Memory effect in Superconductor/Ferromagnet nanostructures as a base for superconducting spintronics.

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Superconducting state in heterostructures superconductor/ferromagnet (S/F) has a lot of peculiarities in comparison with uniform BCS-superconducting state of conventional superconductors. The theory of non-uniform superconductivity predicts existing together with a short-range singlet pairing generation of two additional components: an even-in-frequency and a long-range, odd-in-frequency triplet pairing in samples with two ferromagnetic layers at non-collinear alignment (NCA) of the magnetizations of the F-layers. This triplet pairing we have detected experimentally in a $Nb/Cu_{41}Ni_{59}/NL/Co/CoO_x$ spin-valve type proximity effect coupled heterostructure (whith a very thin Nb film between the F-layers served as a spacer of normal conducting metal, NL-layer). The resistance of the sample as a function of an external magnetic field shows that the system is superconducting at a collinear alignment of the $Cu_{41}Ni_{59}$ and Co layers magnetic moments, but switches to the normal conducting state at a NCA configuration. The last is the evidence that the superconducting transition temperature T_c for NCA is lower than the fixed measuring temperature. The existence of a minimum T_c, at the NCA regime below that one for parallel or antiparallel alignments of the F-layer magnetic moments, is consistent with the theoretical prediction of the appearance of the long-range triplet pairing.
We found, that the resistive state of the nanolayered hybrid superconductor/ferromagnet spin-valve structure (SSV) depends on the preceding magnetic field polarity, as shown in Fig1. The detected effect is based on a strong exchange bias (about 2 kOe) on a diluted ferromagnetic copper-nickel alloy and generation of a long range odd in frequency triplet pairing component. The difference of high and low resistance states at zero magnetic field is 90% of the normal state resistance for a transport current of 250 mkA and still around 42% for 10 mkA. Both logic states of the structure do not require biasing fields orcurrents in the idle mode. This memory effect opens perspectives for design of logic elements for superconducting spintronics.

Fig. 1. Magnetoresistance of the SSV structure Co/CoOx/Cu41Ni59/Nb/Cu41Ni59 . Superconducting transitions at zero applied field for “forward branch” (FB) and“backward branch” (BB) .