Wednesday Morning Poster Sessions

Microelectromechanical Systems (MEMS)
Room: Exhibit Hall B2 - Session MM-WeP

Poster Session

MM-WeP1 Metallization Schemes for RF MEMS Switches, ***K. Leedy***, *R. Cortez, W. Cowan, J. Ebel, J. McFall, R. Strawser, A. Walker*, Air Force Research Laboratory

A series of surface micromachined MEMS switches with composite metal bridges were fabricated by standard photolithographic techniques. The study was conducted in order to assess the influence of film stress and composition on the released shape of cantilever and fixed-fixed beam structures. A 1 µm thick evaporated Au film was the basis for all bridge materials with additional 20 nm layers of evaporated or sputter deposited Ti, Pt, or Au on the top or bottom surface of the thick Au. The planarity and stress gradient of cantilever beam structures and the planarity of fixed-fixed beam structures were measured with optical interferometry. Au-only bridge structures displayed the best planarity of those examined while structures including Ti layers displayed the least planarity. Tensile cantilever stress gradients were calculated using both cantilever tip deflection and radius of curvature techniques. The thin film biaxial moduli used in stress gradient calculations were measured with a wafer curvature technique and were slightly higher than the bulk Au value. Results of this study show that thin metal layers (2% of total beam thickness) have substantial influence on released beam curvatures but that beam planarity can be achieved with a suitable combination of materials.

MM-WeP2 Inorganic Electret Using SiO_2 Thin Films Prepared by r.f. Magnetron Sputtering, *T. Minami*, ***T. Yamatani***, *T. Utsubo, T. Miyata,* Kanazawa Institute of Technology, Japan, *Y. Ohbayashi*, Hosiden Corporation, Japan

The ability to fabricate inorganic thin-flim electrets on low temperature substrates is necessary for applications such as electret actuators and sensors in MEMS. In this paper, we describe the fabrication of silicon dioxide (SiO_2) thin-film electrets that exhibit a highly stable surface potential in tests at high temperatures as well as high relative humidities in air. The SiO_2 films were prepared on various conductive substrates at a temperature of 250 to 400^{o}C by rf magnetron sputtering using a fused quartz target. It was found that operational stability in highly humid atmospheres can be considerably improved by postannealing in a highly humid atmosphere at a high temperature. In addition, the obtained surface potential stability also proved to be dependent on the deposition conditions. The surface potential of SiO2 films postannealed in a highly humid atmosphere at 350 to 450^{o}C for 10 to 180 min was found to be highly stable even when tested at a relative humidity of 90% and a temperature of 60^{o}C. In addition to the postannealing conditions, the deposition conditions were optimized: substrate temperature, about 350^{o}C; sputter gas pressure,0.3 Pa; and O_2 partial pressure, 20%. As a result, the surface potential of SiO_2 electret films prepared under optimized deposition and postannealing conditions exhibited no decay when tested over a long term at a temperature of 60^{o}C and a relative humidity of 90%. SiO_2 thin-film electrets with a thickness of 2 to 5 µm maintained a surface potential above 300 V when tested at temperatures above 250^{o}C in air or at 60^{o}C with a relative humidity of 90%. It was concluded that highly stable thin-film electrets can be realized by SiO_2 thin films prepared on various conductive substrates at a temperature of about 350^{o}C and postannealed at 400^{o}C in a highly humid atmosphere.

MM-WeP3 MEMS Electrostatically Actuated Vertical Mirror Switch for Optical Transceiver, ***M.W. Lee***, *K.C. Lee, S.B. Jo, B.H. O, S.G. Lee, S.G. Park, E.H. Lee,* Inha University, Rep. of Korea, *H.S. Lee, H.G. Ryu*, Neoptek, Rep. of Korea

We have developed a simple structured MEMS vertical mirror switch for optical transceivers. As the optical characteristics and mechanical stability of MEMS switches is sufficient for excellent performance in communication networks, it is necessary to lower the fabrication cost by simplifying or eliminating processes of manual assembly or alignment. Here, novel structures for mirror assembly and stopper are proposed and fabricated to satisfy simplicity and accuracy of a vertically-assembled mirror, made with only three layers by deposition, polysilicon, silicon-oxide, silicon-nitride layers on a silicon substrate. Poly-silicon layer is to build a cantilever and a mirror. The silicon-oxide layer is a sacrificial layer and the silicon nitride layer is for electrical isolation. Fabrication processes of semiconductor micromachine offers accurate position due to it's nature. PR-pads are also used for the technique of photoresist(PR) applied self-assembly (the works of R.R.A. Syms[1]). The characteristics of fabricated devices will be discussed in detail. Low actuation voltage and other performances are considered to be enough for the application in optical communication systems.

[1] Richard R.A. Syms, Surface Tension Powered Self-Assembly of 3D Micro-Optomechanical Structures, Journal of Microelectromechanical Systems, Vol. 8, No. 4, Dec. 1999.

MM-WeP4 Development of Microfluidic Devices for Gas Centrifuge Separation, ***S. Li***, *R. Ghodssi*, University of Maryland

A mass spectrometer on a chip (MSOC) is suited for environmental monitoring with the advantages of fast response, low power consumption and portability. Gas centrifuge separation (GCS) is capable of concentrating the minor constituents in a gas mixture and increasing the sensitivity of MSOC. An integrated MEMS fabrication method is presented for developing GCS devices as the front-end for MSOC. A hybrid device that incorporates silicon, plastic and glass is realized by utilizing a combination of deep reactive ion etching (DRIE) and low temperature wafer bonding techniques. Inlet and outlet ports (500 µm in diameter and depth) are created in the silicon substrate by DRIE. Using standard photolithography, micro converging-diverging nozzles with throats as small as 3.2 µm wide and 5 µm deep are formed in EPON SU-8 supported on the silicon substrate. The second SU-8 layer, coated on a pyrex wafer, is bonded with the first SU-8 layer to form sealed micro nozzles. Macroscale capillary needles (400 µm in diameter) and quick-setting glue are used to interface the microfluidic device to the macroscopic world (i.e., the pressure measurement setup). Measures are taken to prevent the glue from seeping through the gaps and blocking the microfluidic channels. Calibration results demonstrate the feasibility of the test setup for measuring pressure distributions of gas flow in the micro nozzles. Preliminary measurement results and a detailed fabrication process will be presented.

MM-WeP5 Characterization of the Residual Stress in Titanium/Platinum and Tantalum/Platinum Thin Film Electrodes used in the Processing of PZT MEMS Devices, ***R.G. Polcawich***, *J.P. Clarkson, J. Pulskamp, A. Wickenden, M. Wood, K. Kirchner, M. Ervin, E. Zakar, M. Dubey*, U.S. Army Research Laboratory

Residual stress in freely suspended MEMS devices is critical for optimal performance. The high temperature anneals required to crystallize lead zirconate titanate (PZT) thin films create stress gradients within the piezoelectric stack yielding non-planar released structures. From our previous studies, tantalum/platinum (200 Å / 1700 Å) metallization used as bottom electrodes for PZT MEMS has contributed the largest residual stress (~850 Mpa) to the multilayer stack. This research focused on using the sputter deposition parameters as a means of producing low stress (~<450 Mpa) Ta/Pt and Ti/Pt metal layers. Ti, Ta, and O diffusion were investigated with Auger electron spectroscopy by using O^{18} as a tracer during the anneal process. Additionally, x-ray diffraction and scanning electron microscopy were used to identify the presence of second phase compounds within the Pt metal layer. From this combined analyses, oxygen diffusion and the subsequent formation of TiO_2 and Ta_2O_5 compunds within the Pt matrix was the primary cause of reducing the residual stress in metal stacks with Ta and Ti thin films greater than 200Å.

MM-WeP6 Mitigation of Residual Film Stress Deformation in Multi-Layer MEMS Devices, ***J. Pulskamp***, *B. Piekarski, R.G. Polcawich, A. Wickenden, M. Dubey*, U.S. Army Research Laboratory

An approach to compensate for the residual thin film stress deformation of multi-layer MEMS devices is presented based upon analytical modeling and in-process thin film characterization. Thermal and intrinsic deposition stresses can lead to the warping of released MEMS structures. This detrimental phenomenon in many cases can prevent proper device operation. Ellispsometric and laser wafer bow measurements yield thickness and film stress values that are used to update the deflection model during device fabrication; allowing for the compensation of the fabrication process variability. The derivations of linear and nonlinear residual film stress induced deflection models are presented. These models are based upon Bernoulli-Euler beam theory and are thus restricted to the associated geometric constraints. The models are initially validated by comparison with surface micro-machined sol-gel PZT (Lead-Zirconate-Titanate) cantilever structures; with initial experimental results agreeing well with both models.

MM-WeP7 Epitaxial Growth and Characterization of the Ferromagnetic Shape Memory Alloy Co_2NiGa on (001) GaAs, ***T.C. Shih***, *J.W. Dong, J.Q. Xie, X.Y. Dong, S. McKernan, R.D. James, C.J. Palmstrom*, University of Minnesota

Recently Wuttig and his coworkers[1] reported a new ferromagnetic shape memory alloy Co_2NiGa, using bulk samples. This present study focuses on the growth of (001) Co_2NiGa thin films on (001) GaAs substrate by molecular beam epitaxy. In-situ reflection high energy electron diffraction, ex-situ X-ray diffraction, and cross-sectional transmission electron microscopy indicate the single crystal growth of Co_2NiGa on (001) GaAs. X-ray diffraction data from bulk samples[2] indicate that the Heusler alloys $Co_2Ni_{1+x}Ga_{1-x}$ ($0<x<0.3$) order in the B2-phase (CsCl structure) with doubled its lattice parameter close to 5.75 Å, which corresponds to a 1.8 % mismatch to GaAs. The X-ray diffraction data from the Co_2NiGa thin films indicate an out-of-plane lattice parameter of 6.10 Å, which suggests that the Co_2NiGa thin film may grow in a strained epitaxially stabilized tetragonal structure. Vibrating sample magnetometry and superconducting quantum interference device magnetometry measurements have been performed for the Co_2NiGa film with magnetic fields applied in-plane. The room temperature magnetic moment versus applied field curve shows a hysteresis loop with a coercivity of 170 Oe and a saturation magnetization ~250 emu/cm^3. The Curie temperature is above room temperatures which is comparable to the bulk measurement (Tc=326K).[2] In this talk, the crystal structure as a function of growth conditions as well as the mechanical properties of released films will be presented.

[1] M. Wuttig, J. Li, and C. Craciunescu, Scripta Mater., 44, 2393 (2001).
[2] J. G. Booth, R. Cywinski, and J. G. Prince, Journal of Magnetism and Magnetic Materials, 7, 127 (1978).

MM-WeP8 Micromirror Coatings with Low-stress, High Reflectivity, ***Y.N. Picard***, University of Michigan--Ann Arbor, *D.P. Adams, O.B. Spahn*, Sandia National Laboratories, *S.M. Yalisove*, University of Michigan--Ann Arbor, *D.J. Dagel*, Sandia National Laboratories

While thin film coatings can greatly improve the reflectivity of micromirrors used in optical MEMS devices, such coatings can yield a moderate compressive or tensile stress, leading to a significant change in the micromirror curvature. This work seeks to develop highly reflective optical coatings exhibiting near-zero average film stress and minimal through-thickness stress. In this study, multilayer thin films consisting of Cr, Ti, Au, Si and Si_3N_4 are deposited on blank Si (100) substrates using DC planar magnetron sputtering. Au is greater than 90% reflective over a range of infrared wavelengths, and either Cr or Ti can be employed as an adhesion promoter between Au and Si. The residual stress of multilayer films is determined through curvature based measurements using laser-scanning and applying Stoneys equation. The influence of sputter gas pressure and deposition rate on residual film stress is assessed for a variety of multilayer systems. Also assessed is stress aging at room temperature over a period of one year. Using optical interferometry, we have already demonstrated that low stress Au/Ti films deposited on micromirrors 125-500 µm in size induce less than $\lambda/40$ change in bow. This work seeks to extend these initial results by combining low stress Au/Ti films with Si_3N_4/Si Bragg reflectors to achieve a near-zero stress multilayer exhibiting both a ~99% reflectivity for a target wavelength of radiation while inducing minimal curvature changes when deposited on pre-released polysilicon micromirrors. Since thin film microstructural defects and interfacial roughness can contribute to optical absorption, examination of both is conducted using cross-sectional transmission electron microscopy. Surface roughness is also measured using atomic force microscopy. Spectral reflectivity of thin film coatings is measured using an optical spectrum analyzer.

MM-WeP9 Deep Reactive Ion Etching of Silicon Using an Aluminum Etching Mask, ***W. Wang***, *P. Reinhall*, University of Washington

A novel double-sided micromachining process for the silicon based device fabrication has been developed that allows the use of capacitively coupled RIE equipment for high aspect ratio etching. The resulting etch rates in Si of 2.2 µm/min is comparable to 1 to 3 µm/min from the standard ICP deep reactive ion etching process. Although a lower anisotropy (~0.5) and lower selectivity to thermal oxide (Si: SiO_2 = 10:1) and to photoresist (Si: +PR = 9:1) resulted, the proposed process is much simpler and requires only the use of an aluminum mask. Based on the experimental results, a 1000 Å thick Al film sufficiently protects the unexposed substrate while allowing the etching of a 350µm deep hole with an area of 3x3mm^2 when etching with SF_6 /CHF_3/O_2 plasma. A 2000µm long and 100µm wide (with layers of Al/SiO_2/Si and thicknesses of 0.1µm/2.2µm/40µm respectively) cantilever is also achieved. The technique was developed mainly for bulk micromachining of silicon or composite silicon cantilever structures.

Authors Index

Bold page numbers indicate the presenter