Hydrodynamic magnetoresistance in the quantum-critical regime of graphene supermoiré lattice

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Abstract: The Dirac plasma, an electron-hole (e-h) plasma of Dirac fermions at the charge-neutrality point of graphene, acts as a hydrodynamic conductor where e-h collisions dominate the scattering [1-2]. However, little is known about the hydrodynamic transport of Dirac plasma through moiré potential. Here, we design three distinct moiré systems with enhanced moiré potential in hBN/graphene/hBN supermoiré lattice based on our controlled alignment technique [3]. At zero magnetic field, all the moiré systems become temperature-independent with a constant resistivity of ~1 kohm above 150 K, which can be attributed to the onset of the quantum-critical regime where the scattering is dominated by the Planckian frequency $\sim K_B T/\hbar$. Once a magnetic field is applied, all the moiré systems show a linear increase with magnetic field, but their magnitudes are suppressed with enhanced moiré potentials. By minimizing the moiré potential, we observe a new world-record MR value of 16,500% at 9 T and 300 K. We use effective medium theory to reveal that the moiré potentials engineer the band structure of the Dirac cone and increase the carrier density fluctuation, leading to the modulation of the MR effect in graphene. Our work demonstrates a 2D system based on the hydrodynamic regime of graphene supermoiré lattice with robust, stable, and high magnetic field sensitivity, promising the next generation of 2D magnetic field sensor. This work is supported by the MOE Singapore Tier 1 (A-8001967-00-00), Tier 2 (MOE-T2EP50120-0015), and the NRF-ISF Singapore joint program (NRF2020-NRF-ISF004-3518).

References

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Figures

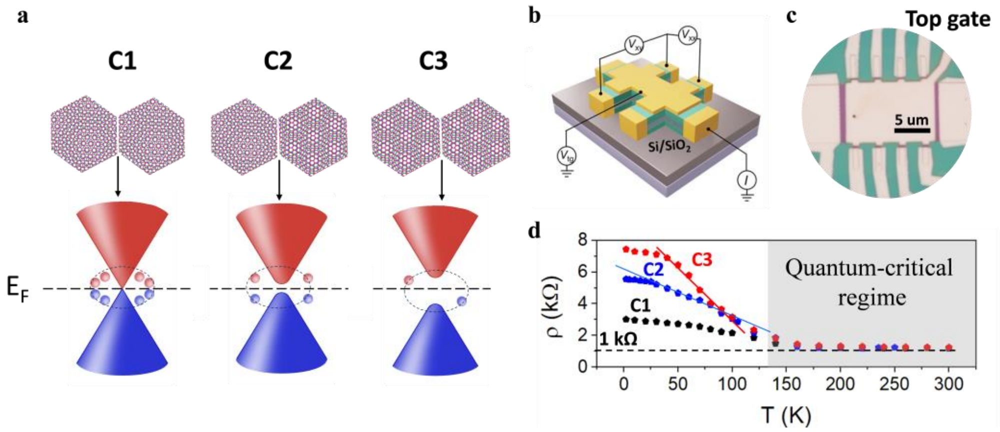

Figure 1: Dirac plasma in graphene supermoiré lattice. **a**, Schematic of three distinct moiré systems with enhanced moiré potential from the weakest moiré potential C1, moderate moiré potential C2 to the strongest moiré potential C3. The low panel is the Dirac band structures modulated by the corresponding moiré potentials. **b**, Schematic of the standard Hall bar structure for transport study. **c**, The typical optical image of supermoiré device. **d**, Temperature dependence of resistivity at the Dirac point for three moiré systems. The slopes of the linear fits (red and bule solid lines) between 20-150 K give the bandgap Δ via $\rho_{CNP}^{-1}(T) \propto e^{-\Delta/(2kT)}$.