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## Nonmonotonic behavior of the superconducting transition temperature in bimetallic ferromagnet-superconductor structures

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### Abstract

For layered ferromagnet/superconductor (F/S) structures we develop a theory of the proximity effect. In contrast to previous approaches, this theory allows for a finite transmission coefficient of the interface between the two metals and competition between the diffusion and spin-wave types of quasiparticle motion in the ferromagnet's strong exchange field. The superconductivity in F/S systems proves to be a superposition of BCS pairing with a constant-sign pair amplitude in the S-layers and Larkin-Ovchinnikov-Fulde-Ferrell (LOFF) pairing with an oscillating wave function in the F-layers. We show that the oscillatory behavior of the superconducting transition temperature  $T_c$  is due to oscillations of the Cooper pair flux from the S-layer to the F-layer, which are the result of oscillations of the discontinuity (jump) of the pair amplitude at the F/S boundary as the thickness  $d_f$  of the F-layer increases. The presence of nonmagnetic impurities leads to heavy damping of the oscillations of the LOFF pair amplitude and rapid deterioration of the coherent coupling of the boundaries of the F-layer in which the  $T_s$  vs.  $d_f$  dependence reaches a plateau as  $d_f$  increases. In F/S superlattices, in contrast to F/S double-layer junctions, there are two forms of the LOFF state, the 0-phase and the  $\pi$ -phase, which differ in their symmetry with respect to the center of the F layer. This gives rise to additional oscillations in the  $T_c$  ( $d_f$ ) dependence due to the 0- $\pi$  transitions. As the most vivid manifestation of LOFF states in F/S-systems, we predict the existence of recurrent and periodically recurrent superconductivities. We give a qualitative explanation of the different behavior of the superconducting transition temperature observed by different groups of experimenters dealing with the same ferromagnet-superconductor structures. © 1998 American Institute of Physics.

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