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GRAPHENE AND BEYOND
From Atoms to Applications

Moirée superlattices, moiré crystals, and moiré quasicrystals

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Abstract

The emergence of moiré superlattice (MSL) designed using van der Waals materials (vdW) bilayers has created unprecedented opportunities to engineer 2D electronic materials with novel properties. Thus far, most superlattices are created at small twist angles ($\theta_t \leq 6^0$). At small angles, the moiré pattern is either commensurate or nearly commensurate to the atomic lattice. Moreover, the moiré wavelength is long, and regions with different interlayer alignments within the moiré unit cell can be treated individually as a local region with different electronic structures (local approximation).

At a large twist angle, the moiré patterns are in general incommensurate with atomic lattices except for a few rare exceptions. One well-known commensurate structure at a large twist angle of $\theta_t = 21.8^0$, is a root 7 by root 7 structure whose lattice constant is rather small (< 1 nm). Here we adapt the terminology "moiré crystal" to make a distinction from the more superlattices. At $\theta_t = 30^0$, an incommensurate moiré structure is formed that breaks the translational symmetry but possesses a dodecagonal rotational symmetry. While the translational symmetry is broken, long-range order exists, yielding sharp diffraction patterns without translation symmetry. By using scanning tunneling spectroscopy, we will uncover the electronic structures in these three regimes: moiré superlattices, moiré crystals, and moiré quasicrystals. As the Bloch theorem is not applicable, understanding the electronic structures of moiré quasicrystals is particularly challenging. I will show how valley-resolved scanning tunneling spectroscopy allows us to uncover how the interlay Umklapp scattering of different orders manifest the formation of a dense set of mini gaps.