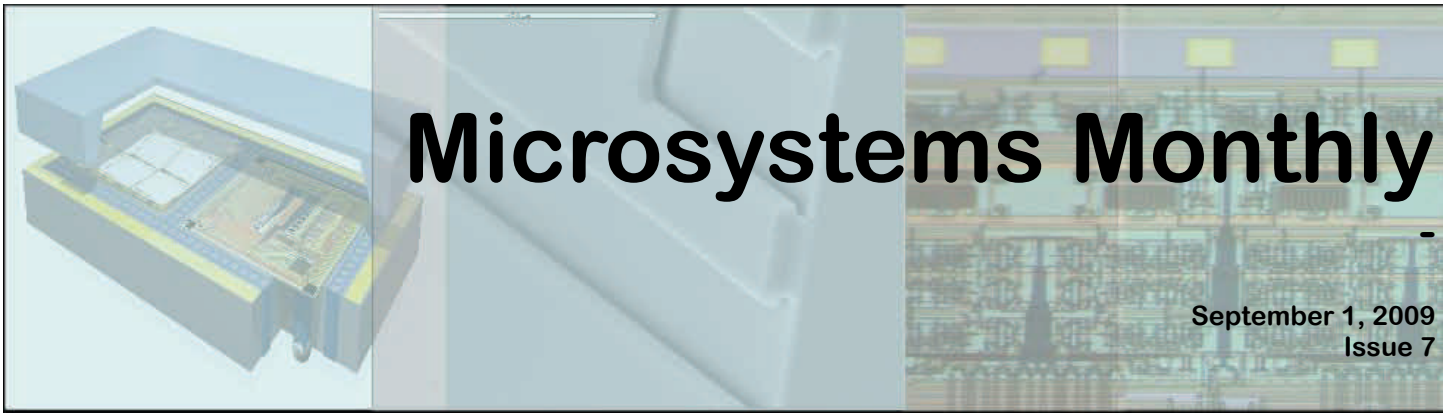

Microsystems Monthly

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Mid-Atlantic MEMS Alliance Mission Statement:

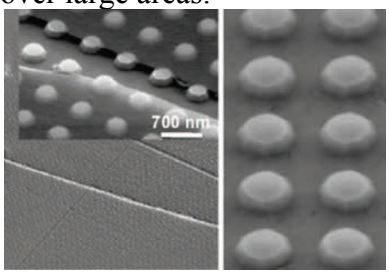
To network expertise, capabilities, and research to facilitate the development of new applications and commercialization of miniaturization technologies.

The Naval Research Lab (NRL) in Washington, DC is the Navy's corporate research lab. *While there is no single MEMS Division, various groups are engaged in active MEMS and microsystems research.*

By M.W. Pruessner, with R.A. McGill, R.S. Pai, J.T. Robinson and T.H. Stievater

Graphene Oxide for High-Q NEMS Resonators

Graphene is a novel material for MEMS/NEMS resonators and is being pursued by NRL researchers, among many others, due to its large Young's modulus, high breaking strength, and low density. Large stiffness-to-weight ratios are desirable for high-frequency and high Q-factor NEMS resonators. However, single- to few-layer graphene has proven difficult to fabricate over large areas.



The 'solution' utilized by NRL researchers is to oxidize graphite, which becomes water soluble and exfoliates as *single* graphene oxide sheets in solution. This approach enables access to the beneficial material properties of graphene and allows large-area, uniform layers to be deposited.

Jeremy Robinson, a researcher in the Electronic Science & Technology Divison at NRL has demonstrated a novel method to develop such large-area, nanoscale thick graphene oxide thin films. Graphene oxide (GO) platelets are suspended in methanol and then spin-coated onto silicon/SiO2 wafers. The resulting films can vary in thickness from a few layers up to tens-of-nanometers. Next, the oxygen in these GO films is partially removed by exposure to a hydrazine hydrate vapor. This forms reduced graphene oxide (rGO) having mechanical properties similar to graphene. The films are subsequently delaminated from the substrate using a basic solution (e.g., NaOH) and floated into a water bath. In order to create NEMS resonators, Robinson used his technique to deposit these *r*GO films onto pre-patterned substrates containing arrays of Si nano-pillars or recessed wells that serve as the anchors of the NEMS resonators. Drum resonators formed in this way display excellent mechanical properties (E≈200 GPa), quality-factors up to Q=4,000, and fundamental resonant frequencies between 10-100 MHz. The performance of the *r*GO NEMS resonators is similar to that expected from graphene NEMS but with the advantage of simple and reproducible processing.

Robinson and co-workers published their work in the prestigious journal *Nano Letters* (2008).

More from NRL on page 6

Dare I Say It?

Shooting from the hip is not a habit that is generally encouraged among engineering and technology researchers. Professional conferences and peer-reviewed journals tend to be conservative avenues for presenting research results, in which speculation and wandering too far afield from one's own area of expertise is frowned upon. In some ways, the entire engineering discipline is conservative, since it can be argued that engineering is the rigorous application of fundamental principles to practical structures, devices and processes in a way that is repeatable and reliable. Yet, as practicing engineers and technologists many of us recognize that there is an important creative component to engineering, and that our best work tends to be that in which disciplined design follows from a more intuitive and creative impulse.

As we look forward to the 2009 Fall Mid-Atlantic MEMS Alliance Symposium, the organizing committee is thinking hard about ways to encourage more speculative discussion and creative brainstorming on the topic of "Micro- and Nano- Technology in the Green Revolution", both during and between our technical sessions. Since its inception in 2000, the MEMS Alliance has organized our Symposia around a broad application area (Biomedical, defense, telecoms, etc.) with the intent that researchers would be encouraged to step outside of their comfort zone and think generally about how a particular technology might be brought to bear on a particular problem. In addition, we have tried to organize our conferences so that we have a mix of technology developers and technology users. This year, we are expecting a presence from the Department of Energy and the EPA, from people giving thought to the next generation power distribution grid and others worrying about in situ pollution and CO_2 monitoring. Clearly, these are watershed problems of the 21st century, and as sensor, microsystems and nanotechnology advocates we can make a big difference here.

There are many MEMS and Nanotechnology conferences out there, and it doesn't make sense to add more of the same to the calendar. One of our most important strengths, and the thing that situates us uniquely, is the remarkable confluence of government, academia and industry that occurs in the mid-Atlantic area, and in particular in Washington DC. More than ever, with this year's Symposium being held in Georgetown, we are urging our members not only to attend the conference, but also to have the courage to get outside of their comfort zone: to allow themselves to be more speculative, to discuss more preliminary results, and to brainstorm creatively with people outside of their normal technical milieu. Rather than offering just a rundown of past and the latest research results, we encourage our speakers to talk about what they might work on in the future, or might try, or have always thought about trying. We hope that attendees who consider themselves more technology users than developers will make it a high priority to attend the afternoon panel discussions (there will be parallel sessions, one for Energy and one for Environmental Sensing) and there to ask impertinent questions along the lines of "have you ever considered…?" or "what if you tried…?" or even, "why can't you just…?" These are not always the questions that are most welcome, or most comfortable to hear as a researcher, but more often than not they are the type of question that prompts new approaches, new collaborations, and novel solutions.

And, as always, we are encouraging participation in advance of the Symposium by anyone reading this newsletter, to contact us and let us know how we can make this a more daring and lively workshop, or to suggest speaker or panel participant ideas. Please feel free to contact me directly for these or any other reasons.

Best regards,

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TEDCO Puts the Spotlight on Available NIST and NIH Bio-Imaging Technologies on October 6th in Gaithersburg!

"*Discover and Commercialize Cutting Edge Bio-Imaging Technologies*" will feature National Institutes of Health (NIH) and National Institute of Standards and Technology (NIST) bio-imaging technologies available for commercialization and/or collaboration on Tuesday, October 6, 2009 at the NIST Main Campus in Gaithersburg.

The unique agenda includes over 20 "fast pitch" technical presentations on new NIST and NIH technologies, as well as:

- over 30 poster sessions
- an exhibit floor for networking with NIST and NIH technology transfer, and other department staff, personally
- a high-level keynote address from both organizations
- 3 special sessions, including "Why Partner/Collaborate with the Fed?" by Mojdeh Bahar, MS, JD, Coordinator, Federal Laboratory Consortium Mid-Atlantic Region, and Chief, Cancer Branch, Office of Technology Transfer, NIH
- Success Stories from award winning nanotechnology and biotechnology companies
- tours of NIST facilities

For more information, and to register, visit www.marylandtedco.org. Registration for US Citizens ends September 30th; non US Citizens registration ends September 21st.

Tech Transfer: TEDCO Supports the Federal Laboratory Consortium Mid-Atlantic Region (FLC MAR) Annual Conference on September 15 - 17 in Gettysburg, PA

The FLC MAR Annual Conference is less than a month away! This year's Conference will provide a range of opportunities to learn how to access and benefit from Federal laboratory expertise, intellectual property and physical assets. The agenda includes sessions on academic/government collaboration, motivating innovation, unique ways to accomplish technology transfer, the marketplace for inventions, the role of inventors in moving toward commercialization, the "human element," ways to conquer the FDA approval process, and more.

Always an advocate of the Federal Laboratory Consortium's work regionally and nationally, TEDCO will have a presence at this year's Annual Conference as a sponsor.

To learn more and register, visit www.flcmidatlantic.org.

Upcoming Events

MEMS Alliance Fall Symposium

MEMS, Nano and Microsystems in the Green Revolution. This conference will explore the role that micro– and nano– technology will play a role in the development of "green" solutions to environmental and energy issues. A :"Stone Soup" problem solving session will link industry and government needs with technology solutions. There will be a poster session with a student award for best presentation. Washington DC **November 30, 2009**. www.mems-alliance.org

PowerMEMS 2009 2009-12-01 - 2009-12-04 Washington DC, USA 9th International Workshop on Micro and Nanotechnology for Power Generation and Energy Conversion Applications
Technical Topics of Interest Include:
Energy scavenging for remote sensors and microsystems
Thermoelectric and photovoltaic materials and systems
Piezoelectric, electrostatic and electromagnetic conversion
Energy management and microsystem integration
Nanostructured materials for energy and thermal management
Micro fuel cells and micro reactors for fuel processing
Micro/nano catalysis, combustion, heat and mass transfer
Micro thrusters and miniature propulsion microsystems
Biologically-inspired energy conversion and cooling
Micro heat engines for power generation and propulsion
Micro and nanofabrication for energy applications
Micro coolers and other thermal management technologies
For more information: http://www.powermems.org/

SPIE Photonics West MEMS MOEMS San Francisco CA **23-28 January 2010**

Local Job Opportunities

AFM Engineer Carbon Nanoprobes, Inc. Malvern, PA USA Carbon Nanoprobes (CNP) is seeking a highly motivated, independent scientist or engineer for further developing and characterizing its line of highly sophisticated atomic force microscopy probes. The individual will be responsible for the experimental planning and execution of a probe characterization initiative and will report directly to senior management. Check out info@cnprobes.com

Parts/Component Engineer The Johns Hopkins University Applied Physics Laboratory Laurel, MD EXPERIENCE: Required: BS degree in math/science (or related field), with minimum 8-10 years equivalent work experience in EEE parts engineering. Comprehensive knowledge of EEE parts engineering activities for NASA space flight programs. Knowledge and application of NASA documents & policies: EEE-INST-002, PPL-21, parts selection, derating, and test. www.jhuapl.edu

Hardware Engineer – PCTEL Germantown MD - RF Solutions Group, is seeking an experienced **Hardware Engineer** to take an active role in leading the development and maintenance of our products to complement its line of wireless network test equipment. Apply online at **www.pctel.com**

Hardware Engineer, CW Controls, Embedded Computing, Leesburg, VA Digital design/ validation using Power PCs, state-of-the-art bridge parts, VME components, etc. Analog power supply design Support of board layout and routing (development of layout and routing rules/ restrictions) Signal Integrity simulation using Hyperlynx software Hardware debug of digital and analog circuits contact www.cwc**embedded**.com/

PROCUREMENT/PROPOSAL OPPORTUNITIES

Request for Information (RFI) for Electronic Environmental and Device Characterization

The Combating Terrorism Division (RD-CXC) of the Defense Threat Reduction Agency (DTRA) is soliciting government, industry, and academia for high quality, innovative, and relevant advanced technologies capable of providing electronic environment and device characterization to support and supplement the Explosive Ordnance Disposal (EOD) community's Render Safe Procedure (RSP) protocols.

Objectives of Electronic Environmental and Device Characterization

There are situations where an Improvised Explosive Device (IED) may be in a place in which its detonation is unacceptable. There are a range of novel technologies that may be useful in preventing the remote detonation of the device. The objectives of this task are to understand the electrical nature of the device and its environment to allow EOD operators to make a rational decision on the next appropriate RSP action. The most preferred approach is to passively detect, identify, and map the environment, electronic components and circuitry within and near the device without changing its state.

The objectives below relate to the effectiveness, selectivity, and understanding of passively and actively detecting and mapping the electronic environment and the circuitry within target devices:

1. Develop technologies that passively characterize the electromagnetic (EM) spectrum from 6 MHz to 6 GHz.
2. Develop technologies that passively detect and map an explosive device (with or without power applied to the device's circuitry) without changing its state.
3. Develop technologies that actively detect and map an explosive device (with or without power applied to the device's circuitry) without changing its state.
4. Develop technologies to do the above described characterization that are vehicle-portable or, preferably, man-portable.

Environmental and Device Characterization: Directly related to objectives 1 and 4, above. EOD operators must accurately ascertain all relevant radiofrequency (RF) energy in the operational environment as well as all RF energy entering and being emitted from the device. A successful proof of concept consists of a detailed RF spectrum analysis of: 1) the operational environment, and 2) the explosive device. Environmental characterization requires technologies that deliver "near perfect" RF information about the environment and the device to include its internal components, their layout, and their status, i.e. charged, armed, etc. Approaches that require significant basic or applied research (i.e. RDT&E categories 6.1 and 6.2) are not desired. Responses shall be submitted no later than 5:00 PM EST on Friday, 2 October 2009 to DTRA, EOD Device Defeat at EODDRFI@DTRA.MIL

https://www.fbo.gov/index?s=opportunity&mode=form&id=1ab07d6639307bbe039a16c06991f7a0&tab=core&_cview=0&cck=1&au=&ck=

IN THE WASHINGTON AREA

TEDCO Funding Briefings at TEDCO's Columbia Office on 10/9

Cut and paste links http://www.marylandtedco.org/calendarofevents/detail.cfm?eventid=254

MIPS Fund for Technology R&D: Applications due 10/15

http://www.mips.umd.edu/

Chesapeake Bay Seed Capital Fund for Qualifying Green Companies

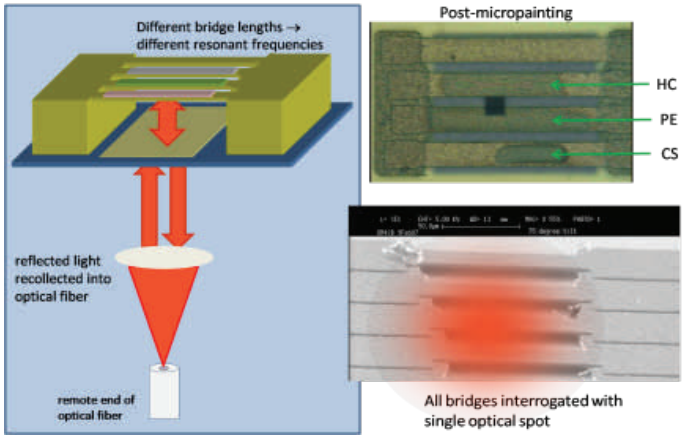
http://www.mtech.umd.edu/funding/cbsc/index.html

SAIC-VentureAccelerator Competition: Applications Being Accepted

http://www.mtech.umd.edu/funding/saic/index.html

NRL—continued Optical MEMS Chemical Sensors

Researchers in the Optical Sciences Division at NRL are combining integrated optical and mechanical resonators to develop novel chemical sensors. Todd Stievater is the lead author of a paper in which he compares the devices to "photonic microharps," where the microharp is "plucked" and "listened to" via two laser beams set at different optical wavelengths (*Optics Express*, 2008). The first laser serves to locally heat the gold microbridges and excite their mechanical resonances. A second laser is then used to measure the displacement as well as frequency of oscillation.



In order to function as *chemical* sensors, the MEMS bridges are coated with chemo-selective polymers, developed in-house at NRL. Upon exposure, the polymer adsorbs the chemical vapor leading to an increased microbridge mass. The result is a downshift in the bridge's natural frequency – a shift that directly correlates to the chemical vapor concentration in the environment. Stievater's group has demonstrated simultaneous actuation and measurement of 1x4 microbridge arrays, each bridge being coated with a unique chemo-selective polymer for increased chemical selectivity. The work has received considerable attention and has been featured in *Science* (2008) and *Optics and Photonics News* (2008). The group is aiming to create even larger sensor arrays by coupling MEMS resonators with optical waveguides.

Marcel Pruessner is leading an effort to develop silicon optical waveguide Fabry-Perot microcavities that are coupled to microbridge resonators. The approach is similar to the microharp sensors, but with the advantage of integrated waveguides to measure many sensors, potentially hundreds, on a single-chip. This work was recently presented at the *Transducers '09 (* Denver, CO.).

Sorbent Materials & Coating Techniques for Chemical-Sensor Applications

MEMS devices for chemical sensing are an active research area at NRL. The chemistry of the sorbent polymers to a large part controls the ultimate sensitivity and selectivity of these sensors. Dr. R. Andrew McGill and his research group in the Materials Science and Technology Division have been developing novel sorbent materials for the past twenty years to sorb and trap vapors from illicit materials with inherently low vapor pressures. An evolution of this work has led to the design and synthesis of hyperbranched hydrogen-bond acidic polycarbosilanes, which offer excellent physicochemical properties for the detection of hazardous hydrogen-bond basic analytes. The polycarbosilanes developed offer a low glass transition temperature (T_g) while maintaining their thermal and chemical stability over time. These properties allow for simple coating solutions, which at normal thicknesses and under ambient temperatures resist gravity driven flow. A hexafluoroisopropanol functionalized hyperbranched carbosilane polymer synthesized by McGill's team offers a useful thermal stability up to 260 ºC, and has been demonstrated as a viable coating on MEMS based devices through millions of thermal cycles in air to approximately 200 ºC.

In a parallel effort to develop chip-sized analytical systems, McGill's group is studying techniques for depositing sorbent materials on MEMS based preconcentrators, gas chromatographs and cantilevers fabricated in-house. Polymer coating becomes especially challenging when arrays of sensors in close proximity are to be coated with different sorbents. One technique being used utilizes a commercial ink-jet technique to print the polymer (directly) on the device. A second technique being explored is micro-painting, in which a needle with micron tip size is used to "paint" a polymer on the MEMS device. Although this latter technique is currently time-consuming, it enables coating devices with minimum feature sizes as small as two microns.

In principle, smaller feature sizes are possible with this general approach. For higher throughput, resonant infrared pulsed laser deposition has been used to non-destructively deliver polymers to MEMS platforms. When used in conjunction with an appropriate mask, specific areas of a device can be coated with the desired polymer at a controllable thickness.

A review paper on past and recent NRL efforts in developing sorbent polymers for chemical sensing was presented at the 17th University/Government/Industry Micro/Nano Symposium

(R.S. Pai et al., *Proc. UGIM) 2008*).