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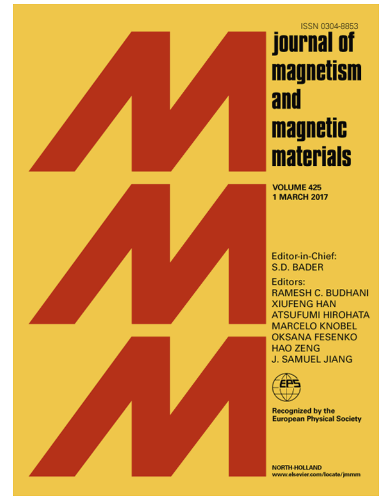

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Hexin Zhou, Xiaofeng Jin

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Stray field and vortex controlled magnetoresistance in superconducting Bi/Ni bilayers

Hexin Zhou[a,b], Xiaofeng Jin[a,b,*]

[a] *State Key Laboratory of Surface Physics and Department of Physics, Fudan University, Shanghai 200433, China*
[b] *Collaborative Innovation Center of Advanced Microstructures, Fudan University, Shanghai 200433, China*

Abstract

The magnetoresistance of superconducting Bi/Ni bilayers is investigated around the superconducting transition temperature. At temperatures within the superconducting transition, the magnetoresistance presents a superposition of symmetric peaks and hysteresis behaviors. The magnetoresistance peaks show the evidence of T_C suppression due to stray fields from domain walls appearing during magnetization switching. The hysteresis behaviors show the effect of vortices motion on the superconductivity of Bi/Ni bilayers. This unusual magnetoresistance controlled by both stray fields and vortices provides a new understanding of the interaction between superconductivity and ferromagnetism in Bi/Ni bilayers.

Keywords: Superconductor, Ferromagnet, Magnetoresistance, stray field, magnetic hysteresis
PACS: 75.47.-m, 75.70.Cn, 74.78.-w, 74.78.Fk

1. Introduction

Hybrid structures consisting of superconductors (S) and ferromagnets (F) have attracted intensive attention due to the proximity effect [1] and potential applications in superconducting spintronics [2, 3]. In S/F hybrids, the complicated interaction between superconductivity and ferromagnetism results in a number of novel phenomena. For example, in an F/S/F spin valve structure, the spin switch effect (SSE) can be achieved by controlling the magnetic configuration of two F layers [4, 5, 6, 7, 8]. Around the superconducting transition temperature T_C, the resistance of the F/S/F valve is higher in the parallel configuration than in the antiparallel configuration, i.e. $R(P) > R(AP)$ (P: parallel, AP: antiparallel). Because the Cooper pair breaking effect due to the exchange interaction of F layers is stronger in parallel configuration than in antiparallel configuration, the T_C in parallel configuration is lower, i.e. $T_C(P) < T_C(AP)$. As a result, the resistance of F/S/F structures around T_C can manifest $T_C(P) < T_C(AP)$ by $R(P) > R(AP)$. In addition, the effect of exchange interaction on superconductors is also observed in S/F bilayer structures by controlling the domain state of F layer [9]. The T_C is enhanced when many domains are present in the F layer, which corresponds to a weaker effective exchange interaction. As a result, the resistance around T_C is decreased when the magnetization of F layer switches. On the other hand, a number of groups have also reported the inverse SSE in F/S/F structures, i.e. $T_C(P) > T_C(AP)$, which corresponds to $R(P) < R(AP)$ around T_C [10, 11, 12, 13, 14, 15, 16]. In trilayers consisting of highly spin-polarized $La_{0.7}Ca_{0.3}MnO_3$ and high-T_C superconducting $YBa_2Cu_3O_7$, the increased resistance was observed below T_C in the AP configuration, which was explained by the spin imbalance theory [10]. Then the inverse SSE was also observed in the simple Py/Nb/Py trilayers, but the authors explained their data by the reflection of spin-polarized quasiparticles at the S/F interfaces [11]. Recently, more and more groups have reported the inverse SSE and explained the phenomenon in the frame of stray field effect [12, 13, 14, 15, 16]. In S/F hybrid structures, the magnetization switching of F layer can produce large stray field which can suppress the T_C. For transport measurement around T_C, the T_C suppression due to stray field can be manifested by the resistance increase during magnetization switching. In F/S/F trilayers, the stray field will cause $R(P) < R(AP)$ around T_C. In order to confirm the stray field explanation of the inverse SSE, S/F bilayers have also been investigated in these experiments [12, 13, 14, 15, 16]. Similar to the inverse SSE in F/S/F trilayers, the resistance of S/F bilayers around T_C is increased (corresponding T_C suppression) during magnetization switching due to stray fields, which is contrary to the T_C enhancement due to the effect of exchange interaction in S/F bilayers [9]. More interestingly, some groups have reported the spin-triplet paring superconductivity in S/F hybrid structures with magnetic inhomogeneities at the S/F interface [17, 18, 19, 20, 21]. Characteristics of the triplet paring are found in magnetoresistance (MR) and tunneling measurements around T_C. This triplet paring can induce long range spin polarized supercurrent which is the building block for the potential application of superconducting spintronics [2, 3].

Recently, a new kind of S/F hybrid structure is discovered in the bilayer consisting of non-superconducting Bi and ferromagnetic Ni. What makes the Bi/Ni bilayer unique is that the two elements are non-superconducting separately, but the interaction at the interface of Bi and Ni can give rise to the unexpected superconductivity. Although the underlying mechanism of the superconductivity in Bi/Ni is still not well known and under inves-

*Corresponding author
Email address: xfjin@fudan.edu.cn (Xiaofeng Jin)