Memory Effect and Triplet Pairing Generation in the Superconducting Exchange Biased $Co/CoO_x/Cu_{41}Ni_{59}/Nb/Cu_{41}Ni_{59}$ Layered Heterostructure

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We fabricated a nanolayered hybrid superconductor-ferromagnet spin-valve structure, the resistive state of which depends on the preceding magnetic field polarity. The 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 μA and still around 42% for 10 μA. Both logic states of the structure do not require biasing fields or currents in the idle mode.

Superimposing two antagonistic phenomena, superconductivity (S) and ferromagnetism (F), on the nanoscale offers rich basic physics[1-3] and provides several opportunities to design superconducting devices having unique features.[4-7] The S/F interaction can in general be described in terms of the proximity effect with a mutual penetration of charge carriers, electrons or Cooper pairs, or stray field mediated correlations. Superconducting spin-valves (SSVs)[8-10], intended to switch between two states with different superconducting transition temperatures, T_c, show extremely large magnetoresistance and are under wide experimental and theoretical consideration since the last decade.[11-18] In both, F/S/F and S/F/F designs of the SSV, T_c is manipulated by altering the magnetic configuration of the F-layers. A positive difference in T_c between anti-parallel (AP) and parallel (P) configuration, $\Delta T_c^{AP\text{-}P}$, is described in terms of the S/F proximity effect,[8-16] while stray-field mediated mutual correlations of micromagnetic structures in the F-layers is a plausible explanation of the negative $\Delta T_c^{AP\text{-}P}$ in F/S/F spin-valves[17-19].

Unconventional odd-triplet pairing, recently considered for S/F proximity systems,[2] deepens the understanding and extends the functionality of the superconducting spin–valves,[20-23] introducing a coupling by long-range spin-polarized Cooper pairs. As a result, $\Delta T_c^{AP\text{-}P}$ in S/F/F-type SSVs can be either positive or negative within the proximity coupling model. Moreover, T_c can have an absolute minimum at non-collinear alignments of the F-layer magnetic moments, resulting in the triplet switching mode.[20]

Control of magnetic configurations in spin-valves is often provided by bringing one of the F-layers in contact with an antiferromagnetic (AF) layer. The interfacial exchange coupling induces a unidirectional magnetic anisotropy, the exchange bias effect, which gives rise to a horizontal shift of the hysteresis loop, coercivity enhancement, asymmetric hysteresis loops, and training effects[24-28].

The exchange bias phenomenon is widely explored in magnetic field sensors,[25-27] however, even now it is not thoroughly understood and hardly predictable for an arbitrary AF-F couple of