The Science of Micro-Electro-Mechanical Systems Topical Conference

Room 620 - Session MM+MI-ThM

Processing and Integration Technology

Moderator: L.M. Miller, Jet Propulsion Laboratory

9:00am **MM+MI-ThM3 Magnetic Micromachining Technology: From Materials to Components to Actuators***, **M.G. Allen**,* Georgia Institute of Technology **INVITED**

The fabrication of micromachined structures based on magnetic elements requires the development of both magnetically soft and hard materials, as well as suitable processes that allow the incorporation of these materials into microelectromechanial systems (MEMS). This presentation summarizes approaches to materials and fabrication techniques for magnetic MEMS, and illustrates their use through several examples, including: flux concentrators to improve the sensitivity of magnetotransistors; integrated inductive components for electronic packages; and fully-integrated, magnetically-actuated microrelays.

10:20am **MM+MI-ThM7 Fabrication and Characterization of Polycrystalline Silicon Thin Films with Hydrofluoric Acid Permeability for Sacrificial Etching of Underlying Oxide Layers***, **Y. Kageyama**, T. Tsuchiya, H. Funabashi, J. Sakata,* Toyota Central R&D Labs., Inc., Japan

Polycrystalline silicon (poly-Si) thin films with permeability to a concentrated hydrofluoric acid solution were fabricated for use in in-situ vacuum encapsulation of micro sensor devices on silicon wafers, and porous microstructures of the films related to the permeability were elucidated. A partial cavitation of grain boundaries, which was induced by heavy doping of phosphorus and consequent segregation of soluble precipitates, was designed for passage of fluid which resolves underlying borophosphosilicate glass (BPSG) or non-doped silica glass (NSG) layer. Poly-Si films of 0.1µm in thickness were made by solid phase crystallization of amorphous films deposited by low-pressure chemical vapor deposition, and were converted to be permeable by doping. Three types of the doping methods were tried, and only a phosphorus oxichloride decomposition method proved to be effective to obtain permeability. The permeability was evaluated by measuring selective removal rates of underlying sacrificial oxide layers, and lateral BPSG removal of more than 50µm was observed within 90 sec at a room temperature through the permeable poly-Si thin films. The removal rates of BPSG layers were about ten times faster than those of NSG layers, which can be attributed to phosphorus concentration in oxide, and were dependent on post-annealing temperatures, whereas those of NSG layers did not depend on the annealing temperatures. The microstructures of these permeable poly-Si thin films were first observed by secondary electron microscope and field emission secondary electron microscope, which revealed submicron pores between silicon grains that acted as the fluid paths.

10:40am **MM+MI-ThM8 A New Chemistry for Rapid Etching of SiO@sub2@***, **C.I.H. Ashby**, C.M. Matzke, L. Griego,* Sandia National Laboratories

Plasma etching of SiO@sub2@ has traditionally been achieved using a fluorocarbon-based plasma. Very fast SiO@sub2@ etch rates (> 1 µm/min) are obtained using high-density plasmas and CH@subx@F@suby@ source gases. Although these plasmas provide fast preferential etching of SiO@sub2@ vs. Si by controlled deposition of a polymer, that same polymer deposition makes CH@subx@F@suby@ processes unsuitable for applications where the surface chemical properties of the SiO@sub2@ are important. Fabrication of deep trenches in fused SiO@sub2@ without chemical alteration of the SiO@sub2@ surface by a fluoropolymer deposit is essential for applications such as electrophoretic and electro-osmotic separations using microfabricated channels ("chemlab on a chip"). Rapid (0.4 µm/min) etching of fused silica has been achieved without the use of polymerizing fluorocarbon gases by the addition of N@sub2@ to SF@sub6@/Ar mixtures in an electron-cyclotron-resonance (ECR) reactor. Addition of N@sub2@ to SF@sub6@ increases the etch rate of SiO@sub2@ by up to 30%. After deep (10 µm) trench etching, the smoothness of the etched surface is comparable to that of unetched SiO@sub2@. Nitrogen might play two roles in enhancing SiO@sub2@ etching: 1) increasing the F atom concentration and/or 2) facilitating the etching of the SiO@sub2@ matrix through the formation of volatile NO@subx@ products. Optical emission studies using Ar actinometry suggest the second mechanism dominates under our plasma conditions. Process characteristics under a variety of plasma conditions will be presented. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

11:00am **MM+MI-ThM9 Residual Stress Characterization of Thick PECVD Oxide Films for MEMS Applications***, **R. Ghodssi**, X. Zhang, K.-S. Chen, K.A. Lohner, M. Spearing, M.A. Schmidt,* Massachusetts Institute of Technology

Vapor deposited films are of vital importance in many sensors and actuators where they are used to form electrical or mechanical elements. In order to achieve higher electrical and mechanical power levels, thicker films are often desired. However, the deleterious effects of residual stress tend to increase with film thickness. In particular, excessive wafer bow and even cracking may prohibit integration within a micro-device. This paper presents residual stress characterization for PECVD Novellus@super TM@ oxide films with thicknesses in the range of 10 - 40 µm. These films are deposited at 400°C and densified at 1100°C in a nitrogen environment. Wafer curvature measurements were performed to investigate the residual stress in the thick PECVD oxide films as a function of temperature. These results show that the residual stress in thick PECVD oxide films is a combination of both thermal expansion mismatch stress and an intrinsic stress due to the deposition process and resulting microstructure. Furthermore, the densification step plays an important role in determining the residual stress state. For instance, a 10 µm thick PECVD oxide film exhibits a wafer bow of 50 µm and 250 µm before and after densification, respectively. Additional high temperature experiments indicated that cracks formed at temperatures between deposition and densification. The tendency to form cracks is a strong function of film thickness. For films thicker than 15 µm, cracks formed in the film at temperature below 1100°C. Laminated plate theory has been applied to extract residual stress data for the curvature measurements. This data is then correlated with the deposition and densification conditions to guide process development so as to reduce wafer curvature and to eliminate cracking.

11:20am **MM+MI-ThM10 Process and Fabrication of a Thin Film PZT Pressure Sensor***, **E. Zakar**, M. Dubey, B. Piekarski, J. Conrad, R. Piekarz, R. Widuta,* Army Research Lab

Piezoelectric crystals or ceramics are very attractive for static and dynamic pressure sensors. One of the very promising piezoelectric materials is PZT (Lead Zirconate Titinate - 52/48). MEMS technology was applied to fabricate several static PZT pressure sensors and capacitance method was used to characterize it. Sol-gel derived PZT thin films (250 - 500 nm) were deposited on platinized (SiO@sub 2@- 1000/ Ti - 20/ Pt - 170 nm) Si substrates. Top Pt electrode was sputtered deposited on PZT films and was patterned using ion milling. The PZT films were etched using Reactive Ion Etching (RIE) and ion milling. Comparative studies (etched surface, sidewalls and electrical properties) of ion milling and RIE of PZT and oxide were also completed. The RI etch rate of PZT was studied using different electrode shield (graphite, alumina, ardel) materials with power (100 to 500 W) and pressure of HC@sub 2@ClF@sub 4@ gas plasma. The measured RI etch rate of PZT varied from 10-100 nm/min. The ion-milling rate of Pt was 33nm/min, PZT-23nm/min and Oxide-31nm/min. A unique technique of soft and hard bake of photo resists along with change in incidence angles of ion beam were used to eliminate fencing problem during ion milling. Desired slope of the etched walls was also produced using above technique. The etched surface and side walls were smooth and clean up to 2µm feature size. Four level photo-mask process was used to fabricate the pressure sensors. A low stress PECVD oxide film was deposited (at 200°C) to isolate the top and bottom electrodes. The Pt electrodes further bonded with Ti/Au leads which were patterned using wet etching (KOH + I@sub 2@). Several pressure sensors with different dimensions (300x300 and 200x200 µm@super 2@) were fabricated. The average values of measured capacitance, 1023 and 453 pF, are in excellent agreement with calculated values.

11:40am **MM+MI-ThM11 Microfabricated Low-Power Broad-Band Light Source Utilizing Tungsten Filaments***, **E.W. Jones**, T. George,* JPL-California Institute of Technology*; M.L. Tuma,* NASA-Glenn Research Center*; R. Hansler,* Lighting Innovations-John Carroll University

A miniature,Si chip-based, incandescent light source utilizing tungsten filaments is being developed for integration into fiber optic systems to wavelength multiplex a suite of fiber-optic sensors operating in harsh environments from -50 C to 600 C. The requirements for the light source are that it operate at 2800 K, with an output power >100 mW in the 500-900 nm spectral band with spectral power variance of no more than 4% over the spectral band. In addition, it should be rugged, long-lived, with an output stabilization time of about 1 second, and have a "footprint" comparable to LED devices. Other uses for these filaments are automobile headlights, and systems for vehicle navigation, in remote applications such as monitoring bridges for stress, and industial plant monitoring. To date, several filament fabrication approaches are being attempted. The first uses sputtered tungsten films (1-2 microns thick) patterned in various filament geometries. These filaments have been operated at < 2200 C) is the mounting of coiled-coil wire filaments on microfabricated Si chips. Lastly, 25-micron-thick W sheet stock is being patterned to produce planar spiral filaments. Filaments satisfying the above criteria will be packaged into a hermetically sealed three-chip stack consisting of a bottom reflector chip, a middle filament chip, and a top 5 mm x 5 mm SiN membrane optical window chip, integrated with an optical fiber. The fabrication procedures as well as the optical and electrical characterization results will be discussed in detail.

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