

(K, Na)NbO₃-based Lead Free Single Crystals: Full Tensor Properties and anisotropic Behavior

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High quality (K,Na)NbO₃ (KNN)-based lead-free single crystals with various compositions, such as (K,Na)(Nb,Ta)O₃ (KNNT), (K,Na,Li)(Nb,Ta)O₃ (KNLNT), Mn doped (K,Na,Li)(Nb,Ta)O₃ (KNLNT:Mn) and (K,Na,Li)(Nb,Sb,Ta)O₃ (KNLNST), were successfully grown by the top-seeded solution growth method in our group. The crystals show either orthorhombic (O) phase or tetragonal (T) phase at room temperature, depending on their compositions. Full tensor properties of KNN-based crystals with both single domain state ("1O" and "1T" domain structure) and multi-domain domain state ("2O" and "4T" domain structure) have been measured. It is shown that high longitudinal electromechanical and piezoelectric properties can be achieved in "4O" and "2T" multi-domain structure while the single domain state shows high shear properties. The orientation dependence of dielectric, piezoelectric, elastic and electromechanical properties for both tetragonal and orthorhombic phase were calculated based on the full data sets of "1O" and "1T", the maximum piezoelectricity is predicted. The extrinsic dielectric and piezoelectric response were extracted. For the crystals with "4O" domain structure, extrinsic piezoelectric contributions from domain wall motions were estimated to be about 20% in the NKNT and NKLNT, and to be 13% for in NKLNT:Mn single crystal.