Broken Symmetry Quantum Hall States in Dual Gated ABA Trilayer Grapehene

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Introduction

Graphene, with its anomalous "half-integer" quantum Hall effect, (QHE) has emerged as a new platform for new physics in low dimensions and special symmetry groups such as SU(4). Bilayer graphene and trilayer graphene (TLG) have also attracted significant attention, as their charge carriers are massive Dirac fermions with many predicted novel phenomena. In particular, TLG offers an exciting platform with unique band structures: ABA-stacked TLG hosts mirror symmetry with respect to the middle layer, and its band structure can be viewed as a combination of the linear dispersion of MLG and parabolic dispersion of BLG, *i.e.* the so-called "2+1" model within tight-binding calculations. Though TLG has attracted more attention recently, the nature of broken symmetry QH states in TLG and their evolutions under electric and magnetic fields remain experimentally unexplored.

Experiment Results

Using low temperature transport measurements, we investigate high mobility dual-gated ABA TLG devices in the QH regime. At low magnetic field B<4T, we resolve single particle QH states at filling factors ν=-8, -2, 2, 6, and 10, which can be accounted for by the "2+1" tight-binding model that includes all hopping parameters. At higher B up to 18T, we observe additional states at ν=±1, ±3, -4 and -5, indicating almost complete lifting of the degeneracy of the lowest Landau level. At constant B, application of an out-of-plane electric field $E_\perp$ gives rise to degeneracy breaking and transitions between QH plateaus, suggesting the interplay of layer polarization induced by $E_\perp$ and B-enhanced exchange interactions of these states. Finally, depending on its polarity, we find the $E_\perp$ *selectively* breaks the LL degeneracy in the electron-doped or hole-doped regimes[1].

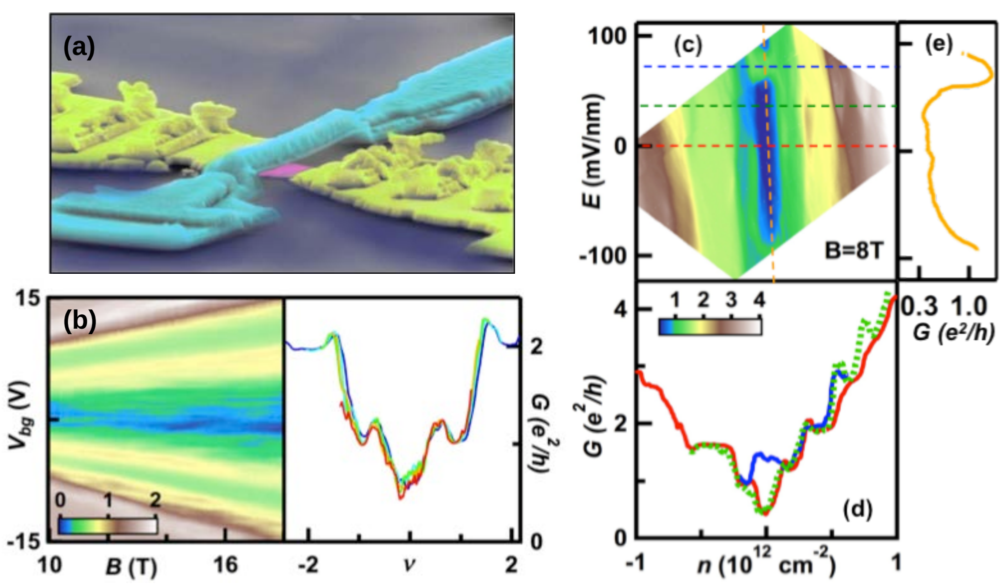

Figure 1. Transport data from dual-gated suspended trilayer graphene device. (a). Device image. (b). *G(V*$_{\beta\gamma}$*, B)* and *G(n)* at *B*=10, 12, 14, 16 and 18T. (c). *G(n,* $E_\perp$*)* at *B*= 8T. (d). *G(n)* along the horizontal lines in (c) at $E_\perp$=0 (red), 43 (green dotted line) and 73 mV/nm (blue), respectively. (e). *G(*$E_\perp$*)* along the vertical line in (c) at

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References

[1] Yongjin Lee, Jairo Velasco Jr., David Tran, Fan Zhang, W. Bao, Lei Jing, Kevin Myhro, Dmitry Smirnov, Chun Ning Lau, submitted.