Quantum Hall Effect in Hydrogenated Graphene

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The quantum Hall effect (QHE) is observed in a two-dimensional electron gas formed in millimeter-scale hydrogenated graphene [1], with a mobility less than 10 cm^2/Vs and corresponding Ioffe-Regel disorder parameter $(k_F\lambda)^{-1} \sim 500$. Our observations with hydrogenated graphene push the limit of disorder where the QHE can still be attained in a strong magnetic field, suggesting that the QHE might be robust to arbitrarily large disorder.

Disordered graphene samples were prepared from pristine, large-area, monolayer graphene samples grown by chemical vapour deposition (CVD) on Cu foils. Disorder was controllably introduced into the graphene by exposure to a beam of atomic hydrogen in a UHV chamber. *In-situ* measurement shows an exponential growth in graphene sheet resistance versus hydrogen dose. We find hydrogenated graphene to exhibit a strong temperature dependent resistance consistent with variable range hopping. We measured the 2-point resistance of hydrogenated graphene at low temperatures in magnetic fields of up to 45T, Fig. 1. A colossal negative magnetoresistance was observed, with a dramatic transition from a highly resistive state of $R_{2pt} = 250\ h/e^2$ at zero field to a quantized resistance $R_{2pt} = 12\ 962\Omega$ at 45T, which is within 0.5% of $h/2e^2$. The quantized resistance corresponds to a QHE state with $\nu=-2$ filling factor, $R_{2pt} \approx |R_{xy}| = h/2e^2$, and $R_{xx} = 0$. The high field resistance versus charge carrier density is consistent with the opening of an impurity-induced gap in the density of states of graphene.

The mean spacing between point defects induced by hydrogenation was estimated to be $\lambda_D = 4.6 \pm 0.5$ nm via Raman spectroscopy. The rapid collapse of resistance and emergence of a QHE state is observed to occur when the magnetic length $\ell_B = (\hbar/eB)^{1/2}$ is comparable to the mean point defect spacing λ_D. The interplay between electron localization by defect scattering and magnetic confinement in two-dimensional atomic crystals will be discussed.

[1] J. Guillemette et al., arXiv:1301.1257 [cond-mat.mes-hall]

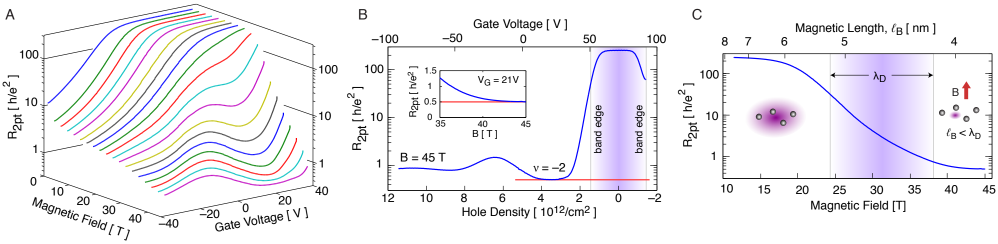

Fig. 1: A) The two-point resistance of a hydrogenated graphene sheet versus magnetic field and gate voltage. All data were taken at a temperature of 575±25 mK. B) At 45T, the resistance versus gate voltage and hole density, with the red line indicating a Hall plateau at $R_{2pt} = h/2e^2$. C) Resistance of the hydrogenated graphene versus both the magnetic field B and magnetic length $\ell_B = (\hbar/eB)^{1/2}$. The shaded region indicates the estimated point defect spacing extracted from the Raman spectra.