MEMS and NEMS
Room 2007 - Session MN-TuA

Fabrication and Characterization of MEMS and NEMS
Moderator: R. Ilic, Cornell University

2:40pm **MN-TuA3 Fabrication and Testing of NEMS Components Made from Nanocomposite Al-Mo Films**, ***D. Mitlin***, University of California; *Z. Lee,* Lawrence Berkeley National Laboratory; *C. Ophus, N. Nelson-Fitzpatrick, L.M. Fischer,* University of Alberta, Canada; *S. Evoy,* National Institute of Nanotechnology; *U. Dahmen, V. Radmilovic,* Lawrence Berkeley National Laboratory

Despite several major advantages over semiconductor-based NEMS components (optically reflecting, electrically conducting, tough-ductile), metal-based components with nm-scale dimensions are notoriously difficult to achieve due to their large surface roughness and grain size, high stress state, and low strength. We were able to overcome these limitations by using room temperature co-sputtering to synthesize nanocomposite alloy films of Al-Mo. We now report having successfully fabricated fully released NEMS cantilevers of various geometries from such metallic materials. At a device thickness as low as 4 nm, these are the thinnest released metal cantilevers reported in the literature to date. A systematic investigation of microstructure and properties as a function of Mo content resulted in an optimum film composition of Al-32at%Mo, with a unique microstructure comprised of a dense distribution of nm-scale Mo crystallites dispersed in an amorphous Al-rich matrix. These films were found to exhibit unusually high nanoindentation hardness and a very significant reduction in roughness compared to pure Al, while maintaining resistivity in the metallic range. A single-anchored cantilever 5 µm long, 800 nm wide and 20 nm thick showed a resonance frequency of 608 kHz, yielding a Young's modulus of 112 GPa, in good agreement with a reduced modulus of 138 GPa measured by nanoindentation.

3:00pm **MN-TuA4 Chemical Mechanical Planarization of BCB Polymer Films: Effect of Cure Temperature**, ***N. Ghalichechian***, *A. Modafe, M.I. Beyaz, R. Ghodssi,* University of Maryland

We report on the chemical mechanical planarization (CMP) of a thick benzocyclobutene (BCB) polymer film with a high removal rate (470 nm/min) and a low density of post-CMP defects suitable for the fabrication of microelectromechanical devices. The effect of polymer cure temperature on Youngs modulus and removal rate of the BCB film was studied. Thick low-dielectric-constant BCB polymer (k=2.65) is used as an insulating layer to reduce the parasitic capacitances and increase the efficiency of an electrostatic micromotor. The micromotor fabrication process requires planarization of a 25-µm-thick BCB film buried in the substrate. High removal rate (hundreds of nm/min) is desired to planarize thick BCB films in an acceptable time. Polymers are generally soft (low Youngs modulus) and chemically resistant to a wide range of acids and alkali solutions; therefore, their planarization using conventional CMP processes is challenging. The removal rate of an uncured film was measured to be 3.66 µm/min; however, the CMP process induced significant film scratching, peel-off, non-uniformity, and surface roughness (188 nm/min peak-to-peak). Partial BCB polymerization can be achieved by curing the film under 250 °C. A series of experiments were conducted to measure the CMP removal rate and surface roughness of BCB samples cured at 120-250 °C. The removal rate was calculated from film thickness measurements before and after CMP steps using vertical scanning interferometer. The surface roughness of the film was measured using atomic force microscope. The removal rate at cure temperatures of 120, 160, and 250 °C was found to be 2000, 470, and 70 nm/min, respectively. An abrupt change in the removal rate was observed at cure temperature of 160 °C and is believed to be due to the change in the Youngs modulus of the film. CMP process details, measured removal rate, surface roughness, and Youngs modulus will be presented in this paper.

3:20pm **MN-TuA5 Borosilicate Glass Deep Etching in NLD Plasma by using Low GWP Gases**, ***Y. Morikawa***, *T. Hayashi, A. Kelly, K. Fuwa, K. Suu,* ULVAC Inc., Japan

One of important etching technologies in MEMS device fabrication is a deep glass etching over 100 um. But the glass contains some elements that the etched products have no vapor pressure at low temperature. So etched surfaces generally show rough morphology, on which the reaction product residue of I to III group elements in periodic table is seen. The deep etching technologies for this glass were reported by X. Li, et al. and T. Ichiki. They used SF6 as an etching gas.@footnote 1,2@ However, it has not been reported that a low GWP gas was used for glass deep etching. So we first tried to etch at the pressure of 1 Pa by using C3F8 as a relatively low GWP gas, by using a NLD etching system. The result showed the rough surfaces. Therefore, we etched the glass at 0.4 Pa in order to eliminate the residue by sputtering and obtained smooth surfaces. Changing the etching gas to C3F7I(GWP < 1) , we also obtained similar smooth surfaces under the same etching condition. Furthermore, the thru hole etching from the top to bottom surfaces of the glass wafer with thickness of 1 mm was examined. This is very difficult because an extremely high selectivity to photo resist is required. Therefore, we examined to use a thin Si wafer with thickness of 50 um as the mask. The thin Si wafer was bonded on the glass by the anodic bonding method, and coated with photo resist (thickness of 50 um), and then patterned by photolithography. Finally, we obtained the etching sample whose structure was Si mask (50 um hole and thickness) / borosilicate glass (Corning 7740) with thickness of 1 mm, prepared after the thin Si etching by using a novel deep etching method.@footnote 3@ @FootnoteText@ @footnote 1@X. Li, et al : Sensors and Actuators A 87 (2001) 139. @footnote 2@T. Ichiki, et al : J. Vac. Sci. Technol. B 21 (5) 2188. @footnote 3@Y. Morikawa, et al : 51st AVS, MN-MoP5 (2004) Anaheim.

4:00pm **MN-TuA7 Molded Electromechanical Shift-Register Memories**, ***G.M. McClelland***, *B. Atmaja,* IBM Research Division, Almaden Research Center

Mechanical bistability is a simple well-understood phenomenon that can be used to store information. However, most designs for mechanical memories require individual elements to be addressed, written, and read electrically. We propose a much simpler design in which bistable levers are arranged in a shift register, so that information is accessed by the simple electrostatic interaction of neighboring levers. A shift register containing > 1000 bits can be operated with only two conductors. The shift register can be molded in a single step from a single elastomeric material (e.g PDMS). In one design, the levers are conducting, and a voltage pulse from a single top electrode pulls charge to the levers, inducing repulsion, and shifting information. We have built a working 100-cm-scale memory based on this idea. In another design, which can work in a liquid, the insulating levers are charged with alternating signs to create primary and secondary components of individual memory cells. The problems of coding, initializing the memory, and recovering from errors are analyzed. A "broadcasting" scheme is described, in which the first lever is made unique, so that only it responds to a write pulse from the upper electrode, while the other elements respond to only shift pulses. These memories have been studied using both realistic finite element methods and phenomenological models. An integration scheme is proposed in which a crosspoint array of shift registers is imprinted into a series of optical waveguides. This structure can be read and written by electrical attachment to only one edge, enabling a memory system in which many layers can be "shingled" onto a silicon drive chip. This geometry, combined with simple one-imprint layer manufacturing, could allow solid state storage with the price/bit of disk drives.

4:40pm **MN-TuA9 Molecular Vapor Deposition Integration with MEMS Manufacturing**, ***B. Kobrin***, *T. Zhang, N. Dangaria, J. Chinn,* Applied Microstructures, Inc.

Molecular vapor deposition (MVD) has already proved itself as enabling technique for anti-stiction prevention and yield enhancement in MEMS devices.@footnote 1,2@. We report on results of MVD process integration with MEMS manufacturing schemes. Vacuum type deposition and self-assembling nature of the coating assures excellent conformality in high aspect ratio structures and narrow air gaps between released components and a substrate. It also enables seamless integration in MEMS back-end process flow. We demonstrated successful deposition of self-assembled monolayers (SAM) through small (micron-size) openings in encapsulated MEMS package. Different selective material deposition and removal techniques (lift-off, substrate masking, UV ozone etch, oxygen plasma) allow integrating MVD process into MEMS back-end packaging and Ink-jet head assembly processes. Some examples of this integration are reported. @FootnoteText@@footnote 1@B. Kobrin , J. Chinn , W. Ashurst, Durable Anti-Stiction Coatings by Molecular Vapor Deposition (MVD), NSTI Nanotech, May 2005 @footnote 2@B. Kobrin, W. Ashurst, V. Fuentes, R. Nowak, R. Yi, Jeff Chinn, Molecular Vapor Deposition for Enhanced Monolayer Stability and Durability, AIChE2005, Nov 2005.

Author Index

Bold page numbers indicate presenter