Moiré Ferroelectric Domain Switching and Neuromorphic Computing Applications

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Abstract

Ferroelectricity refers to the spontaneous electric polarization of materials that can be manipulated through the application of an external electric field. Different regions of a ferroelectric material possess polarization pointing in different directions — these are domains of uniform polarization separated by boundaries of enhanced electrical conductance called domain walls. Domain walls can move in response to an applied voltage, causing the polarization of impacted regions to switch. If these domain walls are part of a domain wall network, their dynamics are instead related to concave and convex motion relative to fixed points rather than unpinned "translational" motion. Here, the domains change in size and flip.

The premise of this experiment is to examine nonlocal ferroelectric domain switching in a moiré lattice of twisted hexagonal boron nitride (hBN). Ferroelectricity arising from moiré structures is unconventional since it is predicated on net dipole moments in different regions due to intra-atomic stacking. Domain size depends on the twist angle used to construct the moiré structure, and using a larger twist angle results in smaller domains with an inherent domain wall network. Using kelvin probe force microscopy (KPFM), we applied a voltage to a predetermined region of domains and observed that the polarization of the entire sample was altered, temporarily erasing the existing moiré periodicity. After some time, the structure returned to its original state. This nonlocal switching is promising as it eliminates the need to construct complex electrical pathways to control multiple areas.

Compared to conventional ferroelectrics and devices dependent on local domain switching and tuning, moiré ferroelectrics provide a host of new applications. Most notably are those to neuromorphic computing, a field that relies on artificial neurons and synaptic connections to create energy-efficient devices capable of facilitating neural network algorithms.

In this talk, we discuss the unconventional nature of moiré ferroelectrics, particularly with respect to a twisted hBN superlattice. After reviewing the construction of this moiré structure and how ferroelectricity can arise due to net dipole moments between hBN layers, we proceed to the results from KPFM measurements after voltage application to a specified region of domains. In particular, we note the ability of our moiré sample to act as a nonlocal switch. We conclude by introducing the idea of neuromorphic computing and how the domain wall network of this unconventional ferroelectric can be relevant to the development of new memristive devices as information can be stored in the domain walls.

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