MEMS and NEMS
Room: Santo Domingo - Session MN-ThA

Integration, Packaging and Reliability of MEMS and NEMS
Moderator: M. Metzler, Cornell University

2:00pm **MN-ThA1 Electrothermal Tuning of Bistability in a Large Displacement Micro Actuator**, ***Y. Gerson***, Tel Aviv University, Israel, *R.B. Ilic*, Cornell University, *S.L. Krylov*, Tel Aviv University, Israel

We report on an approach allowing efficient tuning of the bistability properties in large displacement micro actuators. The devices fabricated from highly doped silicon on insulator (SOI) wafers using Deep Reactive Ion Etching (DRIE) based process incorporate elastic suspension realized as a pair of initially curved beams and are operated electrostatically by a comb-drive transducer. The tuning principle is based on the control of the initial elevation and consequently of stability characteristics of the suspension by passing a current through the beams and electrothermal heating of the beams's material. Experimental results, which are in good agreement with the Finite Elements model predictions, demonstrate the feasibility of the suggested approach and show that the application of a tuning current significantly increases the device deflection and allows efficient control of the critical snap-through and snap-back voltages.

2:20pm **MN-ThA2 Measured and Predicted Temperature Profiles along MEMS Bridges at Pressures from 0.05 to 625 Torr**, ***L.M. Phinney***, *J.R. Serrano, E.S. Piekos, J.R. Torczynski, M.A. Gallis, A.D. Gorby*, Sandia National Laboratories

We will present experimental and computational investigations of the thermal performance of microelectromechanical systems (MEMS) as a function of the surrounding gas pressure. Lowering the pressure in MEMS packages reduces gas damping, providing increased sensitivity for certain MEMS sensors; however, such packaging also dramatically affects their thermal performance since energy transfer to the environment is substantially reduced. High-spatial-resolution Raman thermometry was used to measure the temperature profiles on electrically heated, polycrystalline silicon bridges that are nominally 10 microns wide, 2.25 microns thick, 12 microns above the substrate, and either 200 or 400 microns long in nitrogen atmospheres with pressures ranging from 0.05 to 625 Torr. Finite element modeling of the thermal behavior of the MEMS bridges is performed and compared to the experimental results. Noncontinuum gas effects are incorporated into the continuum finite element model by imposing temperature discontinuities at gas-solid interfaces that are determined from noncontinuum simulations. The experimental and simulation results indicate that at pressures below 0.5 Torr the gas-phase heat transfer is negligible compared to heat conduction through the thermal actuator legs. As the pressure increases above 0.5 Torr, the gas-phase heat transfer becomes more significant. At ambient pressures, gas-phase heat transfer drastically impacts the thermal performance. The measured and simulated temperature profiles are in qualitative agreement in the present study. Quantitative agreement between experimental and simulated temperature profiles requires accurate knowledge of temperature-dependent thermophysical properties, the device geometry, and the thermal accommodation coefficient.

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2:40pm **MN-ThA3 Micro- and Nanoswitches: Materials, Design, Packaging and Reliability**, ***M.P. De Boer***, Sandia National Laboratories, *D.A. Czaplewski*, Argonne National Laboratory, *M.S. Baker*, Sandia National Laboratories **INVITED**

Ohmic micro- and nanoswitches are of interest in numerous potential applications including phased-array radars, cell-phone circuitry, circuit breakers and power savings in advanced CMOS circuits. However, many challenges remain with respect to materials, design, packaging and reliability. An important issue is maintaining a low contact resistance as switch cycling approaches high counts. In this talk, a prototype ohmic microswitch will be presented, and its electrical performance when coated by Pt and Ru films will be compared. A whole-wafer singulation, post-processing and metallization process will be demonstrated. Then, a nanoswitch design will be introduced and initial results including processing and test will be discussed. Continued progress in micro- and nanoswitch technology will lead to insertion in multiple applications.

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3:40pm **MN-ThA6 Bulk Focused Ion Beam Fabrication of Nanoelectromechanical Systems**, ***W.K. Hiebert***, *D. Vick, V. Sauer*, National Institute for Nanotechnology (NRC Canada), *A.E. Fraser, M.R. Freeman*, University of Alberta, Canada

Although the focused ion beam (FIB) has previously been used for fabrication of nanostructures and devices, including MEMS and NEMS, FIB nanomilling out of bulk material has rarely been discussed. In this talk, we will present our methods and results for using FIB to fabricate NEMS devices out of bulk materials. Ion impingement from multiple directions allows sculpting with considerable 3-dimensional control of device shape, including tapering and notching. The tailoring of large gaps between device layer and bulk allows large amplitude NEMS motion, access to a nonlinear readout regime, and a novel calibration method for optical interferometric displacement detection. Finite element modeling of device frequencies agrees with interferometric measurements, including for the effect of a localized notch. The measurements are sensitive enough to determine the thermomechanical noise floor of a bulk FIBed NEMS device with displacement sensitivity of 166 fm / $Hz^{1/2}$, limited only by a combination of optical shot noise and detector dark current. We envision that bulk FIB fabrication will be useful for NEMS prototyping, milling of tough-to-machine materials, and generalized nanostructure fabrication with 3-dimensional shape control.

4:00pm **MN-ThA7 NanoFIBrication of UHAR Vias Using a Material Shaping Technique for Phononic Crystals**, ***D.F. Goettler***, *Z.C. Leseman*, University of New Mexico

In this paper we present both experimental and theoretical results showing the effective use of material shaping to fabricate ultra-high-aspect-ratio (UHAR) vias with a focused ion beam (FIB). With this technique, one can create vias with aspect ratios of 50:1 and higher. This is achieved by placing a 'lower sputter rate' material on top of a 'higher sputter rate' material. We model the FIB as a Gaussian beam with an angular dependent sputter rate. With our model we predict a high sputter rate ratio (high/low) can achieve vias with aspect ratios near 50:1. Experimental results support this prediction. By placing a thin layer of pyrolized carbon on top of silicon, we fabricated UHAR vias. For completeness, we also reversed the sputter rate ratio by placing a 'higher sputter rate' material on top of a 'lower sputter rate' material. Once again, experimental results support the model's predictions. Vias with radii 15 nm have been NanoFIBricated. Using these techniques we have created phononic crystals operating in the GHz regime.

4:20pm **MN-ThA8 Highly Robust Hydrogen Selective MEMS Nanogap Sensor Utilizing the Schottky Barrier at Electrode/Sensing Material**, ***A. Kumar***, *P. Zhang, H.J. Cho, S. Seal*, University of Central Florida

The growing need to explore hydrogen as a near future fuel demands a robust hydrogen sensor which offers high sensitivity, selectivity and response time in order to avoid the danger associated with storage, transportation and use of this highly combustible gas. The sensor platform with Au interdigitated electrodes (IDE) having 8 fingers in each electrode and a gap of 100 nm was fabricated using E-beam lithography on a silica substrate. The Au IDE was dip coated with sol-gel preparation of nanocrystalline 6.5 mol % Indium oxide (In_2O_3)- doped tin oxide (SnO_2) to yield an excellent thin film room temperature hydrogen sensor. The variation in the I/V response of the sensor with atmosphere suggested that the Schottky barrier height could be modulated to sense hydrogen and utilizing this a large sensitivity (~2000) and fast response time (~27 seconds) was observed at a low applied voltage of 0.4 V in 0.09 vol% hydrogen gas atmosphere. The sensing characteristics were severely affected in presence of moisture (>40%). Various polymeric coatings on the sensor were compared in an effort to make the hydrogen sensor robust even in high moisture environment. It was observed that the fluoropolymer coatings improved the sensor behavior in varying moisture environment without deteriorating other characteristics such as sensitivity, response time and recovery of a sensor.

4:40pm **MN-ThA9 Development of Lab-on-a-chip on Mn Induced Nano-arrayed Structures in Sol-gel Derived TiO2 Platforms for Biosensing Applications**, *R.R. Pandey*, Centre for Cellular and Molecular Biology, India, *K.K. Saini*, National Physical Laboratory, India, ***M. Dhayal***, Centre for Cellular and Molecular Biology, India

Development of low cost point-of-care diagnostic system for effective health care is important for rapid screening of routing biochemical tests. To address this, we have used sol-gel derived process in which Mn induced nano-arrayed structured were developed in TiO2 as a platforms for lab-on-a-chip. Mn doped nanopore TiO2 platforms were prepared by using wet chemistry deposition with the help of metal alkaloxide precursor and assembled with micro-fluidics networks to screen multiple interactions. To demonstrate usefulness of this, enzymatic biocatalyst has been used to determine the specificity of multiple interactions on these platforms. These platforms has been characterized by XRD, XPS, FTIR, SEM, cyclic voltametry to determine structure, surface chemistry and electron transfer characteristics for biosensor applications. Mono-enzyme ChOX, urease and GOX were prepared by immobilizing the separate enzymes onto nanopore TiO2 surfaces modified with Mn doping. The electrochemical detection sensitivity for detection of low concentrations of cholesterol, urea and glucose has been enhanced.

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