XXXII Panhellenic Conference on Solid State Physics and Materials Science
Conference Center "Carolos Papoulias", 18-21 September 2016, Ioannina, Greece

GIXRD Study of multiferroic $EuTiO_3$ with in-situ application of electric field

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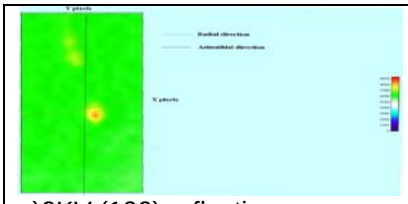
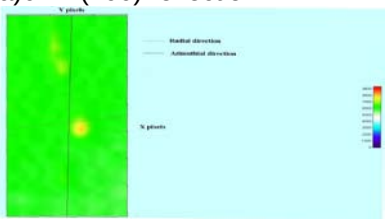
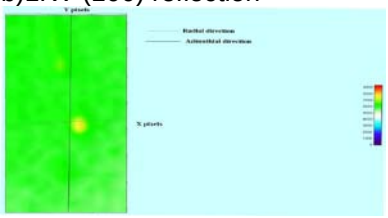
Abstract:

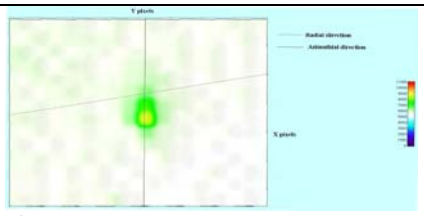
$EuTiO_3$ (ETO) has been discovered many decades ago [i]. Its antiferromagnetic properties below T_N=5.5K [ii] excluded any technological applications, so for a long time it was discarded scientifically. The discovery of a strong magneto-dielectric effect as the temperature approaches T_N [iii] has revived the interest for this material. However, for the bulk material the soft mode frequency tends to zero at around -170K [iv,v], thus there is only a tendency towards a ferroelectric lattice instability. Nevertheless, a tuning of the dielectric constant by a magnetic field reveals that ETO is a strong coupling magneto-dielectric compound. Mainstream thin film technology enables to enhance the multi-functionality in many oxides and also provides valuable information about technological applications. Attempts have been made to realize with these techniques the desired properties for ETO. We have studied a high quality 1 μm ETO thin film grown along the (100) axis on a $SrTiO_3$ (STO) substrate under the application of an external electric field along the (100) axis with the grazing incident angle xrd (GIXRD) technique at the Elettra Sinchrotrone Trieste facility. We have clear evidence that the electric field induces a significant reduction of the disorder of the crystal. The crystal structure itself changes, some crystallographic planes tilt and also there is a profound d-spacing change for planes parallel to the surface (Fig.1a-f), but a symmetry lowering was not observed. The effect shows a hysteresis, but the structural modifications are reversible (Fig.2a-e). Also there seems to be a permanent alternation of the disorder of the crystal as we can see from the profile of the spot (comparison of Fig.2a and Fig.2f). We have observed similar behavior in bulk samples with XRD and Raman spectroscopy. These observations open a new and interesting path for microelectronic applications for ETO thin films as it is obvious that there is a clear effect on the crystal structure with the electric field at room temperature.

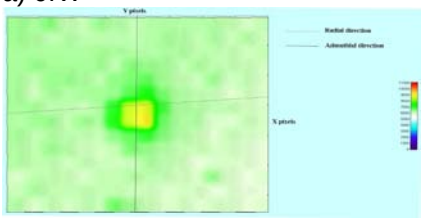

a)0KV (100) reflection

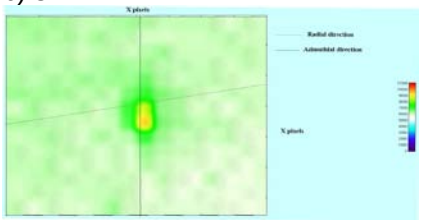

b)1KV (100) reflection

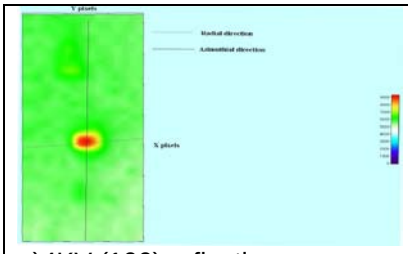

c)2KV (100) reflection


d)3KV (100) reflection

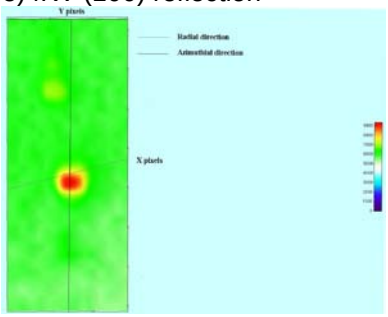

a) 0KV


b) 3KV

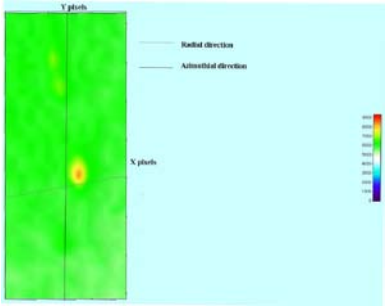

c) 0KV 6 min after the removal of the field



e)4KV (100) reflection

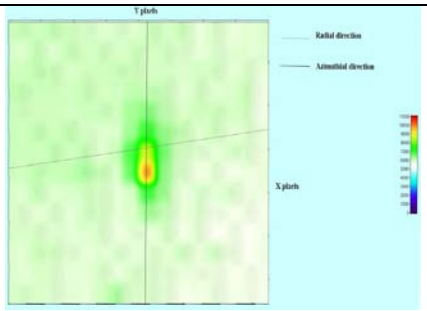


f)5KV (100) reflection

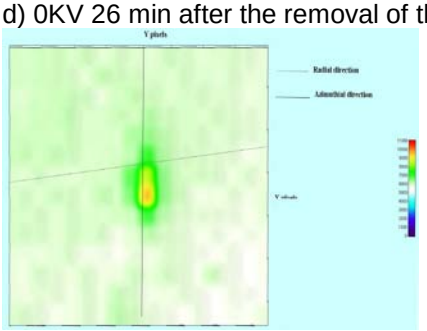


g)0KV relax (100) reflection

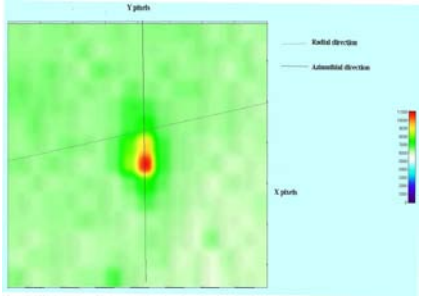
Fig.1a-g. 2-D Image of the (100) reflection with electric field from 0V up to 5kV and immediate relaxation. The corresponding radial and azimuthal directions on the pattern have been marked.



d) 0KV 26 min after the removal of the field



e) 0KV 36 min after the removal of the field



f) 0KV 1 day after the removal of the field

Fig.2a-f. 2-D Image of the (100) reflection with electric field from 0V and 3kV and immediate relaxation for 6, 26, 26 min and one day after. The corresponding radial and azimuthal directions on the pattern have been marked.

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