Probing the electrical properties of multilayer graphene

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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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Abstract

Graphene is a new two-dimensional (2D) material with unique electrical transport, optical and mechanical properties. However, monolayer graphene (MLG) is a gapless semiconductor, which limits its relevance for transistor applications where a large on/off ratio of the current is required. In this work the investigation of transport properties of few-layer graphene (FLG) is presented. These 2D electronic systems offer a novel solution to the problem concerned the absence of an energy gap in single layer graphene, since they exhibit an electric field and stacking-dependent band gap in the energy dispersion.

Thus far, a clear observation of a band-gap in multilayer graphene (e.g. Bernal-stacked bilayers) in transport measurements was hindered by the presence of disorder. Here we develop a reliable and effective method of fabrication of high-quality suspended double-gated graphene devices, which are of crucial importance for probing the low-energy dispersion of few-layer graphene. The current annealing technique, described in details, improves transport characteristics like carrier mobility, which is typically higher than $\sim 10^4$ cm^2/Vs for our multilayer devices.

Electrical transport experiments on suspended dual-gated ABC-stacked trilayer are performed. We report the direct evidence of the opening of a tunable band-gap with an external perpendicular electric field, ranging from 0 meV up to 5.2 meV for an electric field of 117 mV/nm. Thermally activated transport is observed in these samples over the temperature range 0.5 - 80 K. The values of energy gap extracted from both temperature dependence of minimum conductivity measurements and non-linear $I-V$ characteristics correlate well. Our experimental results are in a good agreement with theoretical approximation, based on self-consistent tight-binding calculations. The high quality of our ABC trilayer samples is also demonstrated by a particularly high on/off ratio of the current (250 at applied electrical displacement as low as 80 mV/nm), which makes these devices promising for future semiconductor electronics.

FLG samples with reduced disorder allow us to observe quantum Hall effect (QHE) at magnetic field as low as 500 mT. We present the first study of electric field- induced new QH states in ABC trilayer graphene (TLG). The transitions between spin-polarized and valley polarized phases of the sample at the charge neutrality point are investigated. Resolved novel broken symmetry states along with observed Lifshitz transition

in rhombohedral TLG display exciting phenomena attributed to rich physics in these interactive electronic systems.

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