Breakdown of Quantum Hall Effect in Graphene

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The breakdown of the quantum Hall effect, which is observed as an abrubt change in the longitudinal resistance by several orders of magnitude with an associated loss in quantization of Hall voltage is the major obstacle against improving the resistance standard which is currently based on this effect. Graphene is inherently a 2D material and in comparison with GaAs based 2DEG and has an unsual band structure that allows the quantization of the Hall resistance even at room temperature[1]. These unique properties of graphene make it a good candidate for being used as a high precision metrological characterization tool for the quantum Hall resistance. A relative uncertainty of 1 ppb in the resistance quantization can be achieved by quantum Hall effect GaAs based 2DEG. The uncertainity in the Quantum Hall resistance in graphene has been rapidly improving in the last couple of years, from 15 ppm in exfoliated graphene[2] to 3 pbb in epitaxial graphene[3]. Sufficiently high breakdown currents and low contact resistances are needed to obtain such high accuracy in determining the resistance quantum.

In this work, we report experimental results on the breakdown of quantum Hall effect in graphene. The Hall devices were fabricated on mechanically exfoliated graphene. Single layer, bilayer and a few layer graphene sheets are transferred onto SiO_x substrate where Raman spectroscopy is used to identify the number of graphene layers. Devices are patterned by optical and electron beam lithography. Measurements are done in a temperature range of 1.4 –300 K. Some samples exhibit immediate onset of the breakdown in the longitudinal resitance even at very small currents [Fig.1]. This behavior could be attributed to relatively mobility of the samples (~5.000 cm^2/V.s). However, in the same measurement we observe that the Hall plateaus [Fig.2] can endure to much higher currents. We elaborate on the physical phenomena underlying this behavior in the breakdown of the quantum Hall effect and its possible implications on the improvement of the accurate determination of the plateau levels.

References

[1] K.S.Novoselov, *et al.* Science 315, 1379 (2007).
[2] Giesbers A. J. M. *et al.* Appl. Phys. Lett. 93, 222109 (2008).
[3] Tzalenchuk, A. *et al.* Nature Nanotech. 5, 186–189 (2010).

Figures

Fig.1

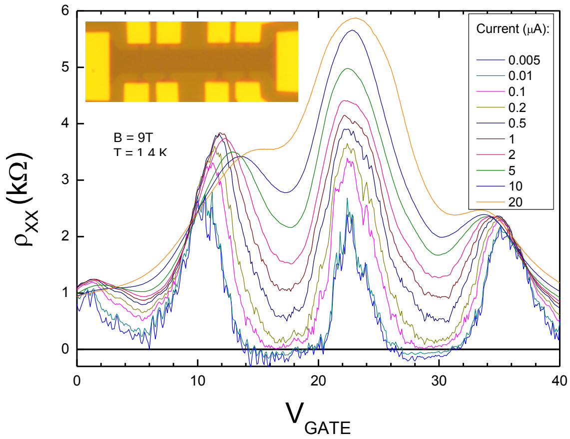

Fig.2

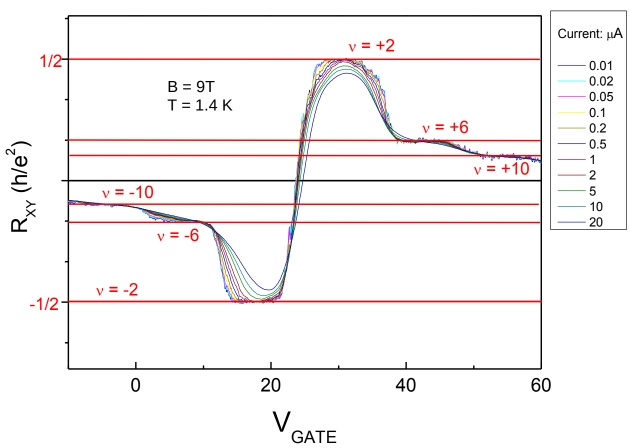

Figure captions

Fig.1. Longitidunal resistance vanishes below 100 nA even for $\nu = \pm 2$ and it rapidly increases for higher applied current values.These nonzero resistance values implies the breakdown of quantum Hall effect. Inset shows the optic microscope image of the graphene hallbar with the contact configuraiton.

Fig.2. The plateaues of Hall resistances at filling vactors $(\nu = \pm 2,6,10)$ due to the unsual band structure of graphene determines the anomalous quantum Hall effect in monolayer graphene. Quantized Hall plateaues at $\nu = \pm 2$ are clearly visible up to 1 μA.