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PiezoMEMS Research at the US Army Research Laboratory

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Mid-Atlantic Micro-Nano Alliance Mission Statement:

To network expertise, capabilities, and research to facilitate the development of new applications and commercialization of miniaturization technologies.

Piezoelectric microelectromechanical systems (PiezoMEMS) offer the opportunity for high sensitivity sensors and large displacement, low voltage actuators covering a very wide application space. In particular, recent advances in the deposition of perovskite thin films point to a generation of MEMS devices capable of large displacements at complementary metal oxide semiconductor-compatible voltage levels. There are a number of available reviews on the piezoelectrics and piezoelectric coefficients of interest for MEMS.[1,2 ,3]

For nearly a decade, ARL has been investing in RF MEMS for applications ranging from tactical radios for secure communications to phased array radars for missile seekers and satellite-communication-on-the-move. The core areas of research have been in switch technologies, phase shifters, resonators and filters, and mechanical logic. PiezoMEMS actuators have enabled the development of RF MEMS switches with insertion loss better than -0.5 dB up through 40 GHz and isolation better than -20 dB using an actuation voltage at 10 volts or less and capable of operation from -55°Cto 125°C (see Figure 1). Current device yields range in the 70 – 85% range without process optimization. Another active area of research is in the development of mechanical logic elements for integrated control of PiezoMEMS phase shifters, mm-scale robots, and other energy-constrained and low-speed applications. The RF MEMS switch can be scaled and reconfigured to create logic elements, in this case an inverter, such as XORs, AND and NAND gates, and single and multi-stage ring oscillators. If one scales the switch technology properly, the drive voltages can be reduced to 100 mV or less and reaching propagation times in the tens of nanoseconds. Lastly, to address the filtering requirements in tactical communications, ARL has been developing a monolithically integrated switchable filter technology combining PZT based switches with PZT based contour mode resonators and filters (see Figure 1).

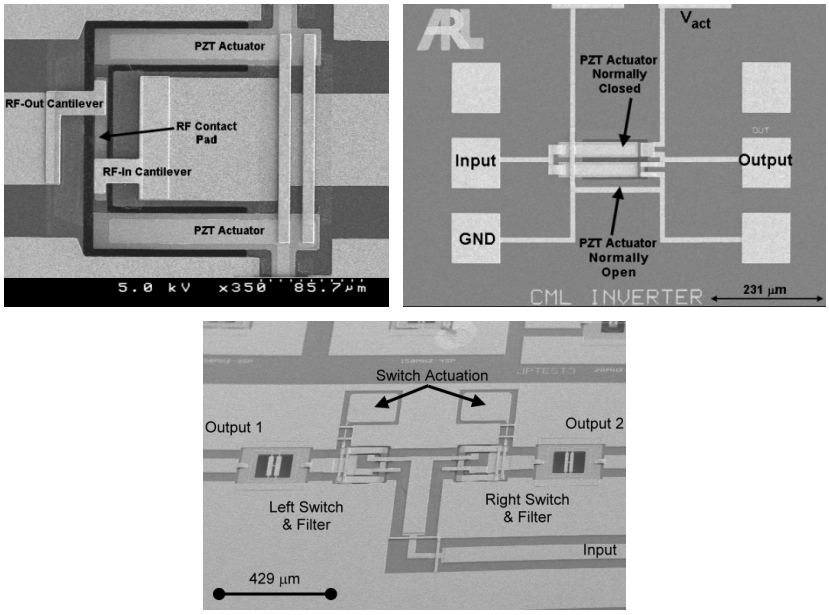

Figure 1: SEM images of a PZT actuated PiezoMEMS Switch (left), PiezoMEMS inverter using a normally open and normally closed switch configuration (center), and monolithically integrated PiezoMEMS switch PiezoMEMS contour mode filters (right).

Chairperson's Notes- Shaping up our next major Event!

. ***The program and schedule for the 2010 Mid-Atlantic Micro/Nano Alliance Symposium (Tuesday, October 19) is taking shape, and we are expecting to release complete details in next month's newsletter. The topic of the symposium will be the commercialization of micro and nano-technology, with our goal being to bring together leaders in the Mid-Atlantic region from private enterprise, academia and the government to interact and exchange information regarding the commercialization of miniaturization technology in our region.***

For the researcher who is building her research program to solve relevant and important problems, the entrepreneur interested in taking innovative technology to the market, to the tech-transfer professional who is trying to connect these two groups: all of us have a stake in moving technology along the development spectrum to the point where it can be widely adopted and utilized. This year's symposium will explore ways in which this process can be executed effectively, and should be of interest not only to industrial participants, but also to researchers interested in what it takes to spin out a technology, or students getting ready to enter the job force and considering private industry.

As usual, we will hold a poster session with contributions solicited on all aspects of microtechnology, MEMS, and nanotechnology. A cash award will be offered for the best student poster, however anyone (student or otherwise) is encouraged to submit a poster. Please look for a formal call for posters in the middle part of June, to include submission details. This is a great time for MEMS Alliance members (which means anyone reading this newsletter) to get involved with the planning stages of this upcoming symposium, and you are highly encouraged to contact us with your ideas. We have a short list of keynote speakers, however we would be very interested to hear your ideas for potential speakers who have successfully taken a technology from the laboratory to the marketplace. In addition, we are seeking ideas for short technical platform talks. Compared to the keynote talk, these will be shorter (20 minutes), more technically focused, and prospective rather than retrospective. We are seeking platform speakers who can describe their current research program and highlight both the market pull and the future challenges to commercialization.

As always you can email comments or suggestions directly to me at brianj@sbmicrosystems.us. We look forward to hearing from you!

Best regards

Brian Jamieson

Save the Date: The next Mid Atlantic Micro-Nano-Alliance Symposium is scheduled for October 19th, 2010 at the Kossiakoff Center JHUAPL Laurel MD!

ARL Research (continued from page 1)

For the past several years, research within the Sensors & Electron Devices Directorate (SEDD) of ARL has been developing key enabling technologies for MEMS-based millimeter-scale robotic systems. The research is currently comprised of four major thrust areas including ground mobility, bio-inspired micro-flight, reversible adhesives for scansorial robotics, and energy harvesting. ARL is exploiting the unique capabilities of PiezoMEMS to provide near biological performance in these actuation, mechanism, and sensing systems required for millimeter-scale robots. For mobility, several integrated piezoelectric actuator technologies have been developed including lateral, rotational, and vertical MEMS actuators that provide large force, large displacement, and ultra-low power consumption solutions. For this application, actuators are being designed to create both the flapping and angle of attack motions used for flight by insects. [4] The current designs (see Figure 2) have enabled 2.5 to 3.0 mm flap amplitude at the tip of 2mm long wings, achieving flap angles of 85º at 4V drive (resonant) along with nearly 35º pitch amplitudes at 25V drive (quasi-static) Although vertical lift has yet to be detected, the improved designs demonstrate many of the required features anticipated to replicate mm-scale flapping bio-mimetic microflight.

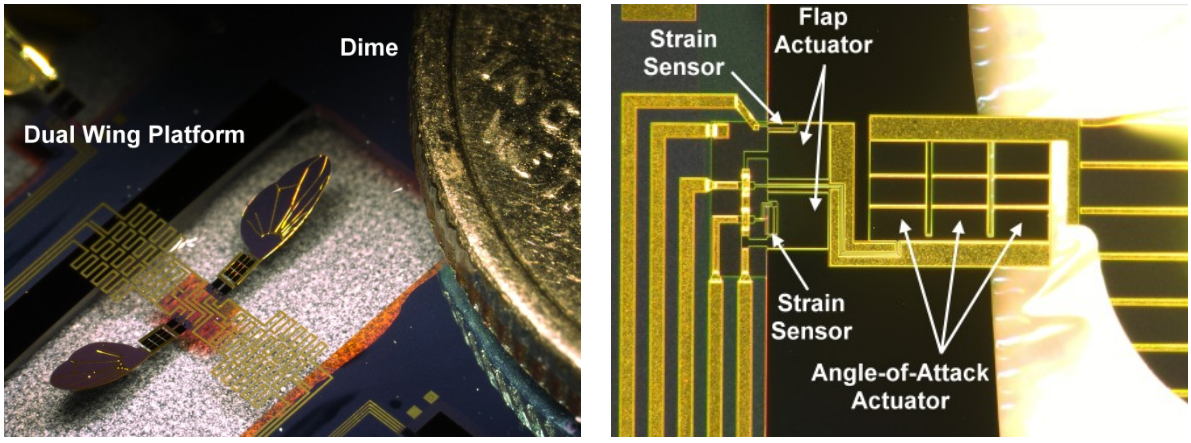

Figure 2: PiezoMEMS actuators for bio-inspired microflight: (left) dual-wing platform suspended with Au springs next to a dime and (right) two degree of freedom actuator (flap and angle-of-attack) combined with integrated piezostrain sensors for feedback.

Acknowledgements:

The authors would like to thank Richard Piekarz, Joel Martin, and Brian Power of the US Army Research Laboratory for their hard work in the fabrication of all the PiezoMEMS devices. Additionally, the authors thank Dr. Madan Dubey and Dr. Brett Piekarski for their overall contributions to work on PiezoMEMS devices.

References:

1) S. Trolier-McKinstry, P. Muralt, *J. Electroceram.* **12**, 7 (2004).
2) P. Muralt, *J. Am. Ceram. Soc.* **91**, 1385 (2008).
3) S.A. Wilson, R.P.J. Jourdain, Q. Zhang, R.A. Dorey, C.R. Bowen, M. Willander, Q. Ul Wahab, S.M. Al-hilli, O. Nur, E. Quandt, C. Johansson, E. Pagounis, M. Kohl, J. Matovic, B. Samel, W. van der Wijngaart, E.W.H. Jager, D. Carlsson, Z. Djinovic, M. Wegener, C. Moldovan, R. Iosub, E. Abad, M. Wendlandt, C.

Business/Research Opportunities

DARPA AND RDECOM

Microscale Rate Integrating Gyroscope (MRIG)

Solicitation Number: DARPA-BAA-10-39
https://www.fbo.gov/index?tab=documents&tabmode=form&subtab=core&tabid=797af24d0ef5ff57aceb59038a3b4ce3

DARPA is soliciting innovative research proposals in the area of microscale inertial sensors, specifically in area of vibratory Microscale Rate Integrating Gyroscopes (MRIG). The MRIG program seeks to develop technology needed to measure rotation over a wide range of dynamic conditions; that is, to operate interchangeably between low-rate and high-rate angular motion while preserving the precision of detection. Proposed research should investigate innovative approaches that enable revolutionary advances in science, manufacturing, devices, or systems. Specifically excluded is research that primarily results in evolutionary improvements to the existing state of practice

GENERAL INFORMATION **Posted Date:** April 28, 2010 **Response Date:** Jul 20, 2010

NRL BAA-N00173-01, NRL-Wide Broad Agency Announcement, FedBizOpps/CBD 1 May 2010.

Specific research topics of interest include but are not limited to:

BAA 57-09-03 HIGH POWER MICROWAVE TECHNOLOGY,
BAA 57-09-04 AIRBORNE ELECTRONIC WARFARE,
BAA 57-09-05 TOWLINE IMPROVEMENT TECHOLOGIES,
BAA 57-09-06 ADVANCED DISTRIBUTED SENSOR TECHNOLOGIES,
BAA 57-09-08 MILLIMETER WAVE SOLID-STATE POWER AMPLIFIER AND POWER COMBINING IMPROVEMENT TECHNOLOGIES,
BAA 57-09-09 SHIPBOARD ELECTRONIC WARFARE,
BAA 61-09-01 DEVELOPMENT OF MICROSENSORS AND MICROSYSTEMS FOR PHYSICAL,CHEMICAL, AND BIOCHEMICAL APPLICATIONS,
BAA 61-09-02 POWER SOURCE MATERIALS AND SYSTEMS,
BAA 63-09-01 SPINS IN SEMICONDUCTORS,
BAA 63-09-02 QUANTUM INFORMATION SCIENCE AND TECHNOLOGY, TRANSDUCERS, AND SENSOR SYSTEMS,
BAA 63-09-04 MATERIALS SCIENCE OF ENERGETIC THIN-FILM DEPOSITION PROCESSES,
BAA 63-09-08 TUNABLE ELECTROMAGNETIC DIELECTRICS,
BAA 68-09-01 RF VACUUM ELECTRONICS,
BAA 68-09-02 RADIATION EFFECTS RESEARCH,
BAA 72-09-01 REMOTE SENSORS AND IMAGING SYSTEMS,
BAA 72-09-02 OPTICAL INTERFEROMETRY,
BAA 72-09-08 PASSIVE MICROWAVE REMOTE SENSING,

UPCOMING EVENTS (continued)

Sensors Expo & Conference 2010

Donald E. Stephens Convention Center Rosemont, Illinois June 7-9, 2010

Visit http://www.sensorsexpo.com for details! **Electronics & Microsystems**

Nanotech and Microtech 2010 Joint Program Announced

Special Symposia in: Nano Electronics, NanoFab, NanoSimulation, NanoReliability, Inkjet, MEMS Device & Fab

Speakers Include: Lockheed Martin, GE, Eastman Kodak, Toray, Fuji Electric, Sanyo, Omron, Honda, Samsung, Panasonic, Seimens, Dimatix, Accelrys, Intel, IBM, Texas Instruments, Applied Materials, NanoInk, Agilent, SoftMEMS, Raith, Asylum, FEI, Veeco, Wispry, Nextreme, SiTime, TranSiC, Baolab, Microlyne, Microvision, Alces, Sand 9, Bartels, Daimler, Infineon, Bosch, Honeywell, Triad Semiconductor, ST Microelectronics and hundreds of leading researchers from around the world...View Program

Hilton Head Workshop 2010:
A Solid-State Sensors, Actuators and Microsystems Workshop

Crowne Plaza Resort Hilton Head Island, South Carolina June 6 - 10, 2010

The thirteenth in the series of Hilton Head Workshops on the science and technology of solid-state sensors, actuators, and microsystems will be held on June 6-10, 2010.
Attendance will be limited to 450 participants, with preference given to authors.

SEMICON West

2010-07-13 - 2010-07-15
San Francisco, California
Annual event for the global microelectronics industry
For more information: http://www.semiconwest.org/

News bites from the Region

University of Maryland:

Clark School honors Rajkowski, Beyaz, Banerjee for student research Congratulations to three ISR graduate students for their outstanding research accomplishments within the Clark School of Engineering.

Jessica Rajkowski, a Master's level Mechanical Engineering student of Assistant Professor **Sarah Bergbreiter** (ME/ISR) has won the 2010 Dean's Master's Student Research Award Competition. Jessica won the competition for her research, "Rapid Polymer Prototyping for Applications in Low Cost and Robust Microrobots."

Mustafa Beyaz, a Ph.D. Electrical and Computer Engineering student of ISR Director **Reza Ghodssi** (ECE/ISR) won second place in the 2010 Dean's Doctoral Student Research Award Competition for his research, "A MEMS Microgenerator for Small-Scale Power Conversion."

Parag Banerjee, a Ph.D. student in Materials Science and Engineering advised by Professor **Gary Rubloff**, won third place in the same competition for his research, "Nano-Energy Devices."

Integrated Silicon-PDMS Process for Microrobot Mechanisms," a paper written by Assistant Professor Sarah Bergbreiter (ME/ISR) and her students Aaron P. Gerratt and Ivan Penskiy, has won the Best Conference Paper Award at the 2010 IEEE International Conference on Robotics and Automation in Anchorage, Alaska.

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