Pressure-Induced Flat Bands and Zero-Field Chern States in Large-Angle Twisted Bilayer Graphene

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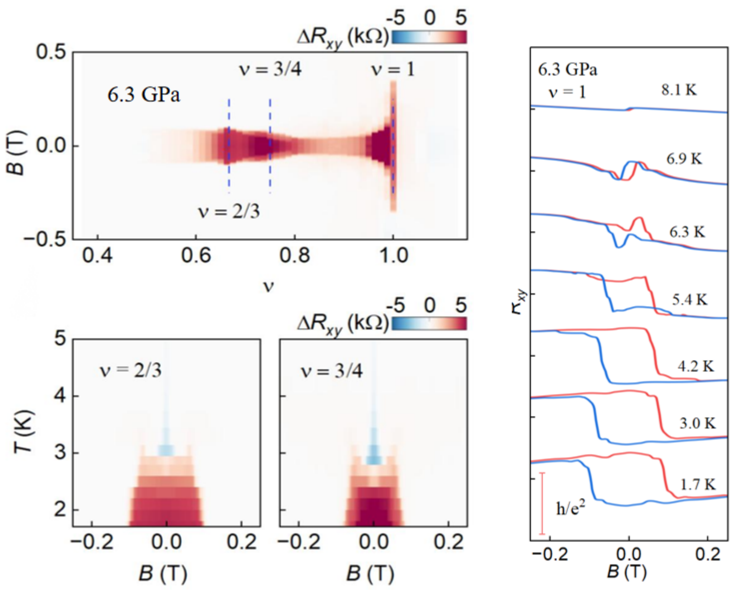
Abstract

Twisted bilayer graphene (TBG) is a moiré quantum material in which electron interactions can be dramatically enhanced by band flattening, giving rise to correlated states reminiscent of those discussed in the context of high-temperature superconductivity, as well as topological phases with quantized Hall response without an external magnetic field. Hydrostatic pressure offers a clean, non-invasive way to tune these electronic states by continuously modifying the interlayer coupling, yet its effects on large-angle TBG at multi-gigapascal pressures remain largely unexplored[1]. Here we develop a diamond-anvil-cell transport platform that enables continuous measurements on the same hBN-encapsulated TBG device up to ~10 GPa and apply it to samples with twist angles of $\theta \approx 1.37°–1.73°$. Pressure strengthens interlayer hybridization, shifts the effective magic-angle condition to larger twist angles, and drives these devices into an optimal flat-band regime near up to ~ 6 GPa, where correlated insulating states are strongly enhanced and the effective Fermi velocity is reduced to ~300 m/s. In this regime, zero-field anomalous Hall states emerge at integer fillings $\nu = 1$ and 2, corresponding to Chern insulators with $C = -1$ and -2 and Curie temperatures up to ~8 K. Near the optimal flattening condition, additional hysteretic anomalous Hall features appear at fractional fillings $\nu = 2/3$ and 3/4, with field dependence consistent with $|C| = 1$, pointing to interaction-driven symmetry breaking and topological charge-ordered states. These results show that hydrostatic pressure does more than recover flat bands in large-angle TBG: it opens access to a stronger-correlation regime in which new integer and fractional topological states can be stabilized.



Zero-Field Chern Insulators at integer and fractional fillings in twisted bilayer graphene under high pressure.

[1] S. Carr, S. Fang, P. Jarillo-Herrero, E. Kaxiras, Pressure dependence of the magic twist angle in graphene superlattices. *Physical Review B*, 2018, 98, 085144.