Master Physique – Condensed Matter and Nanophysics

Academic year 2019/2020

Theory of Scanning Gate Microscopy in two-dimensional Materials

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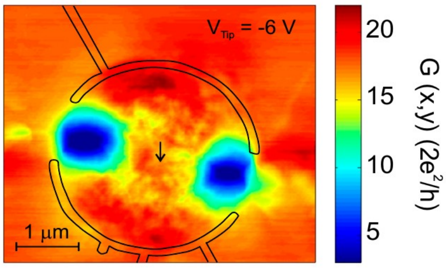
Location: Institut de Physique et Chimie des Matériaux de Strasbourg (IPCMS)



The understanding of electronic transport through nanostructures is crucial for the development of modern electronic devices. Moreover, the subject is of fundamental interest due to the presence of quantum coherent processes and its position at the frontier between classical and quantum physics.

While traditional transport experiments measure the conductance and its dependence on parameters like an applied magnetic field, Scanning Gate Microscopy (SGM) [1,2] adds spatial resolution. It measures conductance changes induced by a local potential perturbation (usually a charged AFM tip) scanning the sample surface. The resulting maps of conductance as a function of tip position (the figure shows an example from Ref. [3]) yield rich information about the transport through the sample. In order to exploit those data for improving our understanding of quantum transport, a theoretical analysis is essential. Our group has developed a systematic perturbative approach [4,5] that proved useful to describe the weak tip regime in experiments on ballistic cavities [6]. For the case of invasive tips, we used numerical quantum calculations [3,6] and a semiclassical approach based on electron trajectories [3] to describe the tip-induced conductance changes.

Most experiments have been performed on semiconductor heterostructures, but recent experimental developments show interesting features in the SGM of strictly two-dimensional materials [7]. The present project is to apply our theoretical approaches to the situation of such materials, in particular single- and bilayer graphene and transition metal dichalcogenide (TMD) monolayers, by taking into account the effects of the corresponding electronic dispersion relations. We will then investigate the particularities of SGM in those materials. Furthermore, we plan to investigate temperature-dependent thermoelectric effects [8] and also to make an attempt to extract details of the disorder potential in a sample from SGM maps using machine-learning methods.

The theoretical tools and concepts to be used are the basic ones of quantum transport through mesoscopic systems, including analytical (semiclassical expansions) and numerical (quantum transport and classical trajectories) methods. The student will work in the Mesoscopic Quantum Physics Team (R. A. Jalabert, G. Weick, D. Weinmann) at IPCMS.

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[8] B. Brun *et al.*, *Phys. Rev. Applied* **11**, 034069 (2019)

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