Chemical solution deposition and advanced characterization of Pb-free, Bi-based, piezoelectric thin films

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Abstract

Piezoelectric materials convert mechanical strain into a dielectric displacement, as well as the converse, allowing these materials to be used as sensors, actuators, and transducers. Currently, lead zirconate titanate (PZT) is the primary material used in these applications. Due to environmental toxicity and safety concerns associated with Pb, development of alternative materials is necessary. Bi-based systems are an attractive area of research in both bulk ceramic and thin film embodiments. Although progress in developing bismuth sodium titanate (BNT)-based solid solutions has been impressive, the combination of cation volatility and high processing temperatures for both bulk ceramic and thin film fabrication can lead to changes in stoichiometry and create defects within the system which can significantly impact material properties.

One of the main sources of defects is often presumed to be related to cation volatility. As such, the diffusion behavior of volatile cations within BNT-bismuth potassium titanate (BKT)-based thin films was studied using transmission electron microscopy (TEM), electron energy loss spectroscopy (EELS), and energy dispersive x-ray spectroscopy (EDS). Results indicated that Bi, Na, and K had all diffused into the Pt bottom electrode, and in some cases the underlying buffer layers. Multi-layer BNT-BKT-bismuth zinc titanate (BZnT) thin films were fabricated using chemical solution deposition (CSD). X-ray diffraction (XRD) and atomic force microscopy (AFM) were used to study structure and morphology changes with processing parameters. The dielectric, ferroelectric, and piezoelectric properties were characterized and values of the effective out-of-plane piezoelectric coefficient, $d_{33,f}$, were extracted from double beam laser interferometry (DBLI) measurements. Lastly, electrical fatigue measurements showed that while $d_{33,f}$ was larger for compositions closer to the BNT-BKT morphotropic phase boundary (MPB), those further away were able to withstand a higher number of cycles at ±400 kV/cm.

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