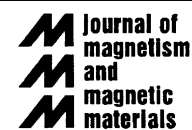




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# Decoupled superconductivity in the four- and five-layered ferromagnet–superconductor nanostructures and control devices

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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  $\pi$  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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