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Research on novel structures and their electronic states realized in two-dimensional materials

Abstract: Through the development of two-dimensional (2D) material transfer processes, van der Waals (vdW) homo/heterostructures have been controllably constructed based on monolayer graphene. By utilizing scanning tunneling microscopy (STM) atomic-scale tip manipulation technology and scanning tunneling spectroscopy (STS) technology, the detection and regulation of novel quantum states have been realized. The research achievements obtained during the doctoral period include:

1. Combining wet transfer technology to controllably construct twisted bilayer graphene (TBG) homostructures. Using STM tip pulses to achieve controllable adjustment of the interlayer coupling strength of TBG, and observing the low-frequency oscillation behavior of the top-layer graphene [1];

2. Combining polydimethylsiloxane (PDMS)-assisted dry transfer technology to controllably construct tiny angle twisted monolayer-bilayer graphene. Realizing the preparation of submicron-scale rhombohedral stacked graphene, and observing the size-dependent flat band characteristic for the first time [2];

3. Through the controllable construction of graphene-transition metal dichalcogenide (TMDC) heterostructures, the preparation of fractional-layer TMDCs has been achieved for the first time using STM tip manipulation technology. Furthermore, lattice reconstruction phenomena and one-dimensional charge density modulation different from those of monolayer 1T'-WTe_2 have been observed in fractional-layer WTe_2 [3]. This provides a relatively comprehensive platform for the research on novel quantum states based on fractional-layer TMDC materials and their heterojunctions.

Key Words: Scanning tunneling microscopy, graphene, flat band, fractional-layer transition metal dichalcogenides

Reference

[1] Ya-Xin Zhao et al., Physical Review Letters, 127(26):266801 (2021).

[2] Ya-Xin Zhao et al., Physical Review B, 109:205155 (2024).

[3] Ya-Xin Zhao et al., Nature Communications, 16:3659 (2025).