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Logarithmic renormalization of interactions and disorder in graphene.

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The fact that the Coulomb interactions induces logarithmic anomalies in the spectrum of the clean gapless semiconductors is known for almost four decades [1]. Recent explosive interest in graphene called for revisiting and refining of old results. In my talk I will review:

1. Renormalization of the one particle spectrum (including trigonal warping) in a clean graphene [2];
2. Renormalization of the short range and umklapp interactions by the Coulomb interaction in a clean graphene [2];
3. Renormalization of the electron-phonon couplings by the Coulomb interaction in a clean graphene [3];
4. Effects of the Coulomb interaction [4] on the logarithmic correction due to the multiple impurity scatterings [5].

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Electric and thermoelectric properties of graphene

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In this presentation, we will review some of recent experimental studies to investigate electric and thermoelectric properties of graphene. First, we will discuss the enhancement of carrier mobilities in suspended graphene samples and the strong temperature dependent conduction in the samples. Second, the nature of these QH states near the charge neutral Dirac point will be discussed as a single particle theory breaks down. We will discuss the transport and IR measurement results that reveal the role of the many-body effects due to the electron-electron interaction in graphene near the Dirac point. In addition, the role of disordered edges in graphene nanostructures will be discussed in the context of localization and variational range hopping conduction. Finally we will discuss thermoelectric power measurement in graphene under magnetic field.

Current-induced cleaning of graphene

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By nature, all the carbon atoms that compose graphene samples are exposed to the surrounding environment. As a result, the electronic properties of graphene depend crucially on the molecular species adsorbed on its surface: adsorbates may act as dopants and scattering centers, and may lower the mobility of charge carriers. Thus, identifying the nature of adsorbates and controllably obtaining adsorbate-free surfaces are essential steps towards improving transport performances of graphene devices.

In this talk, we will first present a study of the electrostatic environment of graphene samples prepared with the micromechanical exfoliation technique [J. Moser, *et al.*, Appl. Phys. Lett. **92**, 123507 (2008)]. Using electrostatic force microscopy, we detect the electric dipole of residues left from the adhesive tape during graphene preparation, as well as the dipole of water molecules adsorbed on top of graphene. Water molecules form a dipole layer that can generate an electric field as large as $10^9\,\mathrm{V/m}$. We expect that such a strong electric field significantly modifies the electrical properties of graphene devices.

Further adsorbates are inevitably introduced during nanofabrication, in the form *e.g.* of resist residues. We will describe a simple, yet highly reproducible method to remove those adsorbates from the surface of graphene samples inside a cryostat. Our method is based on the application of a large dc bias across the graphene sample, thereby generating a large current and correspondingly a thermal power of several tens of milliWatts over an area of a few micrometer squares. Remarkably, graphene can sustain such extreme conditions while adsorbates get removed. We employ atomic force microscopy to visualize this effect in the case of nanofabrication residues and in the case of intentionally deposited CdSe nanoparticles. We show that our cleaning method both suppresses extrinsic doping [J. Moser, *et al.*, Appl. Phys. Lett. **91**, 163513 (2007)] and strongly enhances the mobility of our graphene samples [A. Barreiro, *et al.*, work in progress]. The mobility typically reaches 25,000 $\mathrm{cm^2/Vs}$ for graphene samples in a Hall bar geometry. In addition, the quality of our current-cleaned graphene samples is high enough for us to routinely observe the anomalous quantum Hall effect (σ_{xy} plateaus at $\pm 2\,\mathrm{e^2/h}$, $\pm 6\,\mathrm{e^2/h}$, as the carrier density is varied), as well as the quantum Hall plateau at $\sigma_{xy} = 0\,\mathrm{e^2/h}$ at moderate field strength (B=9 T).

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