Spin superconductor in ferromagnetic graphene

Abstract

We show a spin superconductor (SSC) in ferromagnetic graphene as the counterpart to the charge superconductor, in which a spin-polarized electron-hole pair plays the role of the spin 2($\hbar$/2) 'Cooper pair' with a neutral charge. We present a BCS-type theory for the SSC.

Body

Superconductivity is well understood by BCS theory: Electrons in a solid state system may have a net weak attraction so that they form Cooper pairs, which can then condense into the BCS ground state. The simplest s-wave Cooper pairs are of electric charge 2e and spin singlet. A dual of super- conductor is the so-called exciton condensate in which a Cooper pair-like object is a particle-hole pair which is charge-neutral while its spin may either be singlet or triplet. We name a spin-triplet exciton condensate as the spin superconductor (SSC).
Feromagnetic (FM) graphene contains an imbalance of up and down spins that can be injected, e.g., by ferromagnet contacts (Fig. 1 (b)). When the Fermi level lies in between the spin-resolved Dirac points, the spin-up carriers are electron-like while the spin-down ones are hole-like. These positive and negative carriers attract and form e-h pairs that are stable against the e-h recombination due to the Coulomb interaction, unlike in conventional exciton systems in semiconductors (Fig. 4(a)) where the electron states are above the hole states. If a carrier jumps from the electron-like state to the hole-like one, the total energy of the system rises. This prevents the e-h recombination and means the e-h pairs in FM graphene is stable and can exist indefinitely in principle. Therefore, this e-h pair gas can condense. The ground state of FM graphene is a neutral superfluid with spin $\hbar$ per pair, namely, a SSC state.

For detection of the SSC, one can measure the zero spin resistance or super spin current. Here we propose a four terminal device as shown in Fig.1(c) which can be used to measure the non-local resistance and then confirm the SSC state.

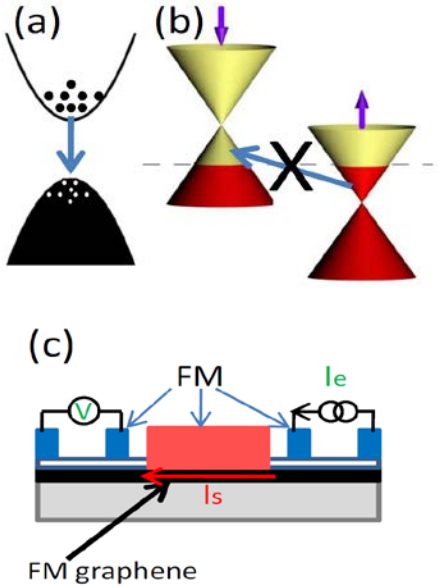

Fig. 1: The schematic diagrams for (a) the band structure for the conventional exciton system; (b) for FM graphene; and (c) for the proposed four-terminal device to measure the SSC state.

Reference

1. Q.F. Sun, Z.T. Jiang, Y. Yu, and X. C. Xie, Phys. Rev. B **84**, 214501 (2011)

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