MEMS and NEMS Technical Group
Room Oregon Ballroom 203-204 - Session MN-ThP
MEMS/NEMS Poster Session

MN-ThP-1 Ferroelectric and Photovoltaic Properties of $Pb_{0.95}La_{0.05}Zr_{0.54}Ti_{0.46}O_3$ Films as a Function of Film Thickness, ***Sneha Kothapally**, S. Kotru,* The University of Alabama

Ferroelectric materials are being extensively studied for optoelectronic, electrical, and photovoltaic applications. Ferroelectric photovoltaics (FEPV) are gaining research interest as their photovoltaic properties are tunable by controlling the ferroelectric polarization with the applied electric field. However, the low photocurrent obtained from FEPV materials is a significant problem that inhibits their practical applications. The surface quality and the crystalline structure of these films are shown to vary with the film thickness which can influence the photovoltaic response. In this work, ferroelectric $Pb_{0.95}La_{0.05}Zr_{0.54}Ti_{0.46}O_3$ (PLZT) films of different thicknesses were prepared on platinized silicon substrate using the sol-gel deposition technique. As-deposited films were annealed to promote crystallinity. The electrical measurements were taken using a capacitor structure (top electrode/PLZT/Pt), where the top electrodes were sputter deposited. The effect of the thickness of the PLZT layer on microstructure, ferroelectric, photovoltaic, and optical properties was investigated to find the optimal thickness for obtaining the best photo response. Enhanced photovoltaic properties coupled with ferroelectric properties exhibit potential applications for energy conversion in microelectromechanical systems (MEMS), and photovoltaic sensors such as UV sensors.

MN-ThP-2 An In-Situ Reflectometry Parylene Deposition Technique for Highly Accurate and Repeatable Film Thickness and Uniformity, ***Steven Larson**, K. Coombes, A. Mings, J. Norris,* Sandia National Laboratories

Parylene is a chemical vapor deposition (CVD) coating process used for conformal coating, energy harvesting, piezoelectric sensors,acoustic resonators, and many other application. Despite its use in a wide variety of applications, parylene deposition system manufacturers provide minimal methods to control film thickness. While methods have been developed for controlling parylene thickness, their widespread adoption has been limited by scalability, complexity, and cost. In this presentation we report a simple, scalable, and cost effective insitu reflectometry technique for parylene deposition that significantly increases the repeatability and accuracy of deposition thickness. We report film accuracy as a relative standard deviation of 2% as opposed to commercial parylene systems which we measure to a relative standard deviation of 17%. We then improve thickness uniformity with deposition flux modeling and a custom stage with planetary motion. Here we show a significantly improved wafer uniformity of 0.2%.

MN-ThP-3 The Effect of CH_4/H_2 Gas Admixture on the Selectivity Towards Pt in Dry Etching of PZT Thin-Films by ICP-RIE, ***Madeleine Petschnigg**, N. Andrianov, S. Azeem,* Silicon Austria Labs, Austria*; S. Trolier-McKinstry,* The Pennsylvania State University

Due to their high piezoelectric coefficients, ferroelectric thin-films based on lead zirconate titanate (PZT) are among the leading materials for active layers in actuator type microelectromechanical systems (MEMS) such as inkjet print heads, adaptive optics like micro mirrors or autofocus devices, and micromachined acoustic and ultrasonic transducers [1–3]**.**

Well defined patterning of PZT films is crucial for the fabrication of MEMS based on this material. Inductively coupled plasma reactive ion etching (ICP-RIE) allows etching of deep trenches with high aspect ratios and anisotropic etch profiles. While Ti and Zr oxides can be etched chemically by the formation of volatile halides [4,5], the removal of PbO is mainly achieved by physical means, which limits the selectivity against masking and electrode materials. A selective patterning process is especially important for large diameter substrates due to typically radial non-uniformities.

This work illustrates the effect of introducing CH_4/H_2 to the etch chemistry on the selectivity in dry patterning of PZT thin-films via ICP-RIE and discusses the potential chemical mechanism entailed. Figure 1 shows a significant increase in selectivity towards photoresist and Pt upon the addition of CH_4/H_2 to a $CHF_3/Cl_2/BCl_3$ gas mixture wihle the PZT etch rate remains approximately constant up to 25 vol% added CH_4/H_2 as illustrated by Figure 2. This approach is expected to simplify the process flow and increase throughput in industrial PZT patterning by allowing a precise etch stop while maintaining high etch rates and aspect ratios using only a single process.

References

[1] S. Trolier-McKinstry and P. Muralt, *Thin Film Piezoelectrics for MEMS*, Journal of Electroceramics **12**, 7 (2004).

[2] H. Bhurga and G. Piazza, *Piezoelectric MEMS Resonators*, (2017).

[3] I. Kanno, J. Ouyang, J. Akedo, T. Yoshimura, B. Malič, and P. Muralt, *Piezoelectric Thin Films for MEMS*, Appl. Phys. Lett. **122**, 090401 (2023).

[4] T. Tillocher, *Deep Reactive Ion Etching of Bulk Titanium for Implantable Devices*, (unpublished).

[5] R. d'Agostino, F. Fracassi, and C. Pacifico, *Dry Etching of Ti in Chlorine Containing Feeds*, Journal of Applied Physics **72**, 4351 (1992).

MN-ThP-4 Nanowatt Chemical Sensor for Unattended Sensing, ***Mieko Hirabayashi**, S. Yen,* Sandia National Laboratories*; O. Faruqe, B. Calhoun,* University of Virginia*; P. Miller, J. Moody,* Sandia National Laboratories

To detect sarin, a potent nerve agent, in unattended applications, we propose a sensor system pairing a sol gel-based transducer with a nanowatt readout circuit. Preliminary measurements demonstrate detection of a sarin surrogate producing a "wake up" signal output while consuming 380 nW of power. This work clears the path to future optimization of the sol gel transducer, use of the multiple channels, and development of the sensor packaging.

Sarin is nerve agent that, when inhaled, induces vomiting and diarrhea, miotic pupils, bradycardia, bronchorrhea, muscle spasms, weakness, flaccid paralysis, seizures, respiratory failure, and tachycardia [1]. For these reasons, sarin gas is notorious as a chemical weapon, and thus its detection at low concentrations is crucial.

Sarin sensors are often carbonnanotube (CNT)-based because this material enables a large surface area and unique electrical properties. These types of sensors are generally sensitive and operate at room temperature [2], but are often fabricated via drop coating, leading to less consistent and less suitable for mass production. By using spray coating of a based catalyzed sol-gel, we are facilitating wafer level sensor fabrication and system integration thereby increasing consistency between fabrication runs and decreasing the overall system size.

With a low power read-out circuit (nano-watt range), we enable unattended, battery-powered detectors for sensing at locations where a wired, full-powered sensor would be difficult to install. Our sensor demonstrates detection of a sarin surrogate using only 380 nW of power. The nW power consumption extends battery life to years for infrequent events [3]. Our results show a single-sensor result (for "waking up" a high-power analysis) with multiple channels for further development for applications and selectivity.

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[1]N. M., Nurazzi. M. M. Harussani, ND Siti Zulaikha, A. H. Norhana, M. Imran Syakir, and A. Norli. *Polimery* 66, no. 2 (2021): 85-97.

[2]J. Li, Y. Lu, Q. Ye, L. Delzeit, and M. Meyyappan. Electrochemical and Solid-State Letters 8, no. 11 (2005): H100.

[3]R.H. Olsson, R.B. Bogoslovov, and C. Gordon.*IEEE Sensors*. 2016.

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