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Transport in graphene-based nanodevices

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Graphene, the first real two-dimensional solid consisting of a hexagonal lattice of carbon atoms, reveals a high carrier mobility and quantum Hall effect even at room temperature. The absence of the hyperfine field in ^{12}C and the weak spin-orbit interaction makes graphene additionally particularly interesting for advanced spin-based devices. However, the implementation of state-of-the-art semiconductor device concepts, such as transistors remains challenging since graphene exhibits no energy band gap.

It has been shown that by tailoring bulk graphene into narrow ribbons an effective band gap (i.e. transport gap) can be induced. A long this line, first graphene quantum devices have been demonstrated, such as graphene nanoribbons, quantum interference devices, and graphene single electron transistors [1,2]. Here we will give an overview over our recent experiments carried out on narrow graphene constrictions [3-5] and graphene quantum devices [6-12] at low temperatures (100 mK – 2K). These nanostructured devices are fabricated by mechanical exfoliation of graphite followed by electron beam lithography and dry etching techniques based on an Ar/O_2 plasma. The fabricated graphene nanodevices are equipped with a number of all-graphene in-plane gates for local electrostatic control. The presented measurements demonstrate the interplay of lithographic confinement, where electron-electron interactions manifest in the appearance of the Coulomb blockade effect, and disorder, even in the simplest single constriction devices. Despite the significant complexity of the physics in single graphene constrictions and nanoribbons, well controllable quantum dot and double quantum dot devices exhibiting Coulomb blockade physics can be fabricated.

Here we focus on recent extensive studies on the transport mechanism in graphene constriction and nanoribbons (see Fig. 1). In this talk we report on the recent progress in understanding the nature of this effective energy scales. Most interestingly we will report on recent studies on the effects of symmetrically applied side gate voltages on both (i) clean and (ii) hydrofluoric acid treated etched graphene nanoribbons. In particular, we show recent low-temperature experiments on 50 nm to 100 nm wide and 100-200 nm long single-layer graphene nanoribbons, where the overall conductance can be tuned to a level of about $8e^2/h$. Most strikingly, the low temperature transport measurements show evidence that the local resonances in the transport gap of these clean nanoribbons can be strongly suppressed by adjusting the voltage on the nearby side-gates. In summary, the high conductance values together with the observation of onsets of individual subbands (quantized conductance plateaus) indicate that the potential disorder can dramatically be reduced, even though the transport mechanism is still mainly driven by substrate and rough-edge induced disorder.

Finally we report on low temperature transport measurements on freely suspended doubly-clamped graphene nanoribbons highlighting that the general transport mechanism in etched graphene nanoribbons does not depend much on the underlying substrate material.

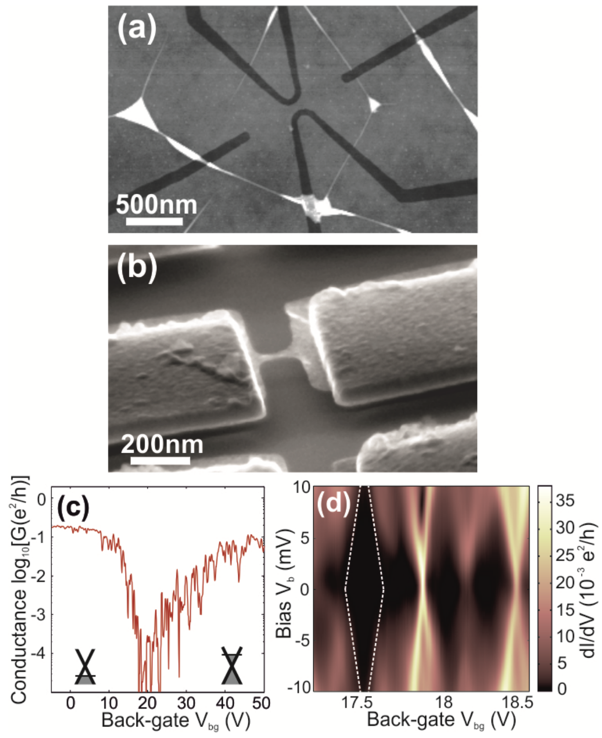

FIG. 1: (a) Scanning force microscope image of an etched graphene nanoribbon on hexagonal Boron Nitride. (b) Scanning electron microscope image of a suspended graphene nanoribbon. (c) Back gate characteristics with hole and electron transport regimes. (d) Differential conductance versus back-gate voltage and bias voltage for a 200 nm long graphene nanoribbon (width of 50 nm). Distinct diamonds of fully suppressed conductance can be observed (white dashed line).

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