BERKELEY SENSOR & ACTUATOR CENTER

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AN NSF / INDUSTRY / UNIVERSITY / COOPERATIVE RESEARCH CENTER
FOUNDED IN 1986

3RD ANNUAL BERKELEY SUMMER INSTITUTE FOCUSES ON MEMS

Berkeley is known throughout the world for its creative academic and unique cultural atmosphere. Berkeley is also an "epicenter" of a technology shockwave which is poised to change entire generations of new products, and in the process, whole industries.

By combining science and engineering disciplines to create micro-electromechanical systems (MEMS), pioneers from bioengineering, chemical engineering, medical science, mechanical engineering, and electrical engineering are creating applications as diverse as wireless distributed sensor arrays, personalized individual drug delivery systems, 3rd generation cellular radios, and monolithic, batch fabricated micro internal combustion engines.

The applications appear boundless, driven by a collaborative, creative, interdisciplinary technology-sharing mindset, which would be hard to envision outside the research/teaching university environment. BSAC combines this university environment with public and industrial funding and participation to facilitate acceleration of new technology *adoption and refining* by industry.

BSAC researchers in conjunction with UC College of Engineering, and UC Extension, have developed a series of short courses to expose technology practitioners to MEMS fundamentals and current research thrusts. These courses are being offered through the Berkeley Summer Engineering Institute.

The faculty includes BSAC Directors and distinguished alumni of the UC Berkeley College of Engineering, now working in corporations and other universities as well as leading faculty, researchers, and industry experts from leading research institutions. Courses are held in June and July on the UC Berkeley campus.

Courses which were offered in Summer 2002, or planned for future sessions, include the following.

Engineering Practical Microsystems for Biochemical Analysis
Micro fabricated systems for chemical and biochemical analysis are attracting a significant amount of research and commercial interest, especially for medical diagnostics and for post-genomic biological R&D challenges. In pursuit of speed, portability, high throughput, and reduced costs, as well as the ability to handle ever-smaller samples in sophisticated research applications, demand is being placed on miniaturization of existing analysis systems as well as development of microsystems that rely on techniques enabled at the micron-scale.

Fundamentals of MEMS
This course introduces MEMS (micro-electromechanical systems) with special emphasis on optical MEMS applications. The course begins with a review of fundamental micromachining processes: bulk-micromachining, surf-

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JOHN HUGGINS JOINS BSAC AS NEW EXECUTIVE DIRECTOR

John M. Huggins

With the conclusion of a one-year, national search by the BSAC Directors, John Huggins has joined BSAC as Executive Director effective August 31, 2002, in time to be part of the upcoming Industrial Advisory Board meeting September 10-11, 2002.

The BSAC Directors are pleased to report that John comes to academia with an insightful industrial perspective from the semiconductor and communications systems industries. He has experience in mixed signal IC design and technical management with Intel, Silicon Systems and TDK Systems. He has entrepreneurial experience as founder and CEO in both spin-out and start-up technology companies. He has been active in IEEE professional activities, as associate editor and guest editor of the *Journal of Solid State Circuits* and as program committee member and subcommittee chair in the *International Solid State Circuits Conference*. He founded and chaired the communications working group of the *PCMCIA Industry Standards Committee*. He has been a recurring collaborator with and beneficiary of university

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ROGER HOWE APPOINTED E.E. ASSOCIATE CHAIR

Roger T. Howe

BSAC Director and EECS Professor Roger Howe has recently been named Associate Chair for Electrical Engineering in the EECS Department, effective July 2002.

In conjunction with his appointment as Associate Chair, he will be responsible for EE-related issues, academic personnel recruitment and promotion cases, and space. He will be responsible for dealing with problems related to the current space crunch and the newly announced delay of the CITRIS-related expansion project in Cory Hall. As Associate Chair for EE, he forms part of the leadership of the EECS Department, which is headed by Prof. Shankar Sastry and includes Professor Jitendra Malik, the new Associate Chair for CS.

He will be relieved from his teaching duties during his three-year term as Associate Chair, which will of course allow him to continue his dedication to BSAC research programs in RF MEMS, bioMEMS, Physical Sensors and self-assembly processes.

We are confident that his extensive research and teaching Careers at MIT, Carnegie-Mellon, and UC Berkeley, his NSF

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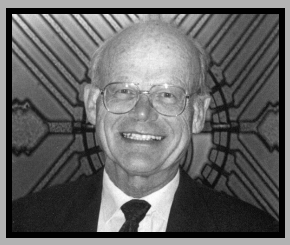
BSAC PROFESSORS IN *SMALL TIMES MAGAZINE*



Think of some of engineering's best and brightest—chances are they were once students of Professor Richard Muller...or a student of his students. Dubbed *one of the most important founding fathers of MEMS*, Richard's contributions and dedication to education has lead to a *MEMS family tree* that includes *'major players at universities, companies, and government institutions,'* and crosses over into the fields of *integrated circuits and microprocessors*. Read about the rich history of Richard Muller, and his stunning accomplishments, including helping develop surface micromachining (with then grad student, Professor Roger Howe), leading the efforts in building the first micromotors, and moving *some of the first MEMS mirrors that later would be found in optical switches* (with Professor Norman Tien). *His willingness to branch out later in life inspires former students*, and inspires us all!

Quotes (italicized) from article in July/August 2002 issue, Volume 2, No. 4. Written by Eric W. Pfeiffer.

There is a fine line between genius and madness, but Professor Kristofer Pister doesn't tread it lightly—he boldly jumps back and forth between the two sides! Yet, it is his brilliant imagination that *developed important cutting-edge tools used in MEMS manufacturing* (including MEMS CAD, a polysilicon hinge, and *a new way to etch MEMS devices using xenon diflouride*) and has made him *one of the most influential and articulate scientists working in MEMS.* Explore the life and motivation behind Kris Pister! Learn about his research into Smart Dust (*little devices capable of sensing movement and temperature in their environment and then wirelessly sending the information back along the network for processing*) and Micro-Robots (*synthetic MEMS insects*)! And hear about his "ground-shaking" quest to build earthquake-resistant buildings!

Quotes (italicized) from article in March/April 2002 issue, Volume 2, No. 2. Written by Eric Pfeiffer.

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BIG NEWS IN SMALL TECH.

MICROBIAL FUEL CELLS TO POWER FUTURE

New Design Promises Medical Breakthroughs

Reprinted from
THE DAILY CALIFORNIAN

By **ATERET HASELKORN**
Contributing Writer

Wednesday, August 28, 2002

An AIDS patient today may require frequent doses of potent drug cocktails every single day.

Aiming to render such incessant pill-popping obsolete, Berkeley researchers have envisioned a tiny, internal drug delivery system that will power the release of essential medicine from within the body.

This scenario may become a reality thanks to the recent work of UC Berkeley mechanical engineering professor Liwei Lin.

Lin and his graduate students have designed a so-called microbial fuel cell that is just .07 square centimeters in area.

The cell generates as much as 300 microvolts for two hours, an amount sufficient enough to operate tiny devices, including microscopic drug delivery systems.

The microbial fuel cell could conceivably power implantable medical devices and aid individuals who require regular doses of drugs.

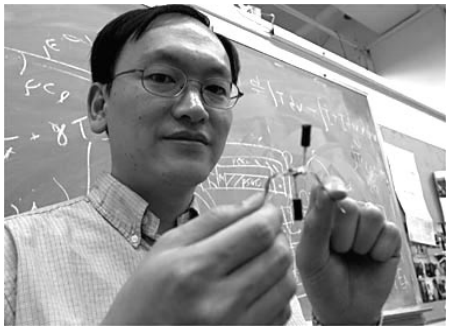
A fuel cell is an electrochemical device that converts fuel energy directly into electrical power.

Apart from its small size, the system is unique because it utilizes glucose, a sugar present in the blood stream, as fuel.

"Nothing is more convenient than drawing power from your own system," said Lin.

Using glucose to drive this 'body battery' provides further benefits.

"(The device) is really a very good energy source because it is renewable. You can get glucose from plants and other sources," said Lin.



MECHANICAL ENGINEERING PROF. LIWEI LIN *holds a microbial fuel cell that promises to revolutionize medical treatment by harnessing the body's own energy reserves to power tiny drug delivery devices.*

Lin's microbial system uses Saccharomyces cerevisiae, also known as Baker's Yeast, to ferment glucose and produce protons and electrons from the hydrogen contained within. The electrons produced supply current to any device attached to the fuel cell.

The byproducts of this process are carbon dioxide and water, substances that the body can naturally filter out.

The use of Baker's Yeast to run the microbial system is another positive characteristic of Lin's work that has sparked interest among the broader scientific community.

"S. cerevisiae is a remarkably benign organism." said Princeton University molecular biology professor Mark Rose. "(It) is one of the safest microorganisms that we commonly come into contact with."

A number of challenges must be overcome before microbial fuel cells can be used to run implantable medical devices.

"These (obstacles) include the means of safely extracting glucose from human fluids and safely exhausting the waste products, carbon dioxide and water, of the fuel cell," said Jacob Brouwer, Associate Director of UC Irvine's National Fuel Cell Research Center.

Lin has already designed two Micro-Electro-Mechanical Systems (MEMS) that could make use of microbial fuel cells, each being comparable to a penny in size.

The first such device is a drug delivery system that would use the fuel cell to pump water into a chamber.

The incompressibility of water would then cause a diaphragm to expand and push a specific amount of drug into the bloodstream of a patient.

Lin's second MEMS is a photosynthetic cell that will use carbon dioxide to create glucose, enhancing the body's energy stores.

Graduate student Mu Chiao, the primary author of the team's most recent publication, hopes to apply the microbial fuel cell to the treatment of diabetes.

"(One) can have long term monitoring of the blood glucose level," said Chiao.

Article available at:
www.dailycal.org/article.asp?Id=9239

JOHN HUGGINS, EXECUTIVE DIRECTOR

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researchers (particularly UC Berkeley) in mixed signal design.

John has claimed that the greatest commercial successes of which he has been a part, have all had a common denominator: supplementing inside expertise with outside collaboration and co-development to enable and accelerate commercial product development. This experience, of working with companies seeking advantages and leverage through collaboration, was important to the BSAC Research Directors in filling the Executive Director position. Moreover, we're pleased to say that John is sure to foster ever-better relations between all our industrial members and the BSAC organization.

In the coming weeks and months, John will be particularly interested in learning more about BSAC member companies, their research interests, and key tie-ins to BSAC research projects. He views a primary goal and responsibility of the Executive Director will be to help Industrial Members realize real advantage from their participation.

That will also mean working with Research Directors and Industrial Members to rationalize, explain, augment and accelerate the exciting but complex array of multi-disciplined BSAC projects in contextual terms, to illuminate possible applications to members' industrial processes and products.

The BSAC Directors and researchers are highly receptive to industrial guidance that improves the relevance and impact of their work. Another of John's goals will be to help the BSAC Directors and researchers further understand Industrial Members' technical obstacles and needs.

John can be reached at 510.643.5663 in his BSAC office at 483 Cory Hall; or on his cell phone at 510.847.7687. His BSAC email address is jhuggins@eecs.berkeley.edu.

BERKELEY SUMMER INSTITUTE

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ace-micromachining, and LIGA. Other advanced topics covered included: plastic MEMS, such as micro hot embossing, micro injection molding, and plastic micromachining; and MEMS processes such as integrated microshell, wafer bonding, and flipchip bonding as applications to MEMS packaging.

BioMEMS

This course introduces BioMEMS, biocompatible polymer-based microdevices, and the growing applications of biomedical micro- and nanotechnology to biotechnology and medicine. It provides a cross-sectional view of the broader biomedical microsystem, with emphasis on practical microsystem fabrication design and biocompatible issues. It begins with a review of fundamentals of biosensors and immobilization of biological components on nano and microdevices. Other topics include lab-on-a-chip, neural prosthesis, enzyme electrode, immunoassay microsystem, calorimetric microsensors, micro piezo-electric transducers, amperometric biosensors, and glucose sensors as applications of BioMEMS.

Parametric Design of MEMS

This course will cover the mechanical design issues in MEMS. After a review of MEMS applications (focused on mechanical aspects), the design, parametric design, and optimal design of flexural elements in MEMS accelerometers, disk drives, and gyroscopes are presented, with emphasis on controlling the stress level in the MEMS material. *(Tentative course)*

Optical MEMS in Communication and Sensing

Optical MEMS (MicroElectro-Mechanical Systems) has created a new fabrication paradigm for optical devices and systems. Using tools developed for the integrated-circuits industry, optical MEMS brings unprecedented levels of miniaturization and integration to optical systems. The payoffs are increased functionality and performance, as well as sharply reduced cost, which enable a variety of applications. Optical MEMS is transforming the telecommunications infrastructure by providing all-optical switches that enable high-capacity networks, and has increasing impact on other information technology applications including displays, imaging, medical diagnostics, environmental monitoring, and remote sensing. *(Tentative course)*

Berkeley Summer Engineering Institute MEMS Short Course FACULTY

Luke P. Lee - Assistant Professor in Bioengineering Dept, Director of BSAC.

Dorian Liepmann - Associate Professor in Bioengineering and Mechanical Engineering Depts, faculty member of the Joint Graduate Group Bioengineering at UCB and UCSF, Director of BSAC.

Liwei Lin - Associate Professor in Mechanical Engineering Dept, Associate Director of BSAC.

Richard S. Muller - Professor in Electrical Engineering and Computer Sciences Dept, Founder and Director of BSAC.

Albert P. Pisano - FANUC Chair of Mechanical Systems in Mechanical Engineering Dept, jointly appointed to the Electrical Engineering and Computer Science Dept; Director of the Electronics Research Laboratory, Director of BSAC.

Kristofer S.J. Pister - Associate Professor in Electrical Engineering and Computer Sciences Dept, Director of BSAC.

Norman C. Tien - Associate Professor in Electrical and Computer Engineering Dept at UC Davis, Director of BSAC.

Albert William (Bill) Flounders - Technology Manager of UCB Microfabrication Laboratory.

Ernest "Charlie" Hasselbrink - Assistant Professor in Mechanical Engineering Dept at University of Michigan, Ann Arbor.

Joseph S. Schoeniger - Principal Member of the Technical Staff, Sandia National Laboratories, Livermore, CA.

Anup K. Singh - Chemical Engineer from North Carolina State University, Senior Research Scientist, Sandia National Laboratories, Livermore, CA.

Olav Solgaard - Associate Professor in Electrical Engineering Dept at Stanford University.

Kirt R. Williams - Member of the Technical Staff, Agilent Technologies, Palo Alto, CA.

UC Berkeley Summer Engineering Institute

For more information:

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ROGER HOWE, ASSOCIATE CHAIR

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Presidential Young Investigator Award, and his prolific publications and patent portfolios have prepared him for the ultimate challenge of mitigating the space problems within Cory and BSAC. At the very least, Professor Howe's great disposition, engaging personality and enthralling oratory will help all of us feel better about it.

His new administrative office is in 231C Cory Hall, in the main EECS Department Office, but he can also be found in 485 Cory Hall. You can reach him at 510.643.7263 or call Robin Lake in the BSAC office at 510.643.6690.

DARPA APPOINTS 3RD BSAC'ER TO MANAGER

There's no doubt that BSAC entails some of the most important and influential directors and researchers of all time. Clark Nguyen is carrying on this tradition of excellence as the third manager of the MEMS program at the Defense Advanced Research Projects Agency (DARPA).

DARPA was previously managed by Professor Albert Pisano, who was followed by BSAC graduate William Tang. Tang is now succeeded by Clark Nguyen, "an engineer at the University of Michigan, vice president of the startup Discera Inc.", and also a BSAC graduate.

"Nguyen's challenges will include taking a more mature technology into a variety of applications, and possibly tackling some of the industry's infrastructure problems. He'll work as overseer and liaison among big business, startups, research labs and defense, and get a first-hand look at how government works."

As BSAC continues to grow, our researchers will continue to lead the way into the future.

Quotes and information from *Small Times Magazine*, July/August 2002 issue, Volume 2, No. 4. Written by Candace Stuart.

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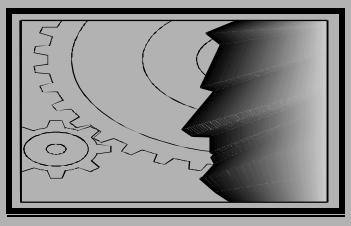
DEGREES EARNED



Colby Bellew Ph.D.
An SOI Process for Integrated Solar Power, Circuitry and Actuators for Autonomous Microelectromechanical Systems

Mu Chiao Ph.D.
MEMS Packaging by Rapid Thermal Processing

Carl Chang Ph.D.
A Magnetically Actuated Scanning Platform for Intravasular Ultrasound Imaging

Tsung-Lin Chen Ph.D.
Design and Fabrication of PZT-Actuated Silicon Suspensions for Hard Disk Drives

Robert Conant Ph.D.
Micromachined Mirrors

Kelvin Fu Ph.D.
Miniature-Scale and Micro-Scale Rotary Internal Combustion Engines for Portable Power Systems

Michael Helmbrecht Ph.D.
Micromirror Arrays for Adaptive Optics

Kirk Seward Ph.D.
Microfabricated Parylene Microneedles and Pneumatic/Hydraulic Actuators for Use in Interventional, Transvascular Drug Delivery

Michael Vestel Ph.D.
Effect of Devitrification Temperature on the Microstructure of NiTi Films

BSAC Researchers presented 18 papers at the Hilton Head 2002 Conference.

BSAC is currently a $7 million enterprise with 20 senior faculty members and over 100 graduate students.

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STAFF UPDATES

BSAC STILL GROWING!

Victor Faessel
Grant Administrator & Executive Assistant

Victor Faessel began at BSAC in May 2002 and is busy assisting Executive Director John Huggins with Industrial Membership issues, including member relations, recruiting, and IAB coordination. Before joining BSAC he helped coordinate the EECS Industrial Relations Office. His BA in political science was earned at San Diego State University. He has studied comparative religion and myth at universities of Chicago, Vienna (Austria), and Pacifica Graduate Institute, where he received his MA and is currently writing a doctoral dissertation.

Robin Lake
Administrative Assistant

Robin Lake has been at the BSAC front desk since February 2002, beginning in EECS one day prior to last fall's memorable IAB! Robin earned a BA in English and a MS in Educational Counseling from Cal State University, Los Angeles. She brings extensive educational experience to BSAC, including 15 years at Golden Gate University and 2 years at Treasure Island Job Corps. But nothing, she notes, tops being honored as Rookie of the Semester by EECS coworkers!

Rochelle Vaughn
Grant Administrator

Rochelle Vaughn joined BSAC in May 2002. She has a BA from Grambling State University and a Non-Profit Management Certificate from CSU Hayward. In addition to significant administrative experience at UCB, she was a member of the City of San Francisco's Housing Authority "recovery team" that re-established the agency's credibility. She has also taught in the Oakland elementary schools.

MIKE YOUNG'S DEPARTURE

On August 1, 2002, Mike Young left BSAC to accept a position with Intel at Fab 13x in Albuquerque, NM. Mike will be responsible for installation, training and sustaining engineering of the 193nm lithography line. The line will consist of approximately 50 steppers. Congratulations and best wishes to Mike in this challenging and exciting new position!

Mike reports that he enjoys watching the balloons rise across the desert in the early morning. We wonder if this is how he now commutes to work!