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SM-O-109 BACK TO CONTENTS BACK TO AUTHOR INDEX

Josephson Effect in SIFS Junctions: Dirty to Clean Limits

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The interplay between dirty and clean limits in Superconductor-Ferromagnet-Superconductor (SFS) Josephson junctions is a subject of intensive theoretical studies[1,2]. SIFS junctions, containing an additional insulator (I) barrier are interesting as potential logic elements in superconducting circuits, since their critical current I_c can be tuned over a wide range, still keeping a high I_cR_N product, where R_N is the normal resistance of the junction. They are also a convenient model system for a comparative study of the 0-π transitions for arbitrary relations between characteristic lengths of the F-layer: the layer thickness d, the mean free path l, the magnetic length $\xi_H=v_F/2H$, and the nonmagnetic coherence length $\xi_0=v_F/2\pi T$, where v_F is the Fermi velocity, H is the exchange magnetic energy, and T is the temperature. The spatial variations of the order parameter are described by the complex coherent length in the ferromagnet $\xi_F^{-1}= \xi_1^{-1}+ i\xi_2^{-1}$. It is well known, that in the dirty limit ($l<<\xi_{1,2}$) described by the Usadel equations both $\xi_1^2=\xi_2^2= v_Fl/3H$.

In this work the spatial distribution of the anomalous Green's functions and the Josephson current in the SIFS junction are calculated. The linearized Eilenberger equations are solved together with the Zaitsev boundary conditions. This allows comparing the dirty and the clean limits, investigating a moderate disorder, and establishing the applicability limits of the Usadel equations for such structures. We demonstrate that for an arbitrary relation between l, ξ_H, and d the spatial distribution of the anomalous Green's function can be approximated by a single exponent with reasonable accuracy, and we find its effective decay length and oscillation period for several values of ξ_H, l and d. The role of different types of the FS interface is analyzed. The applicability range of the Usadel equation is established.

The results of calculations have been applied to the interpretation of experimental data[3] obtained on Nb-Al_2O_3-Cu-Ni-Nb Josephson junctions containing a Ni layer with moderate scattering.

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References

[1] F. S. Bergeret, A. F. Volkov, and K. B. Efetov, Phys. Rev. B **64**, 134506R (2001).
[2] J. Linder, M. Zareyan, and A. Sudbo, Phys. Rev. B **79**, 064514 (2009).
[3] A. A. Bannykh, J. Pfeiffer, V. S. Stolyarov, I. E. Batov, V. V. Ryazanov, M. Weides, Phys. Rev. B **79**, 054501 (2009).

SM-P-1119 BACK TO CONTENTS BACK TO AUTHOR INDEX

Phenomena of Harmonics Spatial Separation in Junctions with Complex Ferromagnetic/Normal Metal Weak Link Region

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It is well known, that a critical current across a Josephson junction with ferromagnetic (F) interlayer exhibits damped oscillations as a function of the ferromagnetic layer thickness, thus providing an existence of Josephson structures with negative critical current, so-called π-junctions [1]. In them the superconductor (S) order parameters phase difference across a structure θ=π in ground state. Under certain conditions (see e.g. [2]) there is also an opportunity to have θ=φ in the ground state with φ≠0 or π, so-called φ-junctions. Existence of those junctions requires a fulfillment of strict restrictions on the current phase relations (CPR), namely the amplitudes of the first and the second harmonics in CPR ($I_S(\varphi) = A\ sin(\varphi) + B\ sin(2\varphi)+$...) should obey the inequalities | B | > A/2, B < 0.

In SFS structures with metal type of conductivity it is typical that A strongly exceeds B except a narrow interval around the point of transition into π state. In this interval A is close to zero, while B > 0 [3] thus prohibited an appearance of φ-junctions.

In this work we have demonstrated that in the structures composed from normal (N) and F films in the weak link region the situation can be completely different, if the supercurrent flows in the direction parallel to NF interface. To do this, in the frame of Usadel equations we solved numerically two dimensional boundary problem for different geometries of S-NF-S structures and calculate the contributions to the current phase relation (CPR) from the N and F parts of the weak link. We demonstrate that under a certain conditions the first harmonic of CPR, $A\ sin(\varphi)$, mainly located in the F film, while the second, $B\ sin(2\varphi)$, is concentrated in the N region. This spatial separation opens a window of parameters providing the opportunity for realization of φ-junctions in the considered S-NF-S structures.

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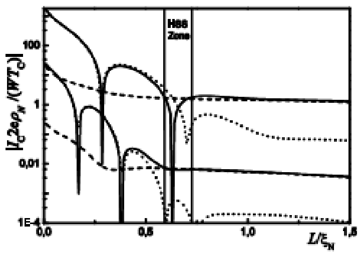

Figure 1. Separation of full current (solid line) between N (dashed line) and F-channels (dotted line) versus length between electrodes L in SN-FN-FS structure. The top and the bottom groups of the lines correspond to the first and the second harmonics respectively.

References

[1] A. Golubov, M. Kupriyanov, and E. Il'ichev, Rev. Mod. Phys. **76**, 411 (2004).
[2] A. Buzdin and A. E. Koshelev, Phys. Rev. B **67**, 220504 (R) (2003).
[3] N. G. Pugach, E. Goldobin, R. *Kleiner*, D. Koelle, Phys. Rev. B **81**, 104513 (2010).

SM-P-1176 BACK TO CONTENTS BACK TO AUTHOR INDEX

Superconducting Triplet Spin Valve F2F1S – General Model with Arbitrary Layer Thicknesses and Boundary Transparencies

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We demonstrate for the first time that the superconducting transition temperature T_c in the superconducting spin-valve F2NF1S can be a nonmonotonic function of the angle α between magnetizations of the two F layers. The role of the N layer (N is a non-magnetic normal metal) in such structures is to separate magnetically the two ferromagnetic layers, F1 and F2, allowing them to rotate independently. The analysis has shown that the N layer has very small impact on superconductivity in the structure if the thickness d_N is made much smaller that the coherence length. Therefore we can study simplified but realistic F2F1S structure.

Figure shows dependence of the transition temperature T_c on the angle α between magnetizations, the outer ferromagnetic layer F2 having fixed thickness. Here T_{cS} is the superconducting transition temperature for an isolated S layer. Tranparencies of the interfaces were taken typical for SF-proximity systems (see the Figure legends). At small thicknesses d_{F1} of the middle ferromagnetic layer F1 (d_{F1}/ξ_{F1} = 0.3) the switching effect is standard, while at large d_{F1} (d_{F1}/ξ_{F1} = 1.0) the effect is inverse. The curve for d_{F1}/ξ_{F1} = 0.7 demonstrates the triplet spin-valve effect [1]. Moreover, the reentrant $T_c(\alpha)$ dependence (d_{F1}/ξ_{F1} = 0.4) is possible. The figure shows a possibility of the spin-valve effect enhancement at approximately equal thicknesses of the F layers.

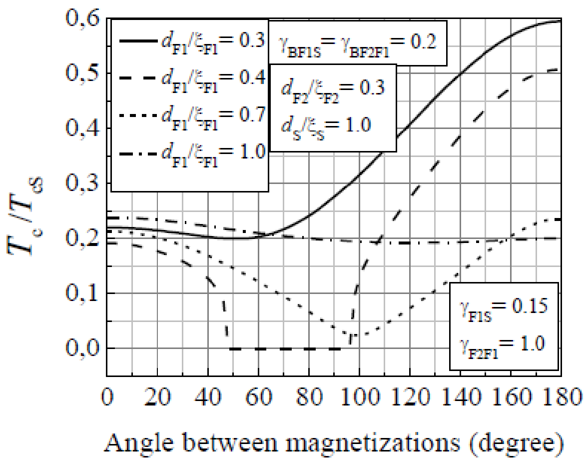

Figure. Dependence of the transition temperature T_c on the angle α between magnetizations

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References

[1] Ya. V. Fominov, A. A. Golubov, T. Yu. Karminskaya *et al.*, JETP Lett., **91**, 308 (2010).

SM-I-1178 BACK TO CONTENTS BACK TO AUTHOR INDEX

Generation of Long-Range Triplet Pairing in a Superconductor-Ferromagnet Proximity Spin-Valve

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The theory of superconductor-ferromagnet (S-F) heterostructures with two and more ferromagnetic layers predicts the generation of a long-range, odd-in-frequency triplet pairing at non-collinear alignment of magnetizations of the F-layers ([1] and references therein). We detected for the first time this odd-triplet pairing in a Nb/$Cu_{41}Ni_{59}$/Nb/Co/CoO_x spin valve type proximity-effect heterostructure. A weak ferromagnet – $Cu_{41}Ni_{59}$ alloy with an equilibrium magnetic moment perpendicular to the film plane was used as a propagator layer adjacent to the bottom niobium layer – a conventional S-wave superconductor. A second very thin Nb film between the $Cu_{41}Ni_{59}$ and metallic cobalt layers served as a normal conducting spacer. An antiferromagnetic cobalt oxide layer exchange biased the in-plane magnetization of the cobalt layer, which plays a role of mixer of the triplet and singlet pairing channels.

Our FMR and SQUID measurements confirmed that the $Cu_{41}Ni_{59}$ layer has easy magnetization axis perpendicular to the film plane. The magnetoresistance measurements at temperatures close to the superconducting (SC) transition temperature T_c, and magnetic field applied in the in-plane direction, have shown a transition from the normal to the SC state when decreasing the magnetic field. Then, upon changing the field polarity and passing the coercive field of the $Cu_{41}Ni_{59}$ layer (*i.e.* near the crossed magnetization configuration of the $Cu_{41}Ni_{59}$ and Co layers) the system returned back to the resistive state followed with subsequent SC transition when the system is driven towards the antiparallel alignment of the $Cu_{41}Ni_{59}$ and Co layers magnetic moments. Finally, upon further increase of the magnetic field in the negative direction, and the Co layer magnetic moment reversal, the system returned back to the resistive state because of the magnetic field pair-breaking. We refer this unusual magnetoresistance behavior to the indication of the triplet pairing generation at the non-collinear alignment of magnetizations in the Nb/$Cu_{41}Ni_{59}$/Nb/Co/CoO_x heterostructure.

To get an experimental confirmation of our interpretation we have made similar measurements in a Nb/$Cu_{41}Ni_{59}$/Si reference sample which did not show the unusual behavior described above. So, the observed sequence of normal to superconducting state and backward transitions seem to be qualitatively consistent with the theory [2].

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References

[1] F. S. Bergeret, A. F. Volkov, and K. B. Efetov, Rev. Mod. Phys. 77, 1321 (2005).
[2] Ya. V. Fominov, A. A. Golubov, T. Yu. Karminskaya, M. Yu. Kupriyanov, R. G. Deminov, and L. R. Tagirov, JETP Lett. **91**, 308 (2010).