Gate-Tunable Flatbands in Graphene Moiré Superlattices

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Periodic moiré patterns in the length scale of a few tens of nanometers can give rise to moiré mini Brillouin zones whose zone corners are at energy ranges accessible by conventional field effects in gated transistor devices. Recent experiments have shown resistance peaks as a function of carrier doping indicative of Mott-like phases in twisted bilayer graphene at the first magic twist angle [1,2] and in ABC trilayer graphene (TLG) nearly aligned with hexagonal boron nitride (BN) [3,4] when the Fermi energy is brought near the superlattice flat bands (SFB). The possibility of tailoring narrow flatbands in systems with such remarkable simplicity in composition as graphene consisting of only carbon atoms makes it an attractive pathway to engineer artificial materials. Here, we study the flatbands that can be engineered in twisted multilayer graphene. In the twisted bilayer graphene (tBG), the flatband minima angles are found to grow linearly with interlayer coupling and decrease with Fermi velocity [5]. In tBG, the fltabands emerge as a function of twist angle, vertical pressure, and interlayer potential differences between the layers. Interestingly, in twisted double bilayer graphene (tDBG) the bandwidth is generally flatter than in tBG by roughly up to a factor of 2 in the same parameter space of twist angle and interlayer coupling, making it in principle simpler to tailor narrow bandwidth flat bands [6]. A related system where flattening of the low-energy bands is facilitated by the presence of a vertical electric field is the ABC trilayer graphene (TG) on hexagonal boron nitride (hBN), TLG/BN [7], where Coulomb effects can lead to correlated gapped phases even without a specific twist angle. We show the narrow bandwidths of ~10 meV are achievable for a continuous range of twist angles $\theta \leq 0.6^{\circ}$ with moderate interlayer potential differences of ~50 meV make the TLG/BN systems a promising platform for the study of electric-field tunable devices. The gate-tunable narrow superlattice flat band (SFB) in graphene moiré superlattices become non-trivial topological bands when they are isolated through avoided crossing of the bands in k-space that can impact the character of the ground-state Hall conductivity depending on the specific configuration of the ground states.

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