Interferometric Atomic Force Microscopy for Imaging the Moiré of Twisted 2D Materials

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Atomic force microscopy (AFM) plays a crucial role in characterizing the moiré pattern of twisted 2D materials. This moiré pattern, a proxy for twist angle, can be directly observed with a variety of AFM modalities. In addition, a new AFM design using quadrature phase differential interferometry (QPDI) [1] confers improvements in both accuracy and precision [2]. This new interferometric AFM's low noise floor (5 fm/√Hz) enables the moiré of twisted hexagonal boron nitride and twisted bilayer graphene (tBLG) to be imaged consistently for the first time in topography. Increasing the imaging force increases the apparent topography (Figure 1), indicating differences in sample stiffness corresponding to domains formed during lattice relaxation and reconstruction. These samples are further investigated with Contact Resonance AFM, with the Kelvin-Voigt model being used to describe the tip-sample interaction. Results indicate that the tip-sample interaction is conservative and not dissipative in nature (Figure 2). Under this framework, contrast in techniques like Contact Resonance and Torsional Force Microscopy (TFM) for tBLG can be understood to be from local variations in sample stiffness and not dissipative interactions such as dynamic friction.

References

[1] A. Labuda, B. Pottier, & L. Bellon. US 11519935.
[2] R. Proksch, et al. In preparation (2025)

Figures

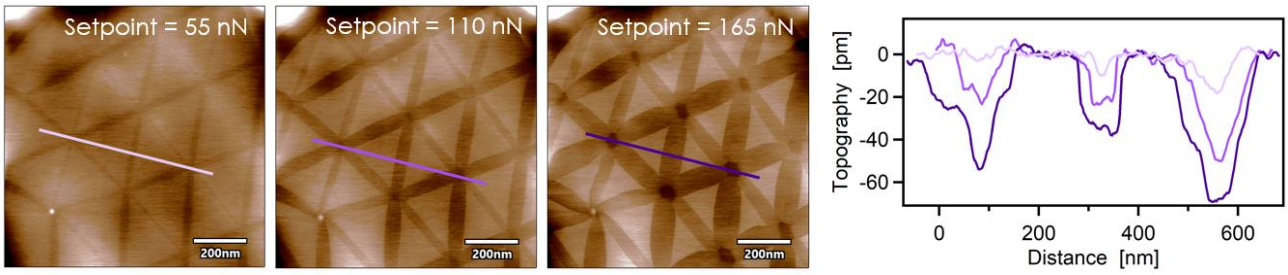

Figure 1: The moiré of twisted hexagonal boron nitride (hBN) observed in the AFM topography channel. Increasing force reveals distinct post lattice-relaxation domains.

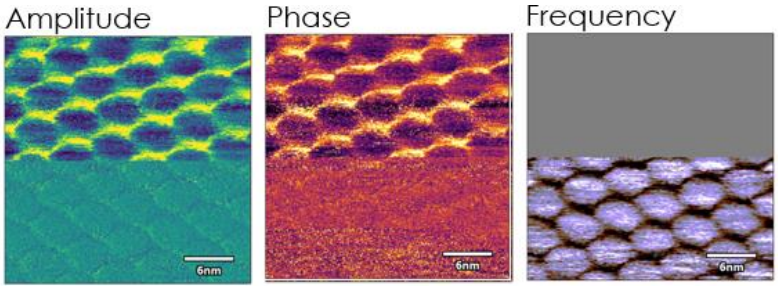

Figure 1: Contact Resonance of twisted bilayer graphene moiré. Contrast shifts from Amplitude and Phase channels into Frequency when resonance tracking is enabled halfway down the scan, indicating that the AFM tip-sample interaction is conservative and not dissipative in nature.