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Probing hidden order in ferroelectric oxide thin films with single crystal diffuse X-ray scattering

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Ferroelectric thin films have attracted great attention for its rich applications in energy-efficient electronic devices because of their relevant physical properties such as high dielectric constants, electrically switchable polarization, and high piezoelectric coefficients [1]. In fact, the growing demand for miniaturized microelectronics has inspired diverse research efforts towards the engineering of ferroelectric properties and domain architectures in the ultrathin regime [2]. Thus, comprehending the structural and electrical properties of ferroelectric thin films on the nanoscale became crucial. Recently, a lot of effort has been put into studying ferroelectric oxide superlattices with complex topologies such as long-range vortex-antivortex arrays of polarization [3]. These works have called for an in-depth structural investigation of the superlattice structures, since the orientation and arrangement of ferroelectric domains define the macroscopic ferroelectric properties in ferroelectric thin films. Here, we report on a newly discovered local order state in superlattices consisting of ferroelectric lead titanate and dielectric strontium titanate using a complete three-dimensional diffuse X-ray scattering data analyzed with 3D-ΔPDF method [4]. The data was collected with single crystal diffuse X-ray scattering technique, which, to the best of our knowledge, was used for the first time to study local order in single crystalline thin films. This work will not only contribute to gaining useful insights on structure-property correlations of ferroelectric oxide superlattices, but also lay groundwork for developing a novel non-disruptive solid-state characterization technique for analyzing local structures of thin films.

[1] Setter, N., et al. 2006

Fong, Dillon D., et al. 2004; Schlom, Darrell G., et al. 2007

Yadav, A. K., et al. 2016; Damodaran, A. R., et al. 2017

Weber, T., Simonov, A. 2012

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