Graphene single electron transistor as a sensor for magnetic molecules

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Abstract

Graphene is a very promising candidate for high precision molecular sensing, due to its extremely large surface to volume ratio, and its electrically tunable large conductivity [1]. On the other hand, being a zero-gap semiconductor with small mass and small density of spinfull nuclei, makes graphene a material with potentially large spin lifetime both, for carriers and host magnetic dopants [2].
Taken together, these two ideas naturally lead to the use of graphene as a detector of the spin state of extrinsic magnetic centers, in the form of magnetic ad-atoms, vacancies and spinfull molecules. This connects with recently reported [3, 4] experiments in which gated graphene nanoconstrictions, operating in the single electron transport (SET) regime, showed hysteric behavior in the linear conductance when a magnetic field is ramped.

In this work we provide a theoretical background to understand how the magnetic state of localized magnetic moments affects transport through the graphene nanoconstriction in the SET regime. We consider transport across a spin-split state [5]. In our system, the energy splitting arises from the exchange coupling to the extrinsic magnetic centers. This spiting effectively gates the nanoconstriction, changing its conductance thereby. We model the graphene nanoconstriction decorated with magnetic centers with a random exchange field tight binding Hamiltonian that we solve numerically. We discuss the experimental conditions, such as temperature, density of magnetic centers, exchange coupling strength, tunnel rate, under which the graphene nanoconstriction can operate an efficient spin sensor. We also compare our modeling with the experimental results [6].

References

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Figures

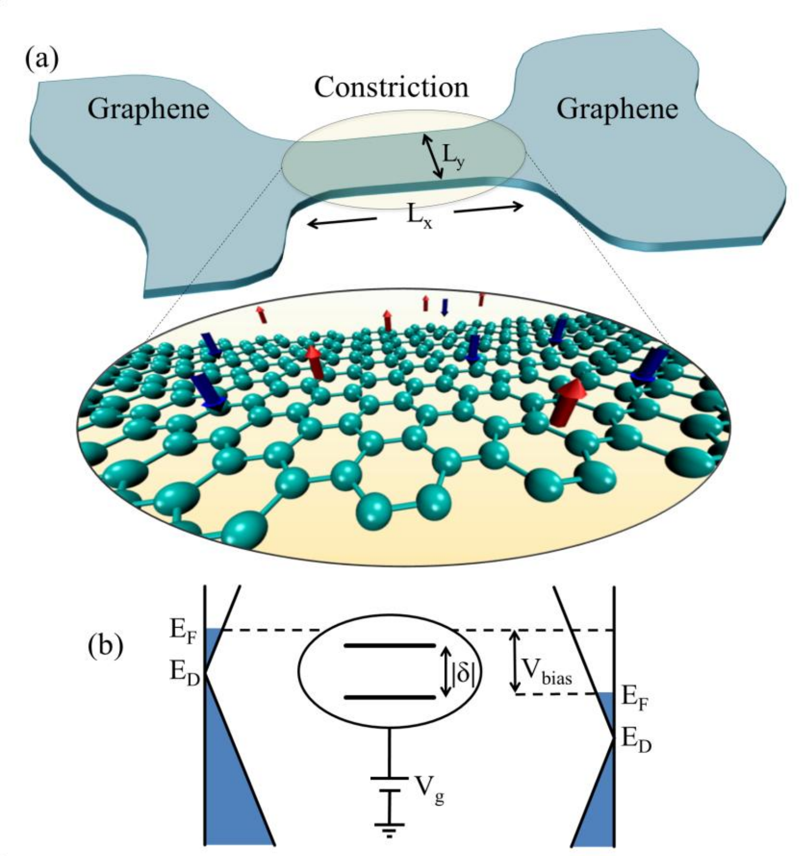

Fig. 1. (a) Scheme of a graphene constriction with randomly distributed magnetic centers. (b) Diagram with the system energy levels and graphene density of states.