MEMS and NEMS Group
Room: Central Hall - Session MN-TuP

MEMS/NEMS Poster Session

MN-TuP1 Method for Patterning Crystal Colloidal Masks Using Poly (Acrylic Acid), ***Connor Smith****, *S.L. Burkett,* The University of Alabama

Nanosphere lithography is a nanopatterning technique which has been a useful method for creating nanoscale features, such as nanopillars, that are used in MEMS and NEMS devices. This is achieved by ordering nanospheres in close-packed crystal colloidal masks on a substrate and physically etching said substrate via the interstitial spaces between the nanospheres. Methods for ordering these nanospheres into crystal colloidal masks has been accomplished in many ways, with spin-coating being one of the most cost effective and simplest to implement. Unfortunately, only a few methods exist for patterning these crystal colloidal masks, and few utilize traditional optical lithography techniques. In this work, a method for patterning crystal colloidal masks that are formed via spin-coating is introduced. This method involves spin-coating nanospheres in a solution of water and poly (acrylic acid), and then using modified traditional optical lithography and plasma ashing techniques to pattern the resulting crystal colloidal mask. Once the mask is patterned, normal physical etching methods may be used to further pattern the substrate below the nanosphere embedded poly (acrylic acid) layer. With this new method, patterning crystal colloidal masks for use in nanosphere lithography should be easier due to the wide spread availability of traditional optical lithography tools and instruments.

MN-TuP2 Understanding the Influence of Space Charge Region on Electrical Behavior of ($Pb_{0.95}La_{0.05}$)($Zr_{0.54}Ti_{0.46}$)O_3 Thin Film Capacitors Designed using Top Electrodes of Different Various Work Functions, ***Vaishali Batra****, *S. Kotru, G.D. Cabot II, V.N. Harshan,* The University of Alabama

Ferroelectric lanthanum modified lead zirconate titanate (PLZT) material has excellent electronic and optical properties due to which it meets the requirements for various device applications such as optical modulators/transducers, MEMS and smart sensors. Recently this material is being explored for photovoltaic applications. To design devices, the material is integrated with conducting electrodes to prepare metal/ferroelectric/metal (MFM) heterostructures. Electrical behavior of the devices strongly depend on the properties of the electrode/s used to design the MFM structures. In this work, we investigated the dependence of electrical properties of metal/PLZT/Pt capacitors, on a variety of top electrodes, having different work functions (Au, Pt etc.) with Pt serving as bottom electrode.

Thin films of $Pb_{0.95}La_{0.05}Zr_{0.54}Ti_{0.46}O_3$ (PLZT) were fabricated on Pt(111)/Ti/SiO_2/Si(100) substrates by chemical solution deposition method. Various metal electrodes, with varying work functions, were deposited on top of these films to prepare metal/PLZT/Pt capacitors. The prepared MFM heterostructures form space charge regions at the interfaces between PLZT film and electrode material. Due to different top electrode used to design the capacitor structure, the top interface differs from each other. A detailed analysis of the polarization-electric field (P-E) curves, capacitance-voltage (C-V) characteristics, permittivity-frequency (ε_r-f), and current-voltage (I-V) measurements of each of the capacitors allowed us to understand the variation in electrical properties as a function of top electrodes. This variation is mainly attributed to the modification in metal/ferroelectric Schottky contact at the top interfaces which results in creation of different interface electric field, thus altering the properties of PLZT thin film capacitors. Results obtained from this study can guide us to choose the correct electrode material for designing capacitors for a particular application (photovoltaic devices or other types of sensors).

MN-TuP3 Tribology and Locomotion of Untethered Scratch Drive Actuators with Applications to MEMS Microrobotics, ***Ratul Majumdar***, University of Illinois at Chicago, *L. Stan, R. Divan,* Argonne National Laboratory, *I. Paprotny*, University of Illinois at Chicago

Untethered Scratch Drive Actuators (USDAs) [1] have been widely used for actuation of MEMS devices, for example the assembly of 3D MEMS structures [2] and as propulsion mechanisms for stress-engineered MEMS microrobots [1]. These electrostatic actuators show fast and reliable motion on a power delivery substrate along with the ability to provide forward force of 30μN [2]. The power delivery substrate of these USDAs consist of parallel set of interdigitated metal electrodes with a high-k dielectric layer deposited on top [1,3]. The metal electrodes consist of Cr/Au/Cr(10/50/10nm) layers of 2 μm spacing patterned by electron beam lithography. Sputtered yittria-stabilized zirconium oxide (YSZ) of 500μm thickness is used as the dielectric layer. The sputtering parameters, especially the deposition pressure, along with the gas flow of argon and oxygen play an important role in determining the dielectric constant and hence, the power transferred to the USDA for actuation. Variation in the deposition pressure can improve adhesion of the dielectric layer and reduce the delamination during USDA motion. Application of ac voltage between the two parallel set of electrodes results in coupling of capacitive force to the microrobot chassis, thus supplying power to backplate and bushing of the USDA for translation.

For straight motion, a waveform primitive (Fig. 1, supplemental file) with amplitude ranging from 0 to 200V and frequency (f) of 15Hz was applied to the substrate. The waveform is symmetric along horizontal X axis to prevent accumulation of charge on the substrate. The lowest (V_{low}) and highest (V_{high}) value of the voltage waveform is varied and the corresponding motion of the USDA is recorded. The cutoff point at which USDA shows actuation depends on the quality of the dielectric (Fig.2). Interesting interaction with the substrate during release stage is observed by analyzing the V_{low} (Fig. 3 and 4). Improved efficiency of the substrate by transferring more power to the USDA is observed for the power delivery substrate with the YSZ grown at higher pressure (25mTorr). That results in reliable motion and less delamination of the dielectric surface.

References

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MN-TuP5 Effect of Seeding Material on $Sc_{0.125}Al_{0.875}N$ c-axis Orientation, ***Erica Douglas***, *M.D. Henry, T.R. Young, B. Griffin*, Sandia National Laboratories

While piezoelectric AlN is presently implemented into several commercial applications for electronic devices (such as bulk acoustic wave (BAW) and surface acoustic wave (SAW) filters), alloying AlN with Sc is actively being investigated as a method for increasing the piezoelectric coefficient d_{33}. $Sc_XAl_{1-X}N$, with x approaching 40%, has reported an increase in the piezoelectric coefficient of almost 4X, with potential for high impact for wireless applications by improving bandwidth and decreasing insertion loss. However, the addition of Sc into AlN has led to secondary grain growth, observed even for low Sc content thin films.

This work will demonstrate enhanced c-axis orientation of polycrystalline $Sc_{0.125}Al_{0.875}N$ on <100> silicon by reactive sputtering with various seeding material, including Si, Pt, and AlCu. We will characterize (100) secondary grain growth on Si as a function of film thickness, as well as X-ray diffraction rocking curve full width half maximum (FWHM) of the (002) orientation. As film thickness increases, rocking curve FWHM approach 1.3 degrees for a 2.1 um film; low FWHM values are known to have high piezoelectric coupling. In addition, c-axis orientation was investigated with metal seeding material such as Pt and AlCu. 750nm $Sc_{0.125}Al_{0.875}N$ exhibited a 20% reduction of (002) FWHM and complete suppression of (100) secondary grain growth when seeding on AlCu as compared to Si.

To quantify the effect of $Sc_{0.125}Al_{0.875}N$ growth, contour mode width extensional resonators (CMRs) were fabricated and tested to extract fundamental device parameters such as quality factor(Q) and effective piezoelectric coupling coefficient (K_{eff}^2). The method for suppression of (100) secondary grain growth and improved (002) FWHM utilizing AlCu is CMOS compatible and is shown to create CMRs with -4 dB insertion losses and K_{eff}^2values of 2.3%.

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MN-TuP8 MEMS-Based, High-Resolution Nanocalorimeter for Characterizing Phase Transitions in Samples in the Sub-Microgram Range, ***Zhu Diao***, Stockholm University / Halmstad University, Sweden, *D. Campanini, A. Rydh*, Stockholm University, Sweden

High quality thermodynamic measurements are among the essential tools to investigate fundamental properties of materials. Novel materials are often

*** MEMS/NEMS Best Paper Award Finalist**

only available in minute amount when first synthesised. Hence, it is of paramount importance to develop thermodynamic measurement techniques for small-sized samples. However, studies involving samples of sub-μg in masses are extremely difficult to perform. Conventional calorimeters are marked by the large heat capacity of the calorimeter cell (addenda), thus, not suitable for measuring sub-μg samples. Rapid development in the MEMS industry has led to the creation of nanocalorimeters [1]. Typically, these devices are constructed on bulk micromachined membranes, whose contribution to the device addenda is vanishingly small.

We have developed a MEMS-based, truly differential nanocalorimetry platform, which is capable of performing specific heat measurements on sub-μg of high-quality, single crystalline samples in a wide temperature range between 0.3 K – 400 K [2,3]. It operates according to a refined ac steady-state method, leading to both ultrahigh resolution (better than several in 10^{-5}) and superior absolute accuracy (1 – 2%) [2]. The calorimeter consists of two 150-nm-thick SiN_x windows, one serving as the sample cell while the other being the reference cell. Each calorimeter cell contains a GeAu thermometer, a titanium ac heater, and an offset heater. The annealed GeAu thermometer shows an almost temperature-independent relative sensitivity $|dlnR/dlnT| \sim 1$, covering the whole temperature span of interest.

We demonstrate the capability of our nanocalorimeter through measurements of high purity gallium samples with masses in the range of several hundred nanograms to a few micrograms. α-Ga, the stable polymorph of solid gallium, melts at 302.9 K. Upon cooling, significant supercooling occurs and it may solidify into the metastable β-phase. Compared with α-Ga, β-Ga retains significantly enhanced electron-phonon coupling, leading to an elevated superconducting transition temperature above 6 K. We show that the melting and solidification transition of gallium can be monitored in-situ on our nanocalorimeter utilizing the offset heater, and present specific heat data of both phases across the full temperature range. The high-resolution of our calorimetry scheme also allows in-depth characterization of the superconducting transition of β-Ga and the deduction of a number of important superconducting parameters.

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MN-TuP9 PLD covering the Innovation Chain to Accelerate the Commercial Uptake of Novel Thin Film Materials, ***Matthijn Dekkers***, *J.A. Janssens*, Solmates, Netherlands

It is well known that Pulsed Laser Deposition (PLD) is a very flexible and versatile technique allowing fast optimization of new and complex material thin films. The unique features of PLD allow for the integration of "Beyond Moore" materials in CMOS and new devices. However, mainly because of the sample size, the developed materials and processes in PLD research tools only just make it into demonstrator devices. In order to make it into commercial applications, next generation PLD equipment is needed to bridge the gap between demonstrator and the prototype – pilot – production stages.

The Solmates PLD platform is the next step beyond fundamental PLD research. The reliable hardware is flexible for fast process optimization and allows uniform thin film deposition up to 200 mm diameter with high reproducibility. The automated software ensures easy operation and stable performance. These characteristics enable the integration of PLD thin films in applications for (pilot) production and commercialization.

In this contribution the latest performance and specifications of Solmates PLD platform are addressed. Data on stability and reproducibility of wafer scale deposition of PZT thin films with excellent properties will be presented. Furthermore, two qualified processes Indium Tin Oxide and Aluminum Oxide thin films will be used to show some key capabilities of PLD such as damage free deposition on organic electronics or control of thin films density and microstructure for optical or sensing applications.

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