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Decoupled superconductivity in the four- and five-layered ferromagnet–superconductor nanostructures and control devices

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Abstract

The ferromagnet/superconductor (F/S) tetra- and pentalayer consisting of rather dirty metals are considered with regard for the boundary conditions. The dependences of critical temperatures T_c versus the thicknesses of the F layers are investigated. The clearest manifestation of *decoupled superconductivity* for the F′/S′/F″/S″ *tetralayer* is the rise of a *hierarchy* of transition temperature T_c, and *different* S′ and S″ *layers* can have *different critical temperatures*. The same is valid for *nonsymmetrical* case of the F′/S′/F″/S″/F‴ *pentalayer*. The complicated phase diagram of the tetralayer is discussed. The *inverse* action of *superconductivity on magnetism* leads to preferable mutual *antiferromagnetic* orientation of magnetizations of the F′ and F″ layers, if the inner S′ layer is in the *superconducting* state. Conceptual scheme of the new nanoelectronics control device, that has up to *seven* different states and combine in one sample the advantages of two different recording channels, is proposed.

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1. Introduction

For the ferromagnet/superconductor (F/S) heterostructures consisting of alternating ferromagnetic metal (F) and superconducting (S) layers, the superconducting order parameter (OP), owing to the proximity effect, can be induced in the F layer; on the other hand, the neighbouring pair of the F layers can interact with one another via the S layer. One can control properties of such systems varying the thicknesses of the F and S layers (d_f and d_s) or changing external magnetic field **H**. Numerous experiments on the F/S *structures* revealed nontrivial dependences of superconducting transition temperature T_c on the thickness d_f (see reviews [1,2] and references therein).

The first solution [3,4] of the boundary value problem (BVP) for pair amplitude in the dirty F/S superlattices led to the possibility of the nonmonotonic dependence $T_c(d_f)$ which was related to periodically switching the ground superconducting state between the 0 and π phases. Later the boundary conditions valid for arbitrary transparency of the F/S interface were deduced from the microscopic theory [1]. An additional mechanism of nonmonotonic dependence $T_c(d_f)$ [1,5–8] has been revealed due to modulation of the pair amplitude flux from the S layer to the F layer by thickness d_f. The reentrant superconductivity predicted by us [1] has been recently observed in the Fe/V/Fe trilayer [9].

The superconductivity in the F/S systems [1,10] is a combination of the BCS pairing in the S layers and the Larkin–Ovchinnikov–Fulde–Ferrell (LOFF) [11] pairing with a nonzero three-dimensional (3D) momentum of pairs in the F layers. Nevertheless, usually it is assumed [3–8,12]

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