Exploring lattice reconstruction in low angle twisted graphene superlattices

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Abstract

Control of the interlayer twist angle in bilayer graphene allows for the fabrication of moiré superlattices with tunable periodicity. These twisted moiré superlattices exhibit extraordinary electronic properties stemming from their low-density flat electronic bands and complex atomic and lattice structures. They have garnered significant attention among researchers since the emergence of highly tunable and strongly correlated insulating states and superconductivity in twisted bilayer graphene (TBG), twisted at around the magic angle (θ≈1.1°) [1]. These properties are susceptible to factors such as twist angle and carrier density [1]. However, TBG undergoes lattice reconstruction, especially at low twist angles, which can alter the twist angle locally and affect the electronic structure, potentially influencing all emergent electronic phenomena.

In TBG, the rigid incommensurate moiré structure reportedly transforms into commensurate domains at low twist angles (θ<2°) by increasing regions of energetically favourable AB and BA stackings with the reduction of regions with AA stacking [2], [3]. Similarly, lattice restructuring has been noted in additional moiré superlattice configurations wherein a monolayer of graphene is nearly in alignment with a hexagonal boron nitride substrate [4]. Despite substantial scientific interest, an experimental study elucidating the factors governing complex lattice reconstruction in TBG as a function of twist angle and materials' mechanical properties is still lacking. Atomic reconstruction at the van der Waals interface could offer a fresh approach to engineering and understanding the moiré superlattice systems.

Here, we present an atomic force microscopy (AFM) study to examine the complex lattice reconstruction at low-angle twists. In this study, we employ advanced techniques to fabricate twisted bilayer graphene with higher yield and cleanliness. Utilising straightforward techniques performed using an AFM setup at room temperature, we characterise the local structure of moiré superlattices. Our study focuses on the lattice relaxation of magic-angle TBG, aiming to demonstrate a relation between the periodicity of relaxed moiré superlattices with twist angles and materials' elastic properties. Our experiments aim to explain the inconsistency reported in experimentally obtained phase diagrams and electronic properties in TBG around the magic angle.

References

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