Imaging topological breakdown of quantum Hall channels in graphene

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Graphene edges are known to strongly affect the topological protection of quantum Hall (QH) channels. Indeed, in Corbino geometry [1], or with a strategic gate design [2] allowing to avoid QH channels located in the vicinity of the physical edges of the device, transport exhibits signatures such as fractional QHE, only visible in extremely high mobility devices. In more conventional device layouts (e.g. etched Hall bars), the screening of the backgate causes charge carrier accumulation at device edges. Hence, both forward and backward QH channels counter-propagate along the same edge, in a region decoupled from the bulk by an incompressible (insulating) strip [3].
We used scanning gate microscopy (SGM) to explore the mechanisms responsible for the QH effect breakdown at graphene edges. In SGM, a polarized metallic tip scanning a few tens of nanometers above the graphene plane acts as a local gate (Fig. 1a). The sample resistance is recorded while changing the tip position, yielding SGM resistance maps.
From the typical Coulomb blockade signatures (concentric higher resistance rings in Figs. 1c-e,g) [4] in SGM maps, and comforted by simulations, we infer that the breakdown is caused by tunnel-coupling through antidots located between counter-propagating channels [5](Fig. 1h). Our study leads to a better understanding of QH effect breakdown in 2D materials.

References

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[2] Ribeiro-Palau et al., Nano Lett. 19 (2019) 2583
[3] Marguerite et al. Nature 575 (2019) 628
[4] Hackens et al. Nat. Comm. 1 (2010) 39
[5] Ihnatsenka et al. PRB 80 (2009) 115303

Figures

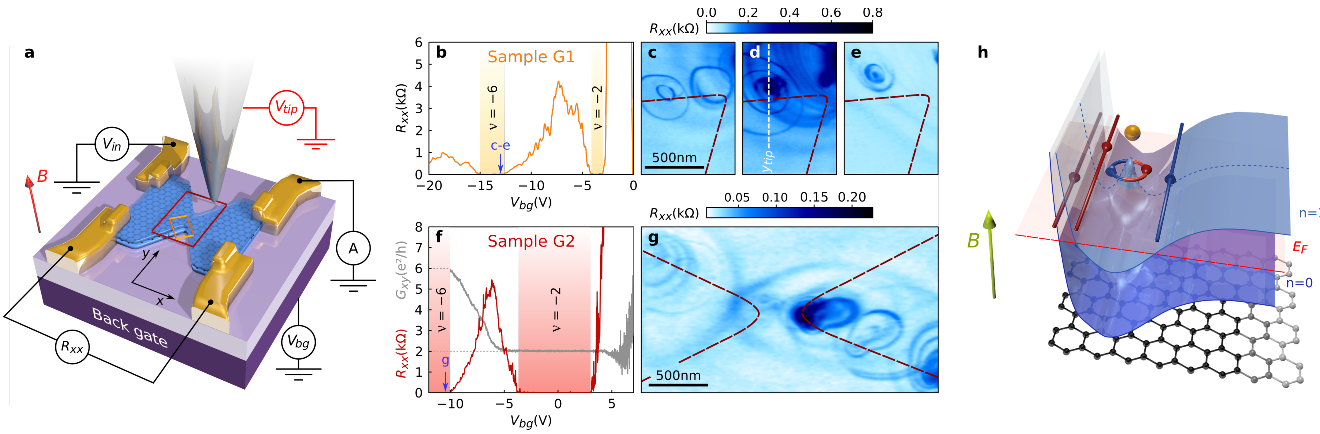

Figure 1: **a** Schematic of the SGM setup. The encapsulated graphene sample (in blue) is scanned by a biased tip. **b** Resistance as a function of back gate voltage (V_{bg}) for sample G1 at B = 12T **c-e** SGM maps obtained by scanning the tip above region orange in a for V_{tip} = 0V (c) +3V (d) and -5V (e) and for the V_{bg} indicated in b. **f** Resistance as a function of V_{bg} for sample G2 at B = 14T **g** SGM map corresponding to the red region in a for Vtip = 0V for the V_{bg} indicated in f. **h** Schematic of an antidot located between forward (red) and backward (blue) QH channels. The planes are Landau levels deformed by the potential landscape.