Memristive and Quantum Hall effect in graphene enhanced by two-dimensional ferroelectric $CuInP_2S_6$

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The miniturisation of electronic devices is taking place at astonishing speed. In 2021, IBM unveiled the first 2 nm chip technology [1]. It is coming extremely close to the regime where the bulk of the device isn't bulk but interface, and where quantum phenomena isn't a textbook example but a reality. It is critical that we study and understand these emerging interfacial phenomena, and apply it in the design of 'More than Moore' devices. In this context, electronic devices based on atomically thin van der Waals materials (2D-vdW) are ideally suited for studying interface-controlled phenomena and quantum physics.

Here, we present a series of studies on the electrical transport properties of graphene, where the graphene conducting channel is gated through vdW ferroelectric $CuInP_2S_3$ (CIPS) (Fig. a). We reveal a hysteresis effect that is sensitive to electric field, temperature, light illumination and magnetic field. The memristive effect arises from charge transfer across the graphene/CIPS interface (Fig. b) [2]. By electrostatically gating graphene, we tune the Fermi energy of graphene so that the current-carrying delocalized states of graphene are brought into equilibrium with localised states in CIPS. As a result, a quantum Hall plateau in graphene is observed over a wide range of temperatures in relatively modest magnetic fields (Fig. c) [3]. These findings on graphene-based systems with heterointerfaces are relevant to the development of hybrid structures for quantum metrology and ferroelectric memory devices.

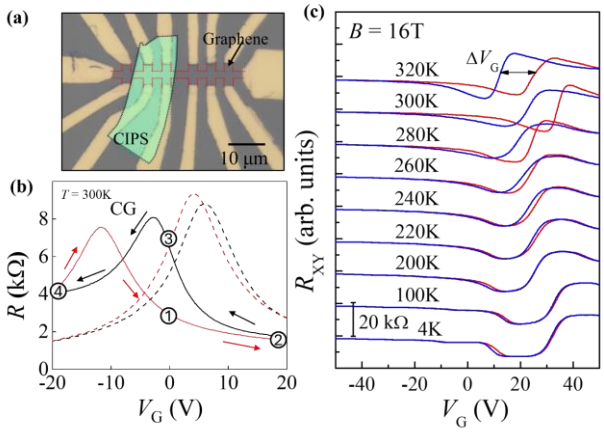

Fig. (a) Optical image of a hybrid device based on graphene and CIPS; (b) transfer curve and hysteresis in graphene (dotted line) and graphene/CIPS (solid line) at 300 K; (c) Hall resistance verus gate voltage, revealing a quantum Hall plateau over a wide range of temperatures.

[1] https://research.ibm.com/blog/2-nm-chip; [2] A. Dey, et al. *2D Mater.* 9, 035003 (2022); [3] A. Dey, et al. *Commun. Phys.* 6, 216 (2023).