The Quantum Hall Effect Near the Dirac Point in Hybrid Graphene

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Introduction

The isolation of graphene has led to the observation of new sets of quantum Hall (QH) states, not found in conventional two-dimensional electron gasses. Monolayer, bilayer, and trilayer graphene each have shown distinct versions of the QH effect, which differ in the Landau energy-level spacing and hierarchy, field-dependence of the energy gaps, the degeneracy of the ground state, the Berry phase, and the symmetry-breaking of degenerate states. While examinations of each of these new QH states have occurred in the past few years, yielding insights into both the QH effect and the physics of graphene, there have been few studies [1] of what happens when these differing QH effects are combined in a single device that links mono, bi-, and trilayers into a hybrid graphene structure.

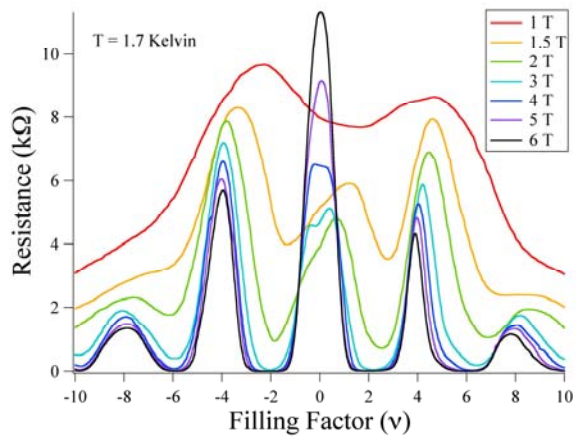

Fig. 1 Low-field formation of the quantum Hall effect in hybrid graphene as seen in longitudinal resistance. The Landau level formation is identical to monolayer graphene, but the Dirac peak is suppressed during formation.

Experimental

Research has focused on the QH effect in monolayer graphene that is natively attached to small (several μm^2) sections of bilayer. 2- and 4-terminal transport measurements are performed on the monolayer section of the hybrid graphene from the low-field regime up to 31T using the DC magnet facilities at NHMFL.

Results and Discussion

With the transport lead configuration arranged entirely on the monolayer section, the measured QH effect is mostly similar to that seen in homogenous monolayer graphene. However, hybrid graphene displays two intriguing anomalies not seen in either homogenous monolayer or homogenous bilayer graphene. As shown in Fig. 1, the Dirac point, where there is a zero-field resistance maximum due to a vanishing density of states, is suppressed during the onset of Landau level formation. At high fields, the degeneracy of the Landau level at this point is lifted, with a new, filled v=0 filling factor being established above 20 Tesla. For homogenous monolayer or bilayer graphene, the formation of this filling factor leads to a diverging resistance with increasing field, but in hybrid graphene the v=0 formation is accompanied by a decrease in the peak resistance (Fig. 2). Both effects demonstrate the presence of the bilayer creates a non-trivial perturbation to the QH ground states.

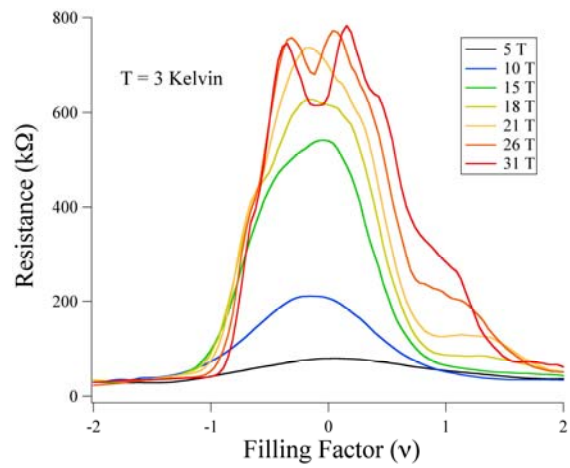

Fig. 2 High-field Dirac point behavior. Above 20T the 4-fold degeneracy of the zero-energy Landau level is lifted. Unlike either homogenous monolayer or homogenous bilayer the Dirac point does not monotonically increase as the v=0 filling factor forms.

Acknowledgements

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References

[1] Tian, J., *et al.*, \arXiv:1308.4058 (2013).