Dielectric Failure in Nb-doped {001} Textured Lead Zirconate Titanate Films

W. Zhu[1*], T. Borman[1], K. DeCesaris[1], S.W. Ko[2], P. Mardilovich[2], and S.Trolier-McKinstry[1]
[1]Department of Materials Science and Engineering, Materials Research Institute
The Pennsylvania State University, University Park, Pennsylvania, 16802, USA
[2]XAAR plc
316 Science Park, Cambridge, CB4 0XR, UK
*W. Zhu: wuz14@psu.edu

Lead zirconate titanate (PZT) films have many potential applications, such as inkjet print heads, actuators, and ultrasonic transducers. The long-term reliability of PZT films is one of the critical properties for these applications. Thus, this work is directed towards understanding the factors that influence the reliability.

Three niobium doped, {001} textured, gradient free, lead zirconate titanate (PNZT) films were fabricated from solutions with different lead contents. Film lead excess was controlled through changes in the average solution lead excess from 14.7, 16, to 17 at.%. For all three sets of samples, 1.5 μm thick films showed a permittivity ~1600, and dielectric loss ~0.024. PNZT with median Pb excess (PNZT-M) have slightly higher remanent polarization ~29±1.2μC/cm^2. During dielectric breakdown process of {001} textured PNZT films, three processes were observed: an increase in leakage current, cracking, and thermal breakdown. At 150^{o}C, with 400kV/cm electric field applied, the mechanical crack density (the number of intersection between cracks and crack-check line per micrometer) of PNZT films increased from 0.060/μm to 0.090/μm as the solution Pb excess increased from 14.7% to 17%. Moreover, the films showed higher crack densities and more thermal breakdown events when the electric field was applied from top to bottom electrode (field down) as compared to the case when the electric field was applied from bottom to top electrode (field up). The films with higher Pb content have a lower breakdown strength. Also all three films showed lower breakdown strength when measured in the field down direction, which is in agreement with the measured lifetimes. The relationships between the long term reliability, the Schottky barrier height and its dependence on the Pb excess amount in PNZT films, and the polarity of the measurement electric field will be discussed.