Nanodomains Coupled to Ferroelectric Domains Induced by Lattice Distortion in Self-doped LuMnxO3±δ Hexagonal Ceramics

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Rare-earth multiferroic manganites of the hexagonal lattice offer promising properties owe to coupling of magnetic, ferroelectric and structural distortions, providing manipulation of one property via other properties. Linking the Z2xZ3 topology of ferroelectric (FE) domain walls in h-$RMnO_3$ crystalline lattices to phase transition phenomena with spontaneous symmetry breaking as described by the Kibble-Zurek mechanism created the opportunity here as in other domains of solid state physics to combine concepts of cosmological theories of the Universe with information on near-critical beha-viour taken in the materials laboratory. The current group publication focuses the interlocking of FE walls to structural distortions in the lattice with profound effects on the FE domain formation [1]. Also, the symmetry change on FE/APB anti-phase boundary structural walls may in turn invoke spin disordering in the antiferromagnetic state of the material, resulting in presence of the weak ferromagnetic component at low temperatures.

Our approach uses TEM/STEM transmission electron microscopy at nano-scale to identify occurrence of nano-FE domains in the lattice of vacancy doped h-$LuMn_xO_{3\pm\delta}$ ceramics, FIG. 1a). Switching of electrical polarization in the lattice is linked to the structural distortions like stacking faults, structural antiphase boundaries and other classes of planar defects, FIG. 1b). The weak ferromagnetic component measurable slightly below Neel transition temperature is coupled to FE and structural walls observed in TEM is revealing the profound impact of internal interfaces on physical properties. Using local probe electron beam with the EELS technique, switching of electrical polarization driven by inhomogeneities in the lattice was investigated. First-principles calculations were used to interpret our measured EELS spectra.

Exploring the underlying mechanisms on the effects of nano-scale features on ferroelectric and magnetic properties of multiferroics as seen in h-$RMnO_3$ manganites can be directly extended not just to sister families of materials like hexagonal rare-earth ferrites but also to the orthoferrites which can be stabilized as epitaxial layers on low-cost substrates.

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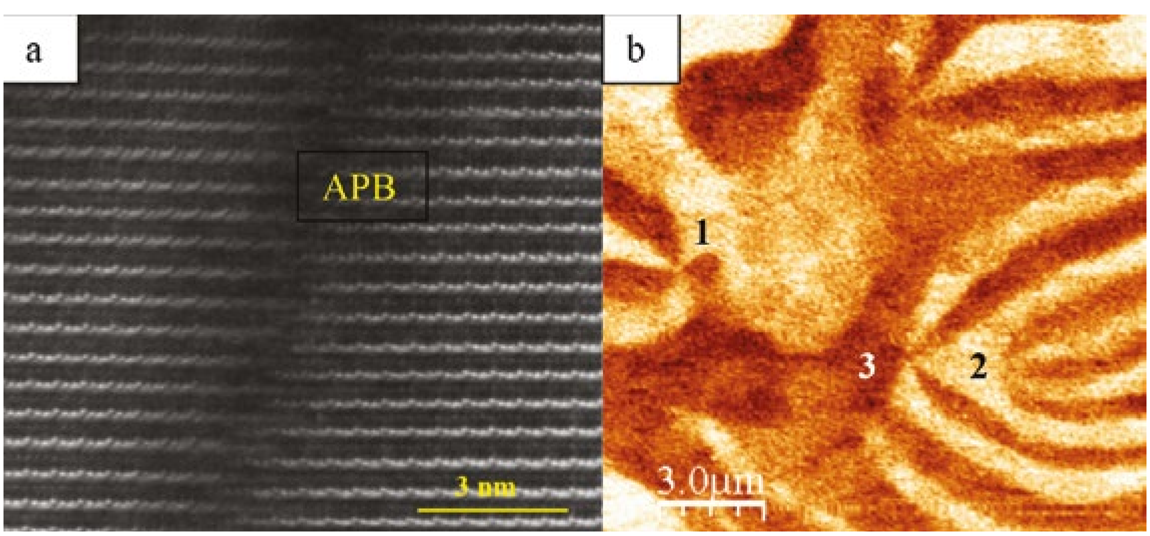

FIGURE 1
a) Cs corrected HAADF/STEM image of interference of the anti-phase boundary (APB) with the ferroelectric polarization (FE) in the lattice of polycrystalline $LuMn_{1.04}O_{3\pm\delta}$ solid solution, the sign of FE polarization each side of the APB is unchanged but the phase order parameter shifts by $\Delta\phi=2\pi/3$, as sintered 1300 ºC, 5 days in air (FEI Titan 200 kV ChemiStem TEM/HAADF-STEM, collaborative research with INL, PT). b) PFM image, development of 2 topological 6-fold vortices (1,2) of FE domains inside the volume of polycrystalline grains and truncation of a topological vortex (3) by interaction with pore free surface, same composition sintered for 10 days, post-annealed above Curie temperature at 1450 ºC 3 h with controlled cooling rate 40 $Kmin^{-1}$, NT-MDT NTEGRA PRIMA AFM/PFM, CICECO/UA infrastructure.