Quantum Hall Effect in Graphene

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Introduction

Graphene, a single atomic sheet of graphite, is a monolayer of carbon atoms arranged in a hexagonal lattice. The unique electronic band structure of graphene exhibits an unusual low-energy linear dispersion relation, radically different from the parabolic bands common to all previous two-dimensional systems. Most interestingly, the charge carriers in graphene mimic relativistic, massless Dirac particles, leading to intriguing new phenomena. In particular, a very unusual half-integer quantum Hall effect and a non-zero Berry's phase have been discovered in graphene.

Experiment Results

The Quantum Hall effect (QHE) is one example of a quantum phenomenon that occurs on a truly macroscopic scale. The signature of QHE is the quantization plateaus in the Hall resistance (Rxy) and vanishing magnetoresistance (Rxx) in a magnetic field. The QHE, exclusive to two-dimensional metals, has led to the establishment of a new metrological standard, the resistance quantum, h/e^2, that contains only fundamental constant. As with many other quantum phenomena, the observation of the QHE usually requires low temperatures (previously reported highest temperature was 30 K). In graphene, however, we have observed a well-defined QHE at room temperature (see Fig. 1.) owing to the unusual electronic band structure and the relativistic nature of the charge carriers of graphene [1]. In addition, we have observed new QH phases at filling factors ν=0, +/-1, and +/-4 at low temperatures and in high magnetic fields (see Fig. 2. for the ν=+/-1 and -4 state), arising from the lifting of the spin and sublattice degeneracy of graphene Laudau levels [2].

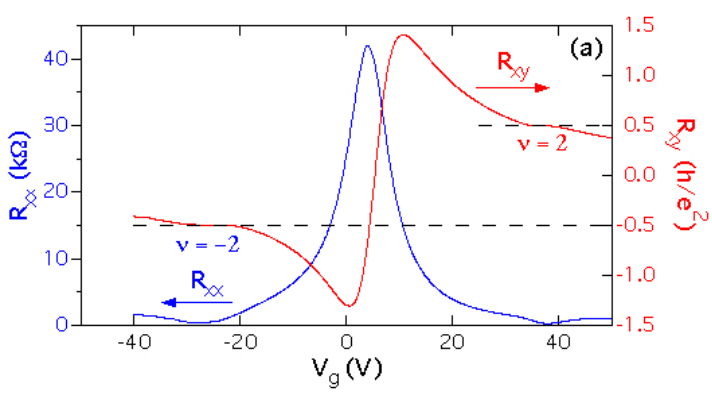

Fig. 1. Magnetoresistance (Rxx) and Hall resistance (Rxy) as a function of the back gate voltage (Vg) in a magnetic field of B=45 T at room temperature.

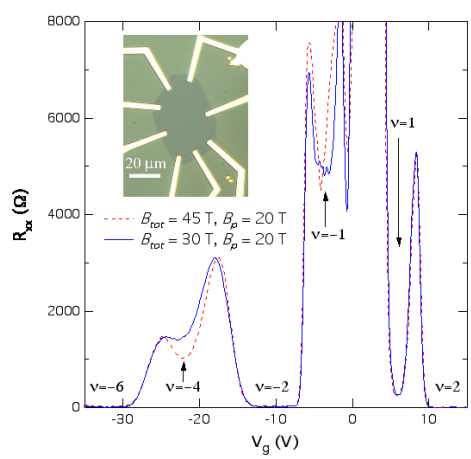

Fig. 2. Rxx vs.Vg in tilted magnetic fields.

Acknowledgements

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References

[1] "*Room-temperature quantum Hall effect in graphene,*" K.S. Novoselov**,** Z. Jiang, Y. Zhang, S.V. Morozov, H.L. Stormer, U. Zeitler, J.C. Maan, G. Boebinger, P. Kim, and A.K. Geim, Science **315**, 1379 (2007).
[2] "*Quantum Hall states near the charge-neutral Dirac point in graphene,*" Z. Jiang, Y. Zhang, H.L. Stormer, and P. Kim, Phys. Rev. Lett. **99**, 106802 (2007).