MS-12-P-2207 In-situ electric-field transmission electron microscopy studies of Ba(Zr$_{0.2}$Ti$_{0.8}$)O$_3$-x(Ba$_{0.7}$Ca$_{0.3}$)TiO$_3$ ferroelectrics

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Due to excellent dielectric, piezoelectric and mechanical properties, lead-containing ferroelectrics with perovskite structure are widely used in piezoelectric sensor and actuator applications. However, because of the toxicity of the heavy metal lead \cite{1, 2}, it is necessary to search for a suitable lead-free alternative for these materials \cite{3}. Our studies were focused on the Ba(Zr$_{0.2}$Ti$_{0.8}$)O$_3$-x(Ba$_{0.7}$Ca$_{0.3}$)TiO$_3$ piezoceramic system, with x = 0.30, 0.50, 0.52 (abbreviated as BZT-xBCT). These different compositions have been synthesized by a conventional solid state reaction method. The evolution of the domain morphology in BZT-xBCT under an applied electric field was analyzed by in-situ transmission electron microscopy (TEM). For all compositions, changes in the domain structure during poling were observed. An electric field induced transformation from the multi-domain to the single-domain state was observed (Fig. 1 - Fig. 4). This transformation is found to be reversible, since multi-domain contrast reappears inside the grains upon field removal. It should be noted that an intermediate nanodomain state has also been observed during electrical poling of BZT-xBCT. The selected area electron diffraction patterns show neither any reflection splitting nor detectable changes during electrical poling for all compositions studied. Domain wall movement during the application of electric fields and the absence of any reflection splitting in the electron diffraction patterns for all investigated compositions lead to the conclusion of a large contribution of the extrinsic effect to the piezoelectric response of the Ba(Zr$_{0.2}$Ti$_{0.8}$)O$_3$-x(Ba$_{0.7}$Ca$_{0.3}$)TiO$_3$.


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Fig. 1: In-situ TEM bright field image of the BZT-0.3BCT along the [1-35] zone axis at virgin state.

Fig. 2: In-situ TEM bright field image of the BZT-0.3BCT along the [1-35] zone axis at 2.5 kV mm$^{-1}$. The direction of the poling field is indicated by the arrow.

Fig. 3: In-situ TEM bright field image of the BZT-0.3BCT along the [1-35] zone axis at 3.3 kV mm$^{-1}$. The direction of the poling field is indicated by the arrow.

Fig. 4: In-situ TEM bright field image of the BZT-0.3BCT along the [1-35] zone axis at 5 kV mm$^{-1}$. The direction of the poling field is indicated by the arrow.