Imaging coherent transport in a graphene quantum ring

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Abstract

The understanding and the control of electronic transport inside mesoscopic devices is an active investigation field, which benefited recently from advances in scanning probe imaging techniques. One of them is Scanning Gate Microscopy (SGM), a powerful technique allowing direct imaging of electronic transport at a local (nm) scale. The principle is to introduce inside a mesoscopic structure a local electrostatic perturbation induced by an electrically-biased Atomic Force Microscopy (AFM) tip, positioned few nanometers away from the device. Hence, by sweeping the tip over the structure and recording the induced change of the sample electrical conductance (G) as a function of the tip position, one obtains a SGM map.

To date, SGM investigations of graphene have already highlighted the influence of defects on the electronic transport inside a graphene sheet, which generates localized states identifiable by Coulomb blockade [1,2]. Moreover, SGM mapping has also been employed to image in real space two coherent effects: the universal conductance fluctuations and the weak localization [3]. Nevertheless, so far, no experimental SGM study has been performed on the Aharonov-Bohm (AB) effect inside a graphene quantum ring (QR).

Here, we report on SGM measurements performed on a mesoscopic graphene QR. The graphene monolayer has been extracted from natural graphite by mechanical exfoliation on a 90nm-thick silicon dioxide thermally grown on the top of a highly doped silicon substrate ($SiO_2/Si(n^{++})$). The number of layers has been confirmed by Raman spectroscopy. The graphene sheet has been electrically contacted by Electron Beam Lithography (EBL) patterning followed by metallization (Ti(5nm)/Au(30nm)) and lift-off. To define the geometry of the QR we used a new functionalization technique aiming to convert graphene regions into electrically-insulating zones: the fluorination [4-6]. The latter step is realized using the combination of EBL with a CF_4 plasma process [7]. The final device is presented on the AFM picture in Figure 1a.

First, in magnetotransport measurements on the QR at very low temperature (down to 30 mK) and in the coherent regime of transport, we find clear AB conductance oscillations confirming that the device operates properly [8-13]. Secondly, thanks to SGM, we can pinpoint the position of defect-induced quantum dots inside the device [1,2]. Thirdly, spatial signatures of the AB effect have been found, which surprisingly differs from previous results in semiconductors QRs. Finally, radial fringes located inside the QR in SGM maps (Figure 1b) are reminiscent of previous SGM observations in semiconductor QRs [14,15] and comparable to SGM mapping simulations on mesoscopic QRs with charged defects [15,16]. Those fringes are ascribed to the presence of resonant structures scarring the local density of states in the QR.

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Figures

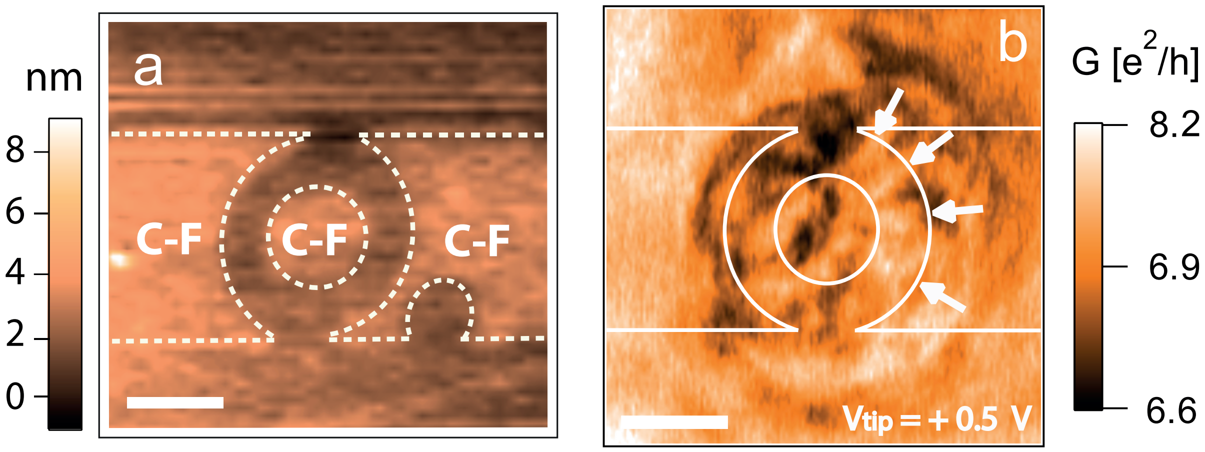

Figure 1 (a) AFM image of the graphene QR. White dashed lines indicate the fluorinated graphene areas (b) SGM map in the vicinity of the QR for V_g = -5 V and a tip-sample distance of 80 nm. The arrows highlight the position of radial fringes inside the QR. White scale bar represents in both cases 400 nm.