Quantum Hall Effect in Hydrogenated Graphene

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Introduction

Two-dimensional atomic crystals have attracted much attention as surfaces with unique low-dimensional electron transport behaviour, most notably the zero-gap semiconductor graphene. The relativistic Dirac dispersion of electrons in graphene leads to an anomalous four-fold degenerate quantum Hall (QH) sequence. Common to these studies is low disorder, with a mean free path large compared to electron Fermi wavelength with the cleanest graphene samples exhibiting the fractional quantum Hall (FQH) effect. We report here our discovery of a quantum Hall effect in graphene at the opposite extreme, whereby hydrogenation was used to induce a short mean-free path beyond the Ioffe-Regel limit for the onset of strongly insulating behaviour. Our work illustrates the importance of the interplay between electron localization by point defect scattering and magnetic confinement in two-dimensional atomic crystals.

Experimental

Our starting material is large-area monolayer graphene grown by chemical vapour deposition (CVD) on Cu [1]. The graphene material quality was verified by Raman spectroscopy. We used a custom-built, high-flux, atomic hydrogen gun to thermally crack a flow of ultra-purified molecular hydrogen directed at a graphene device target while *in situ* electron transport measurement was performed during hydrogenation. The temperature dependence and perpendicular magnetic field dependence of the resistance of hydrogenated graphene was measured in SCM2 so as to identify the optimal sample for the 45T hybrid magnet.

Results and Discussion

Figure 1(a) shows the dependence of the resistance on the perpendicular magnetic field and the carrier density (gate voltage). **Figure 1(b)** shows the quantum Hall effect in hydrogenated graphene where the two-point resistance saturates within 0.5% of $h/2e^2$ at 45T, corresponding to v=-2 Landau filling for hole conduction. Finally, **Figure 1(c)** shows the resistance plotted against the magnetic length. The disorder length obtained from Raman spectroscopy is identified as the shaded region.

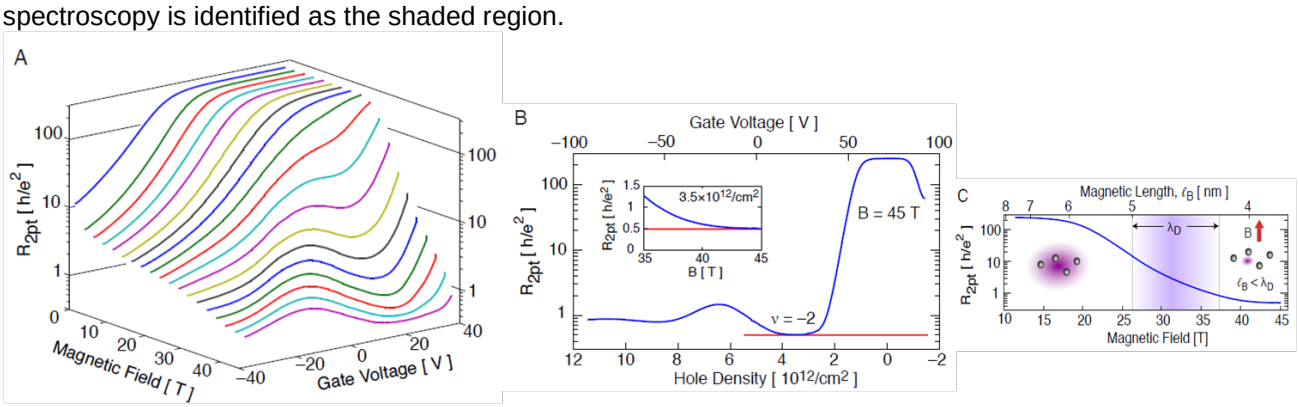

Figure 1: (a) Plot of the resistance versus carrier density and magnetic field. (b) A carrier density sweep at 45T shows the resistance reaching a quantum hall plateau. (c) Resistance versus magnetic length.

Conclusions

The emergence of a quantum Hall state from a zero field effect mobility insulating state raises the question of how much disorder can be introduced into a 2D electron gas (2DEG) and still form a quantum Hall state. Our observations with hydrogenated graphene pushes 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.

Acknowledgements

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References

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