insulating material, such as polyimide or sputtered silicon dioxide, is deposited at room temperature over the circuits, patterned and then coated

with the gold layer. Integrated high-density feedthroughs are brought out from underneath the gold package and are insulated with dielectrics available in a standard IC process. This packaging technology has been incorporated into a micromachined silicon probe process, and test devices have been fabricated (see

picture). Accelerated tests at high temperatures show a mean time to failure at body temperature of more than 150 years, which is more than sufficient for most applications. Additional tests are underway. For more detail see paper by Brian Stark and K. Najafi presented at Transducers '01 in Munich. ~KN



ABOVE: Deep-RIE processed GC-column segment having a channel cross-section of 240 μ m x 150 μ m and a total length of ~1m within a 1.7 x 1.7 cm chip. **BELOW:** Micromachined silicon probes with an integrated gold package for protection of on-chip circuitry. **BOTTOM LEFT:** Preconcentrator structure each packed with a 50-mm-diameter graphitized-carbon adsorbent material. Dimensions of "slat" structures shown are 20 μ m x 120 μ m. **BOTTOM RIGHT:** Scanning electron micrograph (SEM) of a suspended platform housing a two-resonator micromechanical filter ready for bonding to a transistor circuits wafer.



STUDENT LEADERSHIP COUNCIL

OVERVIEW

The past several months have been full of opportunities for ERC students. We have been able to interact not only with each other but with many professionals from outside the university environment worldwide. The most notable activities were the Industrial Advisory Board (IAB) Meeting (May 1-2), followed by the NSF Site Visit (May 22-23). At the IAB Meeting, students were given the opportunity to present their research and/or show recent results in a poster session, which was judged by the IAB. Awards were provided by Deloitte & Touche. At an evening banquet, awards were given to the winners of the poster competition. Congratulations to the following SLC members:

Most Outstanding Poster:

Timothy J. Harpster
Excellence in Poster Design:
John R. Clark, and
Pamela T. Bhatti

The award for the Ardesta/WIMS Scholar was also presented that evening to Timothy J. Harpster.

Congratulations to the winners. Special thanks to Deloitte & Touche for sponsoring the poster competition and Ardesta for providing the scholarship. I'm proud of all the students who took the time to do a great job!

During the NSF meeting, students had the opportunity to sit down with the NSF team and exchange thoughts. The conversation proved valuable for both parties.

Students have also been very busy presenting papers and meet-

ing with industry representatives during this spring's conference season.



TOP: Stephen P. Johns, Senior Vice President of Ardesta, LLC, presenting the Ardesta WIMS Scholar award to Timothy J. Harpster at the IAB meeting banquet. **MIDDLE:** Poster competition winners (left to right) Timothy J. Harpster, Pamela T. Bhatti and John R. Clark. **BOTTOM:** SLC students - (left to right) T.J. Harpster, Arvind Salian, David Lemmerhirt, Stefan Nikles, Wayne Fung (foreground), Kyu Suk Baek and Andy DeHennis - with Honeywell representative at Sensors Expo, Chicago.

Professors Richard Sacks and Edward T. Zellers travelled to New Orleans, LA in March for Pittcon 2001, where graduate

students Tincutta Veriotti and Joshua Whiting presented their research on the μ GC. In May they were on the road again at the 22nd Annual Spring Symposium of the Minnesota Chromatography Forum in Minneapolis. A short rest and they were back out west at the 24th International Symposium on Capillary Chromatography and Electrophoresis in Las Vegas, NV held on May 21-25, 2001.

On June 8-9, the WIMS SLC - with the help of Industrial Liaison Joe Giachino - coordinated a trip to Sensors Expo (Chicago). The Expo gave students the opportunity to meet with members from industry and exchange ideas.

More recently, faculty and several students attended Transducers '01 in Munich, Germany (June 10-14). In total, 7 students gave talks and 4 students presented posters.

On June 18th, we were pleased to welcome Ms. Andrea Messer, President of the SLC at the Marine Bioproducts Engineering Research Center, University of Hawaii, as our guest. We shared thoughts about our ERCs, research and programs. We appreciate her traveling so far to visit.

Thanks to all our sponsors and the students who've participated in events over the last few months. Your enthusiasm, hard work and team spirit are appreciated. We look forward to other exciting activities during the coming semester. ~SN

SOCIAL

The ERC was represented by volleyball, softball, and basketball teams in Spring 2001. The volleyball teams battled to the second round of playoffs, the

softball team lost in the first round of playoffs but Joe Potkay, was "... pleased with the positive attitude and team camaraderie.", while the basketball team advanced to the semifinals, losing to the tournament champions.

We are looking forward to a Multiple Sclerosis fundraising regatta on Lake Erie to be held in mid August. This event will give us another opportunity to get involved in a worthwhile cause. The event is being scheduled with the help of staff member, Robert Gordenker.

For those who have not yet joined any IM activities, why not give it a try this summer or fall? We're always looking for more team members and it's the perfect way to find out what others are doing on and off the field.

For more information on the regatta email Robert Gordenker: gordenk@umich.edu. Email Timothy Harpster: tharpste@umich.edu for details or suggestions on upcoming events. ~TH

UPDATES

University of Michigan students in the Department of Electrical Engineering and Computer Science (EECS) took top prizes for the second consecutive year at the 38th Design Automation Conference (DAC 2001) Student Design Contest. The contest allows entries of both integrated circuits and electronic systems (board-level design) and has two categories: 'Conceptual' and 'Operational.'

EECS students took all three prizes in the Conceptual category. Conceptual designs need not have been implemented but must have been thoroughly simulated and must include a test plan. First place (\$4,000) and Best Paper (\$1,000) went to: Seungbae Lee, Gijoon Nam, Junseok Chae and Hanseup Kim, for their paper, "Two-Dimensional Position Detection System with MEMS Accelerometer for MOUSE Applications". ~RB



SEMINAR SERIES

April 3, 2001

Dr. Richard K. Hester
Texas Instruments
Analog Frontend Design for ADSL

April 7, 2001

Prof. Gary Fetter
Carnegie Mellon University
Design and Fabrication of CMOS Micromachine Systems

April 10, 2001

Prof. Mary Anne Carroll
University of Michigan
Studies of Oxidant Photochemistry and an Atmospheric Measurements Wish List

May 8, 2001

Prof. Chong H. Ahn
University of Cincinnati
Hand-Held Biochemical Detection Systems with Sampling and Analysis Capabilities

May 15, 2001

Haluk Kulah
UM Doctoral Student
Z-axis Micro-g Silicon Accelerometer Microsystem
Junseok Chae
UM Doctoral Student
X & Y-axis High-Performance Silicon Microaccelerometers

May 29, 2001

Reinoud F. Wolffenbuttel
Delft University of Technology
Microsystem Technology in Instrumentation and Measurement Applications

June 1, 2001

Joseph R. Stetter
Illinois Institute of Technology
Electromechanical Sensors for Environmental Monitoring

June 5, 2001

Seungbae Lee
UM Doctoral Student
High-Q Oscillators
Ark Wong
UM Doctoral Student
A Bonded Micro-Platform Technology for Modular Merging of RF MEMS and Transistor Circuits

For more information go to
www.eecs.umich.edu/wims.
To view archived material via
MEonline contact:

Karen S. Richardson
WIMS Administrative Manager
karenr@eecs.umich.edu
(734) 647-1779

PUBLICATIONS

WIMS papers presented at Pittcon 2001, New Orleans, LA.

T. Veriotti and R. Sacks
High-Speed Gas Chromatography Analysis of Environmental Samples using a Tandem Column Ensemble and Pulsed Flow Modulation

T. Veriotti and R. Sacks
Pulsed-Flow Modulation: A New Approach to Selectivity Enhancement in gas Chromatography

J. Whiting and R. Sacks
Integration of Fast Column Heating with Tunable Column Technology Toward the Development of Enhanced Field Portable Chromatographs

J. Whiting and R. Sacks
Tunable and Programmable Selectivity for Vacuum-Outlet GC with Atmospheric-Pressure Air as Carrier Gas

E. T. Zellers and C. J. Lu
Toward a Versatile Microanalytical System for Organic Vapors: Preconcentration, Separation, & Sensor Array Detection

WIMS paper presented at the Gordon Research Conference on Chemical Sensors and Interfacial Design, Lucca, Italy.

E. T. Zellers and M. D. Hsieh
In-Situ UV-Photopolymerization of Gas-Phase Monomers for Microanalytical System Applications

WIMS papers presented at the 24th International Symposium on Capillary Chromatography and Electrophoresis, Las Vegas, NV.

M. McGuigan and R. Sacks
Band-Trajectory Model for Temperature Programmed GC with a Pressure Programmable Column Ensemble

R. Sacks, T. Veriotti and E. T. Zellers
Emerging Technologies for the Development of an Autonomous Micro Gas Chromatograph

J. Whiting and R. Sacks
Strategies for the High-Speed Separation of Air-Borne Organic Compounds

WIMS paper presented at the 22nd Annual Spring Symposium of the Minnesota Chromatography Forum, Minneapolis, MN.

R. Sacks, T. Veriotti, J. Whiting and E. Zellers
TOF, SAW MEMS, and WIMS- The Alphabet Soup of High Speed GC

WIMS paper presented at Sensors Expo, Chicago, IL.

K. D. Wise, K. Najafi, D. M. Aslam, R. B. Brown, J. M. Giachino, L. C. McAfee, C. T.-C. Nguyen, R. O. Warrington, and E. T. Zellers
Wireless Integrated MicroSystems (WIMS): The Coming Revolution in the Remote Gathering of Information

WIMS papers presented at Transducers '01, Munich, Germany. The papers are published in the Technical Digest of the Conference.

P. Chang-Chien and K. D. Wise
Wafer-Level Packaging using Localized Mass Deposition

T. Chou and K. Najafi
3D MEMS Fabrication Using Low-Temperature Wafer Bonding with Benzocyclobutene (BCB)

T. Chou, K. Najafi, M. Muller, L. Bernal and P. Washabaugh
High Density Micromachined Acoustic Ejector Array for Micro Propulsion

J. R. Clark, W.-T. Hsu, and C. T.-C. Nguyen
Measurement techniques for capacitively-transduced VHF-to-UHF micromechanical resonators

M. D. Gingerich, J. F. Hetke, D. J. Anderson, and K. D. Wise
A 256-Site 3D CMOS Microelectrode Array for Multipoint Stimulation and Recording in the Central Nervous System

W.-T. Hsu, J. R. Clark, and C. T.-C. Nguyen
A Resonant Temperature Sensor based on Electrical Spring Softening

W.-T. Hsu, J. R. Clark and C. T.-C. Nguyen
Q-optimized lateral free-free beam micromechanical resonators

S. Lee, M. U. Demirci, and C. T.-C. Nguyen

A 10-MHz micromechanical resonator Pierce reference oscillator for communications

V. Namasivayam, R. Liu, P. Grodzinski and B. Towe
Design of a Self-Contained Microvalve in PDMS

B. Stark and K. Najafi
An Ultra-Thin Hermetic Package Utilizing Electroplated Gold

J. Tsai and L. Lin
Thermal Bubble Powered Microfluidic Mixer with Gas Bubble Filter

A.-C. Wong, Y. Xie, and C. T.-C. Nguyen
A bonded-micro-platform technology for modular merging of RF MEMS and transistor circuits

C. Zhang, K. Najafi, L. Bernal and P. Washbaugh
An Integrated Combuster - Thermoelectric Micro Power Generator

WIMS World is published quarterly by the Center for Wireless Integrated Microsystems.

**Contact us:**

WIMS World
University of Michigan
WIMS ERC
213 Engineering Programs Bldg.
2609 Draper
Ann Arbor, MI
48109-2101
Tel.: (734) 615-3098
Fax: (734) 647-2342
www.eecs.umich.edu/wims
Editor: Luke Ling
email: lukeling@eecs.umich.edu

The Regents of the University of Michigan

David A. Brandon
Laurence B. Deitch
Daniel D. Horning
Olivia P. Maynard
Rebecca McGowan
Andrea Fischer Newman
S. Martin Taylor
Katherine E. White
Lee C. Bolinger (ex officio)

Non-Profit Org.
US Postage Paid
Permit No. 144
Ann Arbor, MI