Observation of the 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, 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. The strongly temperature dependent electrical resistance and high thermal resistance of hydrogenated graphene may further find potential applications in thermometry and bolometry.

Hydrogenated graphene samples were prepared from pristine, large-area, monolayer graphene samples grown by chemical vapour deposition (CVD) on Cu foils. The graphene was controllably hydrogenated 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 962Ω 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. Preliminary work on the application of hydrogenated graphene's electrical and thermal properties to thermometry and bolometry will also be discussed.

This work was made possible with the support of NSERC, FRQNT, the LNCMI (Toulouse) and the NHMFL (Tallahassee).

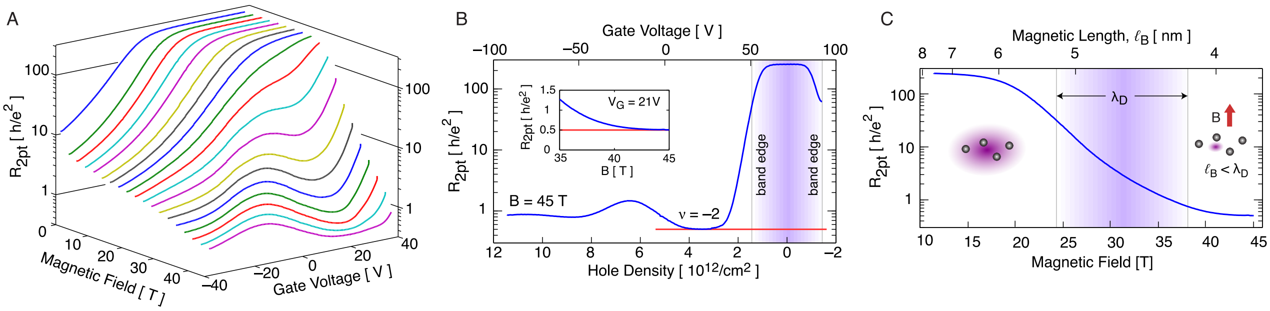

Fig. 1: A) The two-point resistance of a hydrogenated graphene sheet versus magnetic field and gate voltage. All data were taken at a temperature of 575±25 mK. B) At 45T, the resistance versus gate voltage and hole density, with the red line indicating a Hall plateau at $R_{2pt} = h/2e^2$. C) Resistance 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.