Charge and spin transport in bilayer graphene nanostructures using non-equilibrium Green's function technique

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Though it is unsuitable for standard digital applications, the gapless character of graphene with chiral massless Dirac carriers gives to this material unusual and attractive transport properties which deserve to be considered carefully [1]. Additionally, there are several ways of inducing bandgap in graphene, which still enlarge the possible fields of application. The first idea is to cut mono-layer graphene into nanoribbons to benefit from induced quantum confinement effect. Alternatively, the interaction with an SiC substrate can break the symmetry of the two sub-lattices forming the graphene crystal, which can open a bandgap of up to 0.26 eV [2]. A similar bandgap may be also induced in bi-layer graphene by applying a vertical electric field [3,4]. Finally, thanks to very weak spin-orbit interaction leading to spin flip length higher than 1.5 µm [5], graphene also offer a high potential for spintronics.

In this work, the non-equilibrium Green's function calculation developed in ref. [6] has been extended to treat the transport equation of chiral fermions in bilayer graphene nanostructures. The approach has been applied to investigate the transport properties of charges in typical structures, including a single potential barrier, a double gate or a ferromagnetic gate. In single barrier structures, the chiral resonant tunnelling effect and the resulting negative differential conductance is shown to be stronger than in monolayer graphene [7], as illustrated in Fig. 1. Especially, strong oscillation of transconductance with respect to the barrier height can be achieved. In double gate structures, our study shows the appearance of an electrical current gap and therefore demonstrates the possibility of switching the current by tuning the gate voltages [8]. Considering ferromagnetic gate structures, a significant improvement of spin polarization effect and tunnelling magneto-resistance is obtained in comparison with previous results predicted for monolayer graphene, which therefore demonstrates the high potentialo of bilayer graphene for spintronic applications. It is illustrated in Fig. 2 which shows the spin polarization as a function of gate barrier height in both monolayer and bilayer graphene structures. Our NEGF model provides a clear description of charge transport and may provide meaningful information for future development of many kinds of bilayer graphene electronic and spintronic devices.

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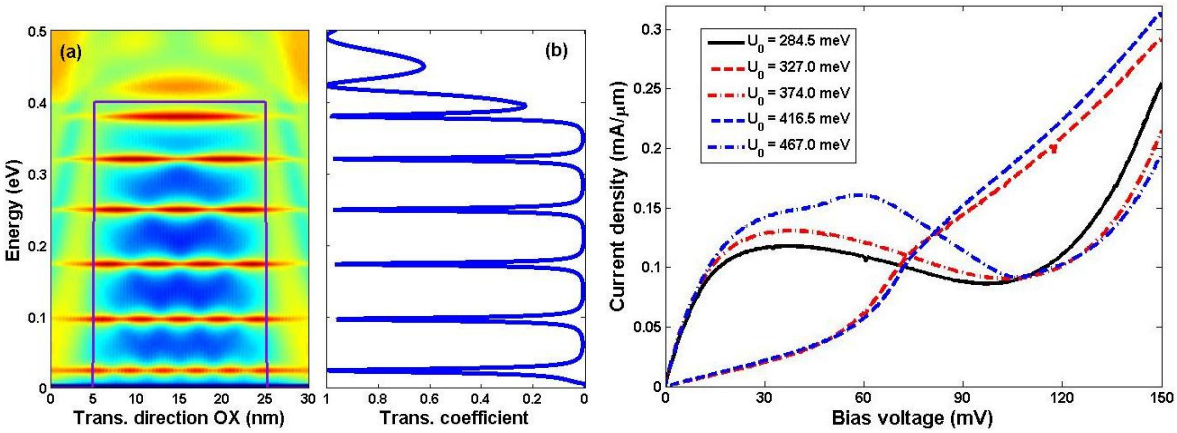

Fig. 1. (Left panel) LDOS and transmission coefficient in a single barrier bi-layer graphene structure under zero bias. Other parameters are $E_y = 50$ meV, $U_0 = 0.4$ eV, and $L = 20$ nm. (Right panel) Low temperature current as a function of bias voltage in a single barrier bi-layer graphene structure of barrier length $L = 20$ nm for different barrier heights.

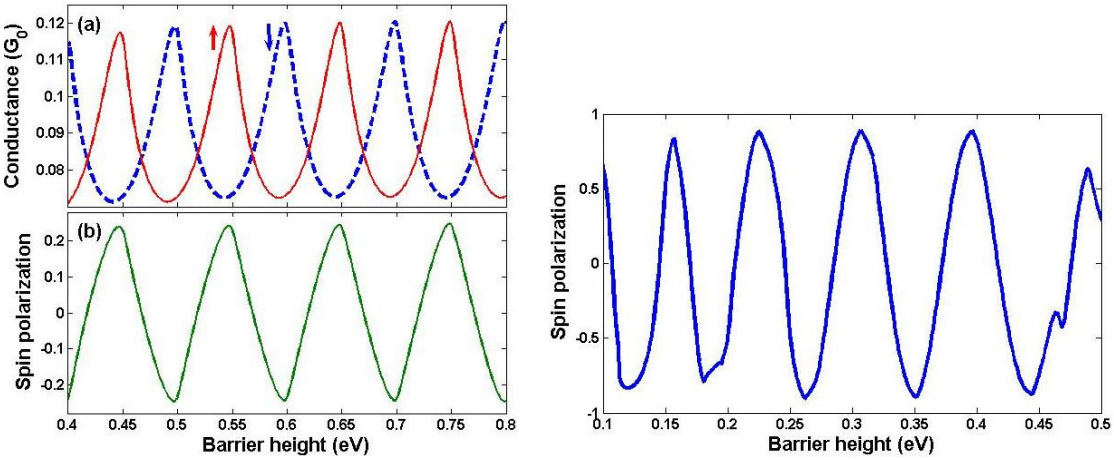

Fig. 2. (left panel) (a) Spin up and spin down conductance and (b) spin polarization in a single ferromagnetic gate monolayer graphene structure as a function of the gate barrier height, for $L = 20$ nm, $E_F = 100$ meV and exchange splitting energy $h = 25$ meV. (Right panel) Spin polarization in a single ferromagnetic gate bilayer graphene structure as a function of the gate barrier height, for L 20 nm, $E_F = 75$ meV and $h = 22.5$ meV.

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