Probing Cracks Induced by Inhomogeneous Stresses in MLCAs

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Electric-field-induced cracking is pervasive in piezoelectric materials due to their electromechanical response. Both microscopic and macroscopic cracks have been well-studied in monolithic piezoelectric ceramics. However, little is known about cracking and, ultimately, failure in multilayer ceramic actuators (MLCAs) and capacitors (MLCCs), where inhomogeneous stresses can develop between regions of electrically active and inactive materials. In the present work, lead-free potassium sodium niobate (KNN) based MLCAs are used as the basis of investigation into the origins of cracking in MLCAs. Thermal etch is performed at 1020 ^{o}C, showing the grain size 5~50 μm between interdigitated electrodes in the MLCAs. The materials have been characterized extensively using X-ray diffraction (XRD) and scanning electron microscopy. Temperature-dependent XRD results reveal the phase transitions from Orthorhombic (*Amm2*) to Tetragonal (*P4mm*) at 15 ^{o}C, Tetragonal (*P4mm*) to Cubic ($Pm\bar{3}m$) at 350 ^{o}C. Lattice parameters in each phase are also determined by Rietveld refinement of high-resolution powder diffraction data from beamline 11-BM at Advanced Photon Source (APS). Finite element modeling (FEM) performed in ANSYS predicts stresses around electrode tips and dead zones are higher than between the overlapping interdigitated electrodes in KNN MLCAs. Results from high resolution X-ray computed tomography (CT) and electron backscattered diffraction (EBSD) show the interior structural information and microstructure around interdigitated electrodes and dead zones. These results will contribute to a fundamental knowledge of microcracking in piezoelectrics and help in the design of new actuators and capacitors.