

# OVPR Seed Grant Proposal

## Towards designer superlattice potentials in 2D material-ferroelectric oxide composites : Developing ordered nanoscale domains

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### Overview/Abstract

Two-dimensional van der Waals (2DvdW) bonded materials have emerged over the last several decades as a powerful platform for technological applications and fundamental physics. Recently, another revolution in the field was initiated by stacking 2DvdW materials with a small relative twist angle, resulting in a striking moiré pattern and dramatically altered physical properties, including emergent superconductivity and quantum anomalous Hall phases.

A key question in this context is whether the physics observed in moiré systems can be generated by other more robust methods rather than twisting, such as the application of a modulated electrostatic potential to the 2DvdW material on a sub 10 nanometer scale. We have a unique approach to applying such a potential: placing the 2DvdW material on a ferroelectric heterostructure with domains engineered to form a periodic potential.

We submitted a DMREF proposal to NSF in January 2021 centered on the development and understanding of these systems. On the theory side we proposed to combine theoretical calculations including continuum models, mesoscale simulations, and atomistic first-principles calculations. To experimentally engineer the 2DvdW-ferroelectric composites, we would combine layer-by-layer synthesis of ferroelectric heterostructures, state-of-the-art characterization techniques from the bench top to the beam line, and nanofabrication and measurement capabilities.

We recently received notification that our DMREF proposal could not be funded in this round. While there was extensive praise for the idea, the team and the potential significance of the work, the decision not to fund the proposal hinged on one critical element: they did not feel we had sufficiently demonstrated that we could engineer ferroelectric domains on the sub 10nm scale with the necessary order for the application. The goal of this seed grant is to obtain the necessary results to bolster our claim that we indeed have unprecedented control over ferroelectric domain structures, and thus our wider goals for modulating 2D materials are also in reach. With this issue convincingly addressed, we plan to submit another NSF DMREF proposal in the next cycle (January of 2023).