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MICROMACHINED MICRODEVICES AND MICROINSTRUMENTS

N. C. MacDonald, S. G. Adams[#], A. A. Ayon[*], K. F. Böhringer[¥], L.-Y. Chen, J. H. Das, D. Haronian, W. Hofmann, X. T. Huang, A. Jazairy, R. E. Mihailovich, S. A. Miller[†], I. Ogo, R. Prasad[§], B. W. Reed[†], M. T. A. Saif, K. A. Shaw, R. Y. Webb, and Y. Xu

School of Electrical Engineering, [†]School of Applied and Engineering Physics, [¥]Department of Computer Science, [§]School of Mechanical and Aerospace Engineering, *School of Nuclear Science and Engineering, [#]Department of Theoretical and Applied Mechanics, and the National Nanofabrication Facility
Cornell University, Ithaca, NY 14853-5401

N. C. MacDonald, Email: nmacd@ee.cornell.edu, Tel: (607) 255-3388, Fax: (607) 254-4777

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The microfabrication technology originally developed for integrated circuit manufacturing has seen a large expansion into the field of MicroElectroMechanical Systems (MEMS). The goal has been to integrate sensors and actuators with electronics on the same chip and provide distributed detection and manipulation capabilities. We present a suite of microanalytical instruments for application in the fields of mechanical testing, actuator design, field emission, acceleration measurement, acoustics, optics, bipolar transistor design, and STM scanning and manipulation; all of which were fabricated using variations on two processes.

Primarily our applications consist of high-aspect-ratio bulk-micromachined single-crystal-silicon MEMS fabricated using variations on the Single Crystal silicon Reactive Etching And Metallization (SCREAM) process. Current processing technology work aims at further increasing the aspect ratio to 100:1 while maintaining a submicron lateral feature size, integration with novel and traditional circuit technology, and MEMS integrated with sharp silicon tips (< 20nm tip radius). A subset of the instruments being presented consist of surface-micromachined suspended tungsten microstructures. Highlights of the versatility that this technology offers include multiple level structure definition using the Selective Tungsten Multiple-Level Planar Process (STUMPP) and the fabrication of self-aligned submicron aperture extraction electrodes for field emitter tips.

The above processing capabilities have been applied to the fabrication of a wide variety of microdevices and microinstruments. We have built structures to study the mechanical properties of MEMS such as buckling and other stress related phenomena (Fig. 1), friction, wear, and the effects of electron and ion radiation damage on MEMS resonators. We have designed actuators to tune the effective stiffness and hence the resonant frequency of a resonator (Fig. 2) and are incorporating them in a novel design for a highly sensitive, wide dynamic range accelerometer. An array of coupled resonators is being investigated to mimic the behavior of the human cochlea by mechanically filtering the acoustic input into frequency bands. Sensorless microactuator arrays have been fabricated to demonstrate distributed manipulation tasks. Bipolar transistors integrated on suspended mechanical beams are being studied as highly sensitive sensors and low-parasitics amplifiers. A variable-function force actuator has been realized using STUMPP; the force generated is an arbitrarily chosen second order polynomial of the applied voltages (Fig. 3). Arrays of sharp Si field emitters with self-aligned gate electrodes have been fabricated and characterized. Series resistors, suspended heaters (Fig. 4) and multiple planar tungsten electrodes (forming electrostatic lenses) have been integrated to improve device performance. High aspect ratio Si tips have also been integrated onto MEMS xyz actuators. These devices have been operated as Micro-Scanning Tunneling Microscopes and have imaged a metal conductor on a silicon chip (Fig. 5). Lateral Si tips with an optional metal (or silicide) coating were made using a variation of the tip process. An out-of-plane Si Fabry-Pérot interferometer with high aspect ratio movable mirror facets has been built using a modified SCREAM process and tuned by moving the mirrors using integrated actuators (Fig. 6). Tunable microwave transmission lines have been realized using suspended metal coated Si beams. The use of the actuators to change the impedance has been demonstrated.

Our microfabrication capabilities provide an enabling technology for the development of a suite of microanalytical instruments. We will present extensive design, fabrication and performance data on the devices listed above.

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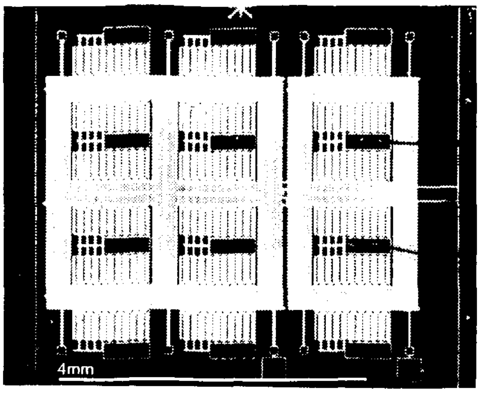

Figure 1. Milli-Newton micro loading device with 4x5 mm^2 size and 11.75 μm depth.

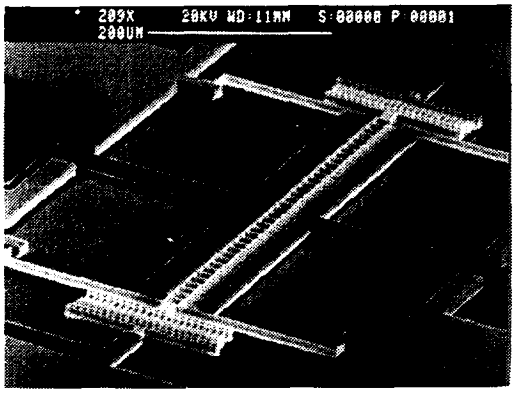

Figure 2. A capacitance based tunable MEMS resonator.

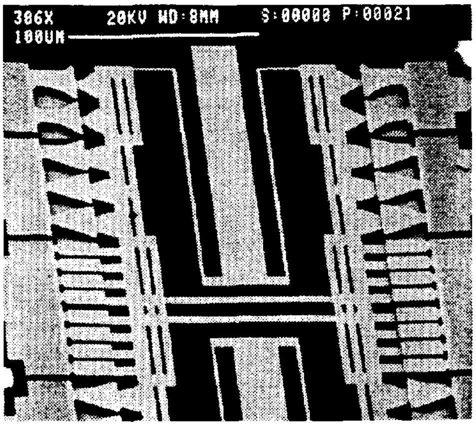

Figure 3. A multiple level tungsten variable-function force actuator.

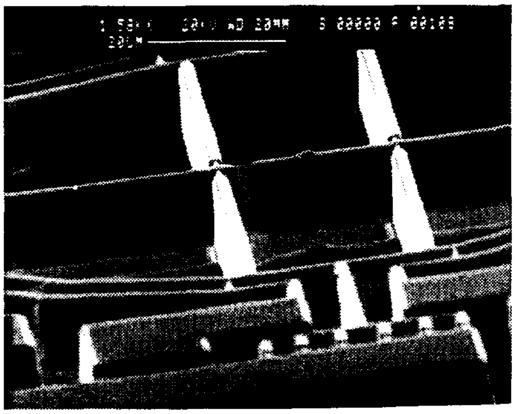

Figure 4. A suspended heater and series resistor for a field emitter.

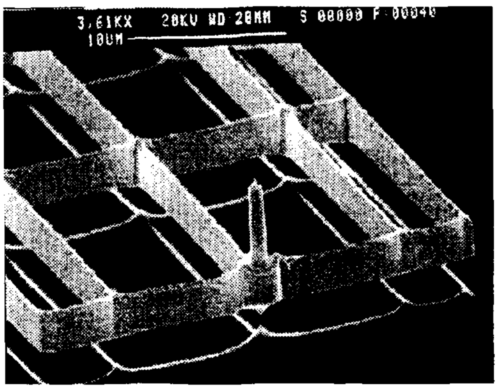

Figure 5. A high aspect ratio SCS tip integrated on the xyz actuator of a micro-STM.

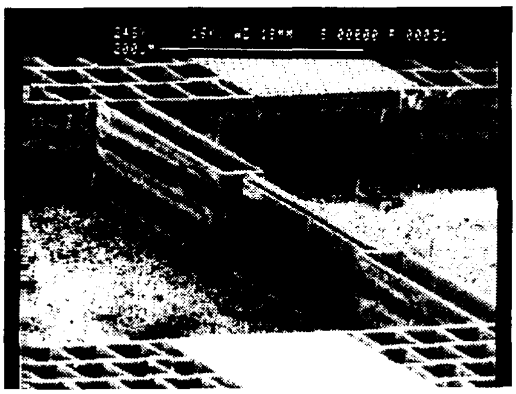

Figure 6. A tunable high aspect ratio Fabry-Pérot interferometer.