

Electronic transport in disordered graphene antidot lattice devices

Stephen R. Power, Antti-Pekka Jauho

Center for Nanostructured Graphene (CNG), DTU Nanotech, Technical University of Denmark, 2800 Kongens Lyngby, Denmark
spow@nanotech.dtu.dk

Abstract

Much recent effort in graphene research has focused on attempts to introduce a bandgap into the otherwise semi-metallic electronic band structure of graphene. Such a feature would allow the integration of graphene, with its many superlative physical, electronic, thermal and optical properties, into a wide range of conventional device applications. In particular, the presence of a bandgap is a vital step in the development of a graphene transistor capable of competing with standard semiconductor-based devices.

Initial investigations were primarily based around graphene nanoribbons[1], with the electron confinement induced by the presence of crystalline edges predicted to introduce a bandgap similar to that found in many carbon nanotubes. More recent efforts have turned towards graphene superlattices, where the imposition of a periodic perturbation of the graphene sheet is also predicted to open up a bandgap. The periodic perforation of a graphene sheet, to form a so-called graphene antidot lattice (GAL), is one such implementation of the latter technique [2].

Theoretical studies of GAL-based systems have suggested that the bandgap behaviour in many cases follows a simple scaling law relating the period of the perturbation and the antidote size [2]. Furthermore, it is predicted that only a small number of antidot rows are required to induce bulk-like transport gaps, suggesting the use of GALs in finite barrier systems which do not suffer from the Klein-tunnelling driven barrier leakage expected for gated systems [3]. Indeed, the potential barrier efficacy of GALs has led to predicted applications in the wave-guiding of charge carriers, in analogy with photonic crystals where antidot lattice geometries are also considered [4].

However, many of these potential devices applications are predicated on atomically precise graphene antidot devices, whereas experimental fabrication (primarily involving block copolymer or electron beam lithography techniques [5]) will inevitably introduce a degree of imperfection and disorder into the system. Much like the properties of nanoribbons were found to be greatly affected by disorder [6], recent studies suggest that the electronic and optical properties of GALs may also be strongly perturbed [7]. We should therefore expect that the transport properties and device fidelity of the systems described above will depend on the degree of disorder present in the antidot lattice

Motivated by this concern we have simulated a wide range of finite GAL devices, in both simple-barrier and waveguide geometries, with various disorder types and strengths [8]. We find that the geometries predicted to give the largest bandgaps, namely those with a dense array of small holes, are particularly susceptible to the effects of disorder and that transport gaps are quickly quenched as leakage channels form at energies in the bandgap. Geometric disorder, consisting of fluctuations in the positions and sizes of the antidots, is found to have a particularly dramatic effect (see Figure 1). However, the signatures of such disorders are found to be strongly dependent on the edge geometry of individual antidots, and different behaviour is observed when the antidot edge atoms have armchair or zigzag configurations, or alternating sequences of both. Recent experimental progress [9] in controlling the edge geometry of perforations in graphene suggests that, even in the presence of disorder, the properties of GAL systems may be manipulated in order to produce devices with desirable electronic transport properties.

References

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Figures

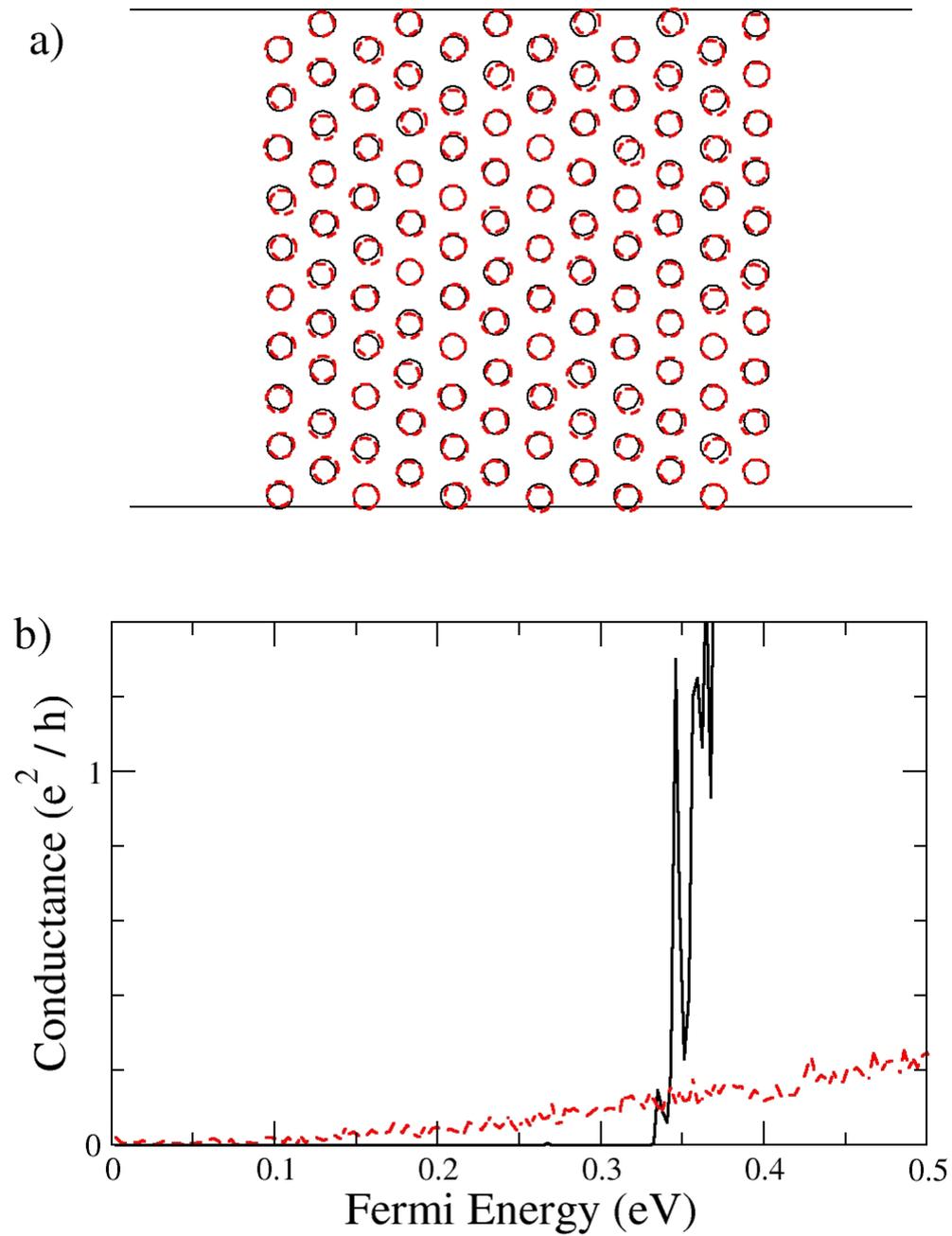


Figure 1: a) Schematic of an antidot barrier in a wide nanotibbon with perfect periodicity (black circles) and with a small position disorder (red dashed circles). b) The conductance calculated through both systems. The bandgap in the range 0 - 0.33eV in the perfect system (black line) is clearly washed out in the disordered case (red dashed line).