Advanced AFM Techniques for Graphene Research: Integrating Atomic Resolution, Electronic Properties, and Nano-Manipulation

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Abstract:
Graphene, with its exceptional structural, electronic, and mechanical properties, continues to attract intense research interest for applications ranging from nanoelectronics to energy storage. To fully exploit its potential, advanced nanoscale characterization and manipulation techniques are essential. Atomic force microscopy (AFM) offers a versatile platform, enabling unprecedented insight into graphene's surface, electronic behavior, and local interactions under varied environments. Here, we present recent advances in AFM-based approaches tailored for graphene research, highlighting the integration of high-resolution imaging with multifunctional probes. Conductive AFM (C-AFM) provides localized current mapping to evaluate charge transport across defects and grain boundaries; Kelvin Probe Force Microscopy (KPFM) reveals surface potential variations arising from doping, adsorbates, and moiré patterns; and Piezoelectric Force Microscopy (PFM) investigates electromechanical coupling in graphene-like 2D systems. Complementary Lateral Force Microscopy (LFM) is employed to study interlayer friction, edge effects, and nanomechanical response, while Scanning Microwave Impedance Microscopy (sMIM) enables non-invasive subsurface electronic property mapping with nanoscale resolution. Case studies will demonstrate how these combined techniques provide a comprehensive toolkit for probing atomic-scale morphology, local charge distribution, and functional manipulation of graphene. The talk will discuss prospects for integrating AFM-based nano-manipulation (graphene cutting) with property mapping to accelerate device-oriented graphene research.

References

[1] **Zeng, Y., Tschirhart, CA. L., Finney, J., & Zhang, Y. (2023).** Imaging inter-valley coherent order in magic-angle twisted trilayer graphene. *Nature, 621*(7977), 488–493].

Figures

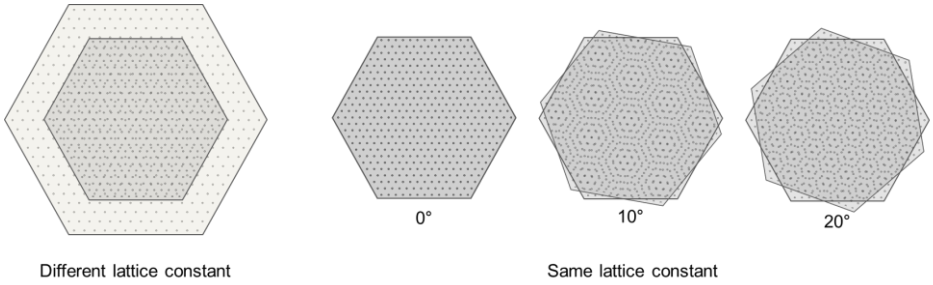

Figure 1: Shows moiré patterns of a graphene layer with different twisting angles