Synchrotron Studies of $PbMg_{1/3}Nb_{2/3}O_3$ under Applied Electric Field

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Introduction

Lead magnesium niobate $Pb(Nb_{2/3}Mg_{1/3})O_3$ (PMN) is a relaxor ferroelectric with dielectric constant >30,000 near $T_m = 270K$. The high dielectric constant of relaxor ferroelectrics, electrostriction, and piezoelectricity are attractive features for applications in the capacitor and actuator[1] industries. Temperature-dependent crystallographic studies of PMN and their connection to the relaxor behavior are our primary goal. Our previous studies were focused on temperature dependence of superlattice reflections.[2] In this work we studied the effects of the electric field and temperature simultaneously. Previous *in situ* measurements of the fundamental Bragg reflections with an applied electric field were reported in the literature.[3,4] The effect of the electric field on superlattice reflections at low temperatures is not yet known.

Methods and Materials

A single crystal of PMN, grown by the Bridgman technique[5] and with linear dimensions 5 x 7 x 0.5 mm^3 was cut with surface normal perpendicular to the (111) crystallographic planes. Gold electrodes were deposited on the two largest parallel surfaces for *in situ* application of the electric field up to 6 kV/cm. Low-temperature measurements (10-300K) were performed in a closed cycle He-compressed gas cryostat (Displex), which was mounted on the Newport six-circle kappa diffractometer. The sample height was regularly adjusted to compensate for the temperature contraction of the sample holder inside the cryostat. Measurements were performed on the UNICAT undulator beamline (Sector 33-ID) at the Advanced Photon Source (APS), Argonne National Laboratory. The x-ray energy was tuned to 10 keV with a double-crystal monochromator using Si 111 and focused vertically by two Rh-coated mirrors. The size of the incident beam was 0.2 mm vertically and 0.5 mm horizontally. Diffracted radiation was measured with an Oxford scintillation detector.

Results

Fundamental Bragg and superlattice reflections were studied under an electric field applied perpendicular to the (111) planes. The full width at half maximum (FWHM) of the fundamental Bragg reflections was less than 0.007° for ω rocking curve scans. Rocking curves with open detector slits of the 112 Bragg peak at 215K with and without applied filed are shown in Fig. 1. A peak shift was found to be independent of temperature. No field-induced structural phase transition was observed during field cooling, and no effect of the applied electric field on the superlattice reflections has been observed in this sample.

Discussion

We were not able to induce the structural phase transition in PMN reported in the literature.[3,4] We think that the peak shift shown in Fig. 1 is a result of electrostriction.[1] The change in the lattice parameter associated with the peak shift in Fig. 1 is $\Delta a = 0.05$ Å. The peak shifts gradually with an applied electric field, and Fig. 1 shows a maximum value at 5.5 kV/cm. We cannot rule out that the peak shift could be also due to the deformation of the sample under applied field not related to the lattice constant changes. Superlattice reflections were found to be much broader, and we were not able to determine any effect of the electric field on these peaks. It is known that the relaxor properties strongly depend on the composition and the method of preparation of the sample. The sample in this work was grown by the Bridgman technique, and we need to do composition measurements to determine the source of inconsistencies with results reported in the literature on PMN grown by the Chochralsky method.

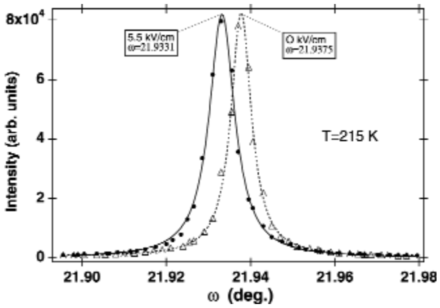

FIG. 1. Dependence of 211 Bragg reflection on electric field at 215K.

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References

[1] S. Nomura and K. Uchino, Ferroelectrics **41**, 117 (1982).

[2] A. Tkachuk, P. Zschack, E.V. Colla, et al., in 2001 Workshop on Fundamental Physics of Ferroelectrics, Williamsburg, VA, (2001).

[3] G. Calvarin, E. Husson, and Z.G. Ye, Ferroelectrics **165**, 349 (1995).

[4] S.B. Vakhrushev, J.-M. Kiat, and B. Dkhil, Solid State Communications **103**, 477 (1997).

[5] S.G. Lee, R.G. Monteiro, R.S. Feigelson, et al., Appl. Phys. Lett. **74**, 1030 (1999).