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# ABSTRACT BOOK

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## Double Proximity Effect In Hybrid Planar Superconductor-(Normal Metal/Ferromagnet)-Superconductor Structures

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The coherent transport in Josephson superconductor - normal metal - superconductor (S-N-S) and superconductor - ferromagnet - superconductor (S-F-S) nanocontacts attracts intense interest nowadays. Ferromagnetic materials suitable for Josephson S-F-S junction fabrication have the superconducting order parameter decay length of about several nanometers [1] which is much smaller compared to the decay length in normal metal. To increase the decay length in structures with ferromagnets different types of Josephson junctions with complex bilayered (NF) and trilayered (FNF) weak links have been proposed in theoretical work [2]. We report the fabrication of planar Josephson S-N-S and S-NF-S junctions and their characterization down to T=300 mK. Samples were fabricated by electron beam lithography, using two-layer resist, and subsequent shadow deposition at two angles. We used aluminum films with thickness of 100 nm like superconducting banks, while a 15-60 nm thick copper film was used as a normal metal layer and 10 nm thick iron film as a ferromagnetic one in a planar bilayered barrier. Two different types of structures (S-N-S and S-NF-S) with the same geometry were investigated. It was found that current-voltage characteristics become hysteretic as temperature decreases despite the high transparency of SN-interfaces [2].. In the resistive part of current-voltage characteristics, the features related to the multiple Andreev reflections and the presence of a minigap were detected [3]. The nanofabricated S-NF-S structures of the second type had the space L between superconducting banks in the range of 30-200 nm. The Josephson supercurrent was observed in structures investigated. The critical current Ic of S-NF-S junctions was much smaller than that for S-N-S junctions. The rapid decrease of Ic with L increasing is due to the suppression of the superconducting proximity effect by the F-layer. In the differential resistance (density of state) characteristics of S-NF-S junctions a double peak peculiarity was observed at the voltage corresponding to the minigap. The effect observed can be explained by the induced electron spin polarization in the normal layer due to the ferromagnet.

References

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## Experimental Observation Of The Triplet Spin-Valve Effect In A Superconductor-Ferromagnet Heterostructure

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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). As a consequence of the unconventional triplet pairing the triplet spin-valve effect has been predicted in [2]. To observe this effect experimentally we realized Nb/$Cu_{41}Ni_{59}$/Nb/Co/CoOx spin-valve type proximity-effect heterostructure [3]. 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 underlying 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. 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/CoOxheterostructure. The superconducting Tc also shows pronounced minimum close to the crossed magnetic configurations giving further support towards triplet spin-valve interpretation of the observed phenomena.
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