Andreev quantum dots in graphene-superconductor hybrid devices

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Although graphene is not intrinsically superconducting, Cooper pairs from a superconducting contact can diffuse through it. The superconducting proximity effect was observed experimentally in graphene Josephson junctions with contacts made of various superconducting materials like Al, Pb, Nb and even layered materials like NbSe2 [1,2]. When the energy of the electrons in the graphene layer is below the superconducting gap of the contacts, they will be bound in the normal region. These are the well known Andreev bound states. We consider a graphene layer deposited on top of a superconducting surface such that the graphene layer can be considered to be partially freestanding and/or strained. It was recently shown that strain has a peculiar effect on the electronic properties in graphene, namely that it will coupled exactly like a gauge field [3,4]. Under certain conditions it is thus possible to have strong pseudo-magnetic fields and even pseudo-Landau levels coexisting with superconducting correlations [5]. By using an efficient numerical method [6] we solve the Bogoliubov-de Gennes equations for a tight binding model of the graphene layer. We show that in the regions where the sheet is freestanding, bound states due to Andreev reflections appear, thus forming Andreev quantum dots. We provide various ways to manipulate the energy states inside the dots, and further more devise inter-dot coupling.

References:

[1] H. B. Heersche, P. Jarillo-Herrero, J. B. Oostinga, L. M. K. Vandersypen, and A. F. Morpurgo, Nature (London) **446**, 56 (2007).

[2] A. Kanda, T. Sato, H. Goto, H. Tomori, S. Takana, Y. Ootuka, and K. Tsukagoshi, Physica C **470**, 1477 (2010).

[3] F. Guinea, M. I. Katsnelson, and A. K. Geim, Nat. Phys. **6**, 30 (2009).

[4] N. Levy, S. A. Burke, K. L. Meaker, M. Panlasigui, A. Zettl, F. Guinea, A. H. C. Neto, and M. F. Crommie, Science **29**, 544 (2010).

[5] L. Covaci and F. M. Peeters, Phys. Rev. B **84**, 241401(R) (2011).

[6] L. Covaci, F. M. Peeters, and M. Berciu, Phys. Rev. Lett. **105**, 167006 (2010).