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Physica B 284–288 (2000) 509–510

PHYSICA B

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Boundary conditions for quasiclassical Green functions at superconductor–ferromagnet interface

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Abstract

The quasiclassical equations of superconductivity for a metal with spin-split conduction band are derived. The boundary conditions for the Green functions at the interface between a ferromagnet and a superconductor are obtained. They are valid for the arbitrary magnitude of exchange splitting of a ferromagnet conduction band. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Boundary effects; Superconductor–ferromagnet contact

Magnetoelectronics is a new class of electronics which exploits the spin-polarized carriers transport in ferromagnetic metals [1]. The performance of magnetoelectronic devices improves as the polarization of a ferromagnet conduction band increases. Meservey and Tedrow (see, for example, Ref. [2] and references therein) pioneered the superconductor/ferromagnet (S/F) spin-polarized tunneling to probe the electronic spectrum near the Fermi energy. Very recent S/F point contact spectroscopy works [3,4] established the experimental basis for the Andreev spectroscopy of magnetic materials by means of contact with a superconductor.

Either tunneling spectroscopy or the point contact spectroscopy deal with transmission of Cooper pairs from a superconductor into the spin-polarized conduction band of a ferromagnet and vice versa. To describe the electronic transport in S/F systems we extend the quasiclassical (QC) theory on superconductor/ferromagnet couples taking explicitly into account the spin dependence of transmission probabilities through the S/F interface and different Fermi momenta of spin-subbands of a ferromagnet.

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1. Equations for Green functions

Assume that the contact of a superconductor and a ferromagnet is flat. The equations for the QC thermodynamic Green functions of S/F contact are derived by a method close to that one developed by Zaitsev [5]. We suppose that S/F interface does not mix spin channels, as was considered in Ref. [5] for S/N and S/S′ contacts. The spin-active interface between two superconductors was considered in Ref. [6]. The equations for QC Green function in F and S sides of S/F contact read:

$$\hat{v}_x \frac{\partial \hat{g}^>}{\partial x} \hat{v}_x + \frac{\vec{v}_{\|}}{2} \frac{\partial}{\partial \vec{\rho}} (\hat{g}^> \hat{v}_x + \hat{v}_x \hat{g}^>) + \hat{K} \hat{g}^> \hat{v}_x - \hat{v}_x \hat{g}^> \hat{K} = 0, \quad (1)$$

$$\hat{K} = \mathrm{i}\left(\tau_z \frac{\partial}{\partial \tau} - \frac{1}{2} m \hat{v}_x (\hat{v}_x - \tau_x \hat{v}_x \tau_x) - \hat{\Delta} + e\Phi \right) \delta(\tau - \tau') + \mathrm{i}\hat{\Sigma}(\tau,\tau'), \quad (2)$$

where all quantities with hats and τ_z are matrices in particle–hole space. The spin structures of the Green function and x-component of Fermi velocity $\hat{v}_x$ are the following:

$$\hat{g}^> = \begin{vmatrix} g_{\alpha\alpha} & f_{\alpha-\alpha} \\ -f_{-\alpha\alpha} & \bar{g}_{-\alpha-\alpha} \end{vmatrix}, \quad \hat{v}_x = \begin{vmatrix} v_{x,\alpha} & 0 \\ 0 & v_{x,-\alpha} \end{vmatrix}. \quad (3)$$

Direction x is chosen along the normal to the contact plane, $mv_{x,\alpha} = \sqrt{2m(\varepsilon_F + \alpha h) - p_{\|}^2}$, $2h$ is the spin-split-

0921-4526/00/$ - see front matter
PII: S0921-4526(99)02102-X