Ning Wang

Department of Physics and Center for Quantum Materials, the Hong Kong University of Science and Technology

phwang@ust.hk (Ning Wang)

Intrinsic valley Hall transport in atomically thin semiconducting transition-metal dichalcogenides

Electrons hopping in two-dimensional honeycomb lattices possess a valley degree of freedom in addition to charge and spin. In the absence of inversion symmetry, these systems were predicted to exhibit opposite Hall effects for electrons from different valleys. Such valley Hall effects have been achieved by extrinsic means, such as substrate coupling, dual gating, and light illuminating. We realized intrinsic valley Hall transport without any extrinsic symmetry breaking in the non-centrosymmetric monolayer and trilayer MoS2 [1]. We demonstrate experimentally that the nonlocal resistance measured from MoS2 shows cubic scales with local resistance (see FIG. 1). Such a hallmark survives even at room temperature with a valley diffusion length at micron scale. By contrast, no valley Hall signal is observed in the centrosymmetric bilayer MoS2. The pronounced nonlocal signals are observed in our MoS2 samples with length up to 16 µm and at temperature up to 300 K. A DC electric field induced by dual gating can effectively break the inversion symmetry in bilayer MoS2, resulting in valley Hall transport phenomena as evidenced by non-local transport measurement. In twisting bilayer WSe2, depending on the twisting angles, the cubic scales with local resistance can be observed at various gate voltages. Our work elucidates the topological origin of valley Hall effects and marks a significant step towards the purely electrical control of valley degree of freedom in topological valleytronics. Our observed intrinsic VHEs and their long valley diffusion lengths are promising for realizing room-temperature low-dissipation valleytronics.

References

[1] Z. F. Wu, et al., “Intrinsic valley Hall transport in atomically thin MoS2”, Nature Comm. 10 (2019)611. This research was support by the Research Grants Council of Hong Kong (16300717, C7036-17W).

Figures

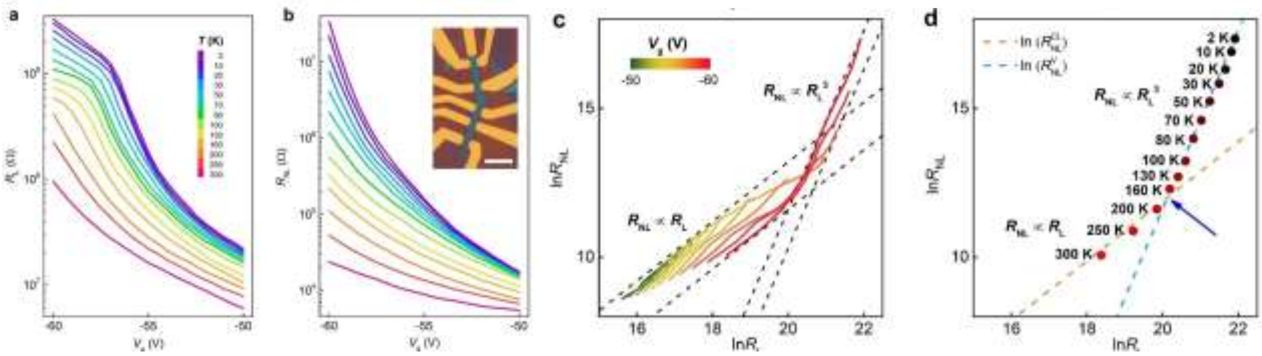

Figure 1: Local and nonlocal resistances of monolayer MoS2. a, b Semilog plots of RL and RNL as a function of Vg measured at varied temperatures. Inset of b: optical micrograph of our typical h-BN/MoS2/h-BN device with multi-terminal Hall Bar configurations. Scale bar: 5 µm. c Scaling relations between ln RL and ln RNL at Vg ranging from −50 V to −60 V. When the electron density is relatively high, i.e., RL and RNL are small, RNL is linearly proportional to RL. When the electron density is relatively low, a crossover from linear to cubic scaling is observed. The critical density nc = 4 ×1011 cm−2, with the gate voltage Vg =−57 V. d Crossover phenomenon by considering classical diffusion (RNL ∝ RL) and valley Hall transport (RNL ∝ RL3). The experimental data (solid circles, Vg = −60 V) clearly show two different regimes which are fitted by two linear curves (orange dashed line with slope 1 and blue dashed line with slope 3). The critical temperature is around 160 K~200 K, as marked by the blue arrow.