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"Skin" effect in highly piezoelectric perovskites

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Beamline(s): X17B1

Introduction: Rhombohedral $Pb(Zn_{1/3}Nb_{2/3})_{1-x}Ti_xO_3$ (PZN-x%PT) single crystals show spectacular electromecahical properties, with deformations up to 1.7% when poled along the <100> directions[1]. The investigation of the microscopic processes taking place when the electric field is applied is complicated. On the one hand, the high lead content of these crystals reduces the penetration length of typical x-ray energies to a couple of microns. On the other hand, in this type of mechanically "soft" materials, the mechanical boundary conditions and internal strain fields play a very important role. This makes the first microns below the surface (the "skin") of the crystal, where the strain induced by the electric field is more easily released, very different from the rest of the crystal.

Methods and Materials: High-energy high-resolution synchrotron x-ray diffraction is thus needed to perform diffraction experiments in transmission mode and to be able to sample the crystal bulk. At X17B1 we have used a 67keV beam for this purpose. Moreover, the high-flux beam allowed us to use a narrow beam of about 50μm to measure at different points across the crystal thickness while the electric filed is applied *in-situ*.

Results and conclusions: The results obtained for a PZN-8%PT 2x2x0.5 mm^3 crystal under a 10kV/cm electric field applied along the [001] direction are shown in Fig. 1. (Top) The plot of the intensity *versus* the vertical position of the sample shows the crystal profile along its thickness (along the direction of the field). Two sample positions with respect to the 50μm beam are highlighted as yellow arrows: the top-surface of the crystal (dashed arrow) and the center of the sample thickness (solid arrow). (Middle) Longitudinal scans, L scans, in the H0L zone, taken at both the top surface and the bulk, where the horizontal axis has been converted to d_{001}-spacing. The right and left scans are two different points in the transverse direction (different Ω or H values). It can be seen that in the right-hand side both skin and center scans produce very similar results, while in the left-hand side, at a different H value, the two positions give quite different intensity profiles. These results are sketched in the bottom plots as 2D reciprocal space plots. While in the skin we find a single d-spacing with certain width and a broad mosaic; in the center of the crystal, we observe two very well-defined and sharp peaks, in agreement with the two d-spacing values expected when the crystal jumps to the tetragonal phase[2]. These experiments show that the results previously obtained by lower-energy synchrotron x-rays [2,3] and lab x-rays[4], showing the existence of two very different correlation lengths are due to the observation of the skin of the crystal.

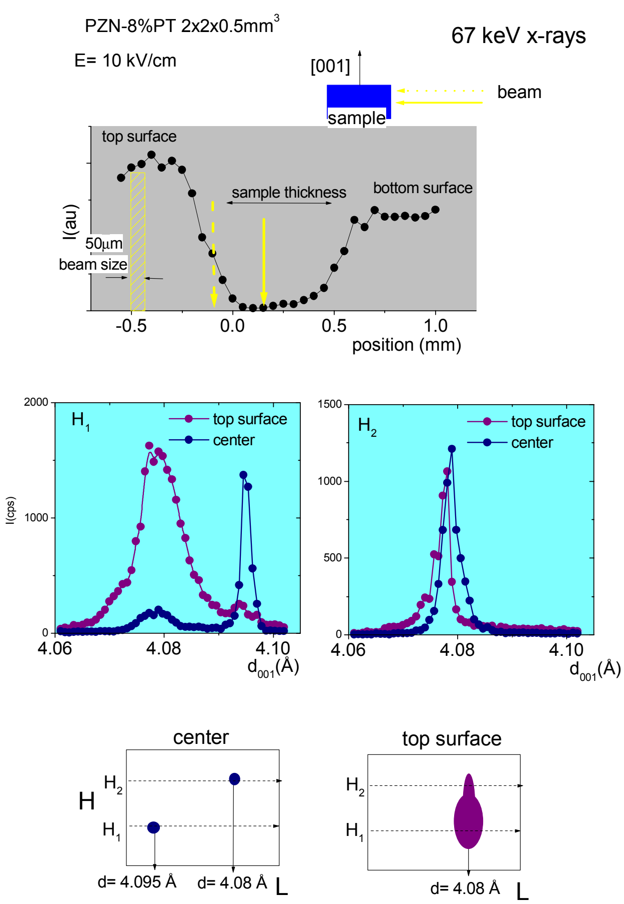

FIG. 1 High-energy x-ray diffraction scans showing the different behavior of the "skin" and the bulk of a PZN-8%PT crystal under an applied electric field, as described in the text.

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References: [1] S.E. Park and T. Shrout J. Appl. Phys.82, 1804 (1997); [2] B. Noheda et al., Phys. Rev. Lett. 86, 3891 (2001); [3] B. Noheda et al. Ferroelectrics (in press) <cond-mat/0109545>, [4] M. Durbin et al. J. Appl. Phys. 87, 8159 (2000).