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Topological Lifshitz transition and electron-correlation in cross-plane thermoelectricity at near magic-angle twisted bilayer graphene

Introduction of 'twist' or relative rotation between two atomically thin van der Waals (vdW) membranes gives rise to periodic Moiré potential, leading to substantial altercation of the band structure of the planar assembly. These twisted meta-materials, owing to their exceptional tunable nature, have emerged as the ideal platform for studying many novel concepts of condensed matter physics [1,2]. While most of the recent experiments primarily focus on the electronic-wavefunction reconstruction by probing transport properties in the in-plane direction, we report on thermoelectric measurements across the van der Waals gap in twisted bilayer graphene (tBLG) at small twist angle ($\Theta \sim 0.6^0$). The cross-plane Seebeck coefficient shows Lifshitz transitions as the band topology changes from electron-like (hole-like) massless Dirac to hole-like (electron-like) massive bands at the van Hove singularity point. Additionally, we observe temperature dependent splitting and strong non-linearity at half filling of the lowest bands even at temperatures ~ 125 K, indicating strong electron correlations due to localization of electronic density of states in the system. The twist-controlled cross-plane thermoelectricity in tBLG may provide fundamental insights towards the electron-electron and electron-phonon interactions in Moiré superlattices which can leverage the broad electro structural phase space of layered solids.

References

[1] Cao, Y. *et al.* Correlated insulator behaviour at half filling in magic-angle graphene superlattices. *Nature* **556**, 80 (2018).
[2] Cao, Y. *et al.* Unconventional superconductivity in magic-angle graphene superlattices. *Nature* **556**, 43 (2018).

Figures

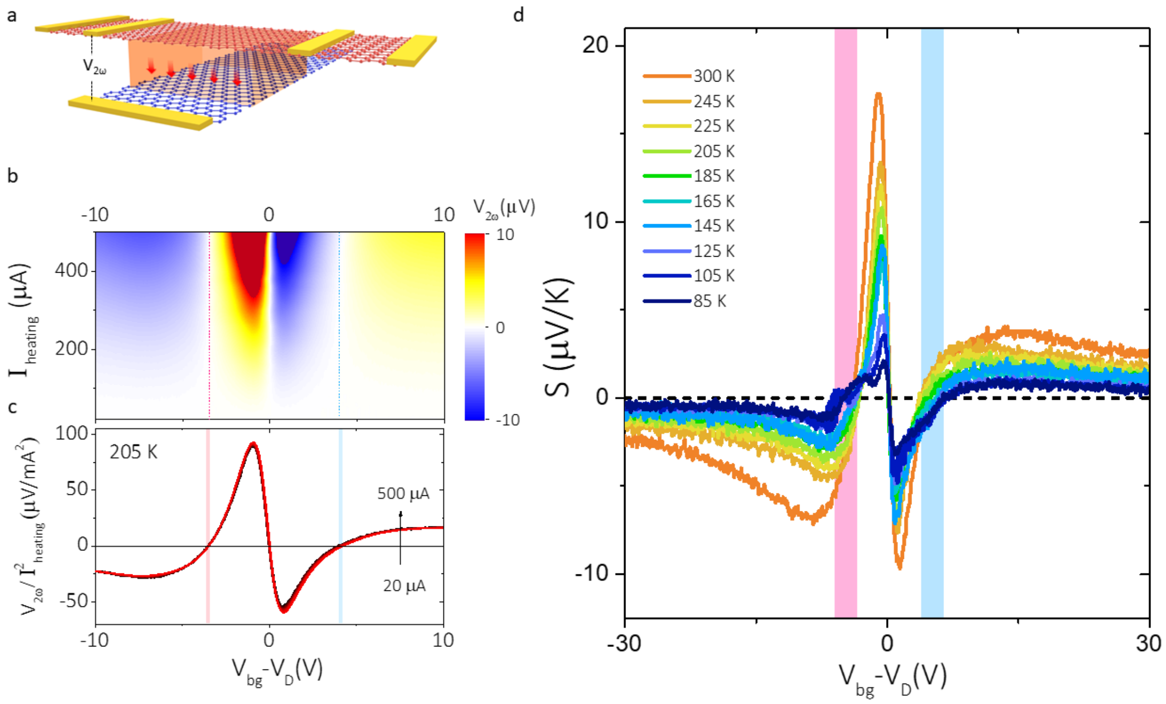

Figure 1: Observation of Lifshitz transition in cross-plane thermoelectricity: (a) schematic showing the heat flow and the thermo-voltage between the two graphene layers. (b) Color plot of the thermo-voltage ($V_{2\omega}$) as function of heating current and doping at 205 K. The dotted lines show the Lifshitz transitions as the $V_{2\omega}$ abruptly changes sign. (c) $V_{2\omega}$ / $I_{heating}^2$ as a function of doping for heating current (20-500 μA) . (d) The Seebeck coefficient for different temperatures as a function of doping. The shaded areas show the position of the VHS.