Structure-property relationships for single crystals in the PMN-PT system

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Abstract

Data are reported for single crystals grown in the lead magnesium niobate, Pb3MgNb2O9 (PMN)-lead titanate, PbTiO3 (PT) system, as a function of PT content, x. Following an introduction to rhombohedral PMN (x=0) and tetragonal PT (x=1), and the crystalline solution series (x= 0 to 1), attention is paid to compositions (x=1/3) in the morphotropic phase boundary (MPB) region. Attention is paid to the unusually high piezoelectric coefficients (d ¿¿1000) and coupling factors (k ¿0.9) reported for MPB compositions. Results are given for the phase transformation behavior between the rhombohedral (R) and the higher temperature cubic (C) state; the tetragonal (T) to C transformation; and, the R to T to C sequence of transformations in the MPB region. Structure-property relationships determined from thermal studies (e.g., thermal expansion, DSC and heat capacity measurements) are discussed in terms of anomalies observed in dielectric constant (K). This temperature dependence of K is reported for various crystallographic orientations (hkl) for both poled (e.g., 111, 001,110) and unpoled specimens. Similar anisotropies in other properties are reported; especially for d and k. Results are discussed in terms of temperature and field-induced transitions. In addition, information is reported for the domain states observed in the hot stage of a polarizing microscope; and polarization-reversal characteristics are illustrated by the new technique of electro-thermal imaging with an IR camera. The overall dielectric, ferroelectric, and piezoelectric properties are discussed in the context of structure-property relations in the PMN-PT system, especially in the MPB region. From an understanding of the anisotropies that exist, directions for enhanced property performance may be determined. Some of the outstanding piezoelectric properties are reported for single crystal orientations, e.g., longitudinal, transverse and shear coefficients in excess of 3500 pC/N, 1700 pC/N, and 6000 pC/N, respectively.