CHEMICALLY-INDUCED MOBILITY GAPS IN GRAPHENE NANORIBBONS: UPSCALING DEVICE PERFORMANCES

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The rise of graphene-based science has been driven by the huge charge mobilities measured in undoped two-dimensional (2D) graphene materials close to the Dirac point [1]. However, owing to its zero energy bandgap, the 2D graphene-based field effect transistor (FET) has shown relatively poor field effect efficiency, with ON versus OFF current ratio (Ion/Ioff) that can be tuned no more than a small factor (less than one order of magnitude). By using graphene nanoribbons with reduced lateral sizes, more efficient graphene-based FETs can be designed with enlarged energy bandgaps and more reasonable Ion/Ioff characteristics, provided their lateral size is reduced to a few nanometers width. This, however, strongly reduces charge mobilities and ultimate device performances, and disallows the recourse to conventional lithographic techniques to massively integrate active devices and circuits at the wafer scale.

We present an *ab initio*-based study of mesoscopic quantum transport in chemically doped graphene nanoribbons with a width up to 10 nm and variable lengths up to the micron scale. The occurrence of quasibound states related to boron impurities results in mobility gaps as large as 1 eV (see figure), driven by strong electron-hole asymmetrical backscattering phenomena [2]. This phenomenon opens new ways to overcome current limitations of graphene-based devices through the fabrication of chemically-doped graphene nanoribbons with sizes within the reach of conventional lithography. Our study shows that, due to chemical doping impurities, a marked electron-hole asymmetry develops, and results in charge mobility gaps of up to one eV in nanoribbons whose electronic bandgaps before doping are only a few tens of meV large [3]. Such transport gaps should likely result in strong improvement of Ion/Ioff ratio of doped graphene-FETs, without the need to use very narrow ribbons beyond the reach of current lithography.
Our theoretical results, based on first-principles and mesoscopic transport calculations, clearly evidence the potential of chemically doped graphene nanoribbons as a new material for designing performant graphene-FETs.

References:

[1] A. Cresti, N. Nemec, B. Biel, G. Niebler, F. Triozon, G. Cuniberti and S. Roche, Nano Research, **1** (2008) 361.
[2] B. Biel, X. Blase, F. Triozon and S. Roche, Phys. Rev. Lett., **102** (2009) 096803.
[3] B. Biel, F. Triozon, X. Blase and S. Roche, (submitted)

Figures:

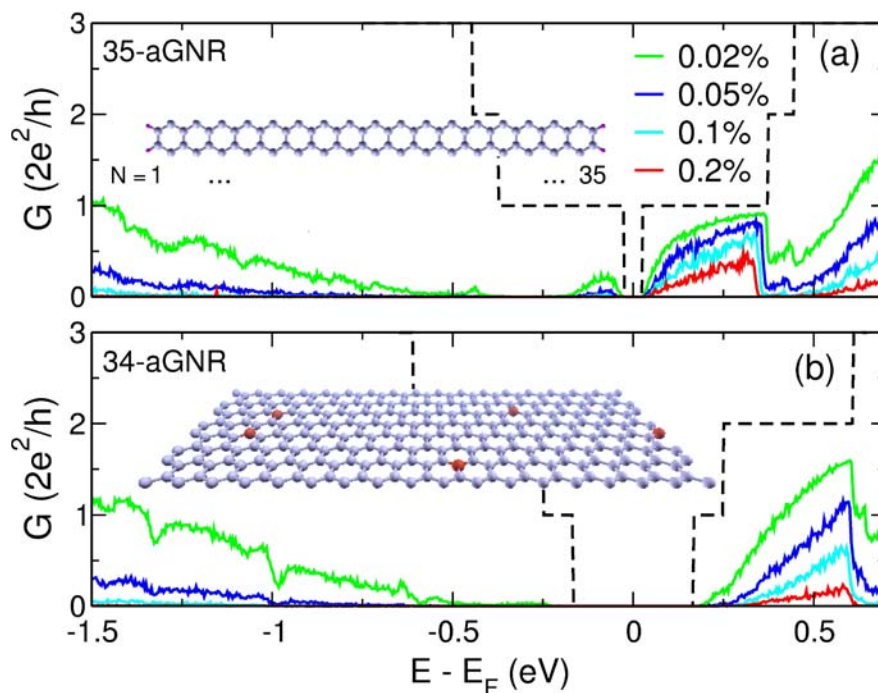

Figure: (a) Average conductance as a function of energy for a pseudo-metallic armchair GNR with N=35 (35-aGNR) for doping rates 0.02%, 0.05%, 0.1% and 0.2% (from top to bottom). The dashed black line corresponds to the ideal (undoped) case. The averages have been performed over 500 disorder realizations with a ribbon length of 1 micron. The inset shows the unit cell of the 35-aGNR with passivating H atoms. N indicates the number of dimer chains in a N-aGNR. (b) Same as in (a, main frame) for the semiconducting 34-aGNR. Inset: Schematic view of a randomly doped GNR.