Thermal Fluctuations of Ferroelectric Nanodomains Studied with Wide-angle X-ray Photon Correlation Spectroscopy (WA-XPCS)

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Ferroelectric polarization in epitaxial nominal atomic layers often forms into stripe nanodomains to minimize the total electrostatic energy of the system. Material properties at domain walls can deviate significantly from the bulk due to the very large atomic strain, providing new venues for tuning thin film properties. We measured the thermally-driven equilibrium dynamics of ferroelectric nanodomains in a 100 nm thick PbTiO$_3$/SrTiO$_3$ superlattice. The electric coupling between the ferroelectric PbTiO$_3$ layers is tuned by the SrTiO$_3$ layers and results in nm-periodicity domains with serpentine striped patterns commonly observed in spinodal decomposition systems. The temperature dependence on the time scale of domain fluctuation can be described using Arrhenius equation yielding an activation energy of 0.35 ± 0.21 eV. This energy level corresponds to the average height of energy barriers that separates domain configurations with similar energy levels and implies that the formation and fluctuation of nanodomains may be affected by pinning mechanisms such as oxygen ion vacancies [1]. The 10× higher brilliance at NSLS-II allowed for investigation of thermal fluctuation at temperatures closer to T$_c$ and revealed intriguing jamming/unjamming behaviors. Discussion will also include the in-situ study of atmosphere-induced topotactic phase transition in SrCoO$_{2.5}$ thin film on SrTiO$_3$ substrate. XPCS speckle analysis in this study reveals physics that is inaccessible via monitoring only the average statistics of diffuse scattering features during synchrotron x-ray microdiffraction experiments.

This research was performed at beam line 8-ID-E of the Advanced Photon Source, Argonne National Laboratory under Contract No. DE-AC02-06CH11357. Work at the University of Wisconsin-Madison was supported under Grant No. DE-FG02-10ER46147 (P. E.). Work at Stony Brook University was supported by the U.S. NSF Divisions of Materials Research under Grant No. 1055413 (M. D.).

References