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Proximity effect and superconducting transition temperature in superconductor/ferromagnet sandwiches

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Abstract

The theory of proximity effect for superconductor/ferromagnet (SC/FM) sandwiches is developed. The superconducting transition temperature T_c of a sandwich is calculated taking into account the finite transparency of the SC/FM interface, the exchange splitting of conduction band and breaking of superconducting pairs in the ferromagnetic layer(s). It is found that in SC/FM bilayers and FM/SC/FM trilayers T_c may exhibit nonmonotonic, oscillating or re-entrant behavior as a function of the ferromagnetic layer(s) thickness. The qualitative relevance of the theory to existing experiments is discussed. The experiment which allows one to distinguish the formation of 'π-phase' or '0-phase' in SC/FM multilayer systems is proposed.

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1. Introduction

Since the pioneering works by de Gennes and Guyon [1] and Hauser, Theuerer and Werthamer [2] there appeared permanent interest to the investigations of artificially layered superconductor/normal metal (S/N) structures (see the summary in the review by Deutscher and de Gennes [3]). The experimental study of interplay between superconductivity phenomena and ferromagnetism in sandwiches and multilayered films was started by the work of Hauser et al. [4]. It was found that the magnetically ordered metallic overlayer, deposited atop the superconducting film, suppresses transition temperature of the latter much stronger, than nonmagnetic overlayers studied in a previous investigations. They interpreted the results introducing in the de Gennes–Werthamer [1,5,6] theory of S/N-proximity effect the finite life-time for Cooper pairs (pair-breaking) due to exchange scattering on localized magnetic moments, responsible for the magnetism, in a fashion introduced first by Abrikosov and Gor'kov [7,8].

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