Towards Transferable Large-Scale MBE-Grown 2D Ferroelectric SnSe

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Among the candidates for 2D ferroelectric materials, SnSe has attracted attention due to its robust in-plane polarization down to the monolayer limit at room temperature [1]. Unlike layered ferroelectrics relying on interlayer sliding mechanisms, SnSe is an intrinsic ferroelectric van der Waals (vdW) material — yet the roles of stacking configuration, strain, and polarization switching mechanisms remain incompletely understood [2]. These questions have been addressed primarily using single-crystal flakes [3], which offer a well-controlled platform but do not capture the challenges of large-scale fabrication, where nucleation dynamics, grain boundaries, and defects may play a decisive role in ferroelectric behavior.

In this work, we report the successful growth of SnSe thin films of variable thickness by Molecular Beam Epitaxy (MBE) on mica, and their structural characterization from the macroscopic to the atomic scale. A highly crystalline anisotropic layer was achieved using a single SnSe effusion cell at a growth rate of 0.1 ML/min. Layer-by-layer vdW epitaxy is confirmed by Atomic Force Microscopy (AFM) terraces (Fig. 1a) corresponding to the SnSe monolayer thickness. Crucially, the growth optimization on mica is developed to enable large-scale film transfer [4] — a step not addressed in previous MBE reports [5].

A large-scale wet transfer protocol, made possible by the air stability and robustness of the films, enables plan-view Scanning Transmission Electron Microscopy (STEM) characterization, with Raman spectroscopy confirming that crystalline quality is preserved throughout. Plan-view STEM maps reveal variant distribution (Fig. 1b-c), grain boundaries, and a predominant AB antiferroelectric (AFE) stacking (Fig. 1d), accounting for the absence of Piezoresponse Force Microscopy (PFM) signal.

The transfer protocol serves a dual purpose: it simultaneously enables multi-scale structural characterization by STEM — providing direct access to grain boundaries, domain misorientation, and stacking defects — and integration of the films onto target substrates for device fabrication. This dual functionality establishes a direct feedback loop between MBE growth conditions and atomic-scale structural insight, offering a pathway to tailor stacking configuration, suppress growth-related defects, and favor the ferroelectric phase in a reproducible, large-scale process.

References

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Figures

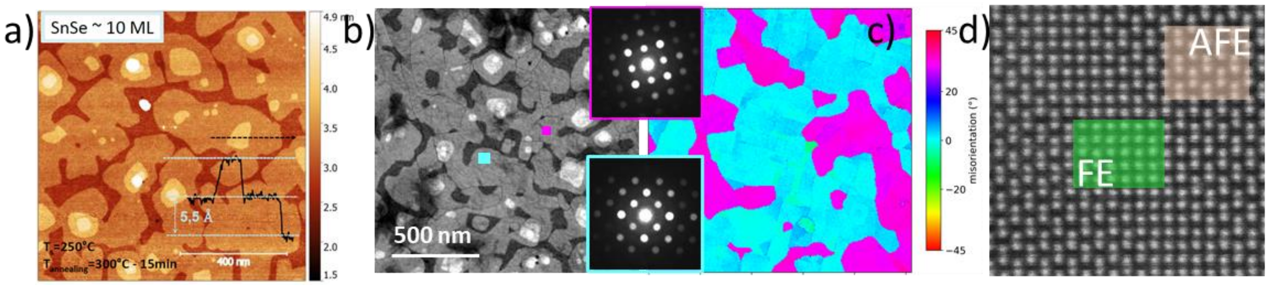

Figure 1: a) AFM topography. b) Reconstructed ADF image and its respective orientation map (c). d) High-resolution plan-view STEM image showing the ferroelectric (FE) « square » lattice and antiferroelectric (AFE) « dumbbell » lattice stacking configurations.