Beilstein Journal of Nanotechnology, 2016, vol.7, N1, pages 957-969

Thickness dependence of the triplet spin-valve effect in superconductor-ferromagnet-ferromagnet heterostructures

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Abstract

© 2016 Lenk et al.Background: In nanoscale layered S/F1/N/F2/AF heterostructures, the generation of a long-range, odd-in-frequency spin-projection one triplet component of superconductivity, arising at non-collinear alignment of the magnetizations of F1 and F2, exhausts the singlet state. This yields the possibility of a global minimum of the superconducting transition temperature Tc, i.e., a superconducting triplet spin-valve effect, around mutually perpendicular alignment. Results: The superconducting triplet spin valve is realized with S = Nb a singlet superconductor, F1 = Cu41Ni59 and F2 = Co ferromagnetic metals, AF = CoOx an antiferromagnetic oxide, and N = nc-Nb a normal conducting (nc) non-magnetic metal, which serves to decouple F1 and F2. The non-collinear alignment of the magnetizations is obtained by applying an external magnetic field parallel to the layers of the heterostructure and exploiting the intrinsic perpendicular easy-axis of the magnetization of the Cu41Ni59 thin film in conjunction with the exchange bias between CoOx and Co. The magnetic configurations are confirmed by superconducting quantum interference device (SQUID) magnetic moment measurements. The triplet spin-valve effect has been investigated for different layer thicknesses, dF1, of F1 and was found to decay with increasing dF1. The data is described by an empirical model and, moreover, by calculations using the microscopic theory. Conclusion: The long-range triplet component of superconducting pairing is generated from the singlet component mainly at the N/F2 interface, where the amplitude of the singlet component is suppressed exponentially with increasing distance dF1. The decay length of the empirical model is found to be comparable to twice the electron mean free path of F1 and, thus, to the decay length of the singlet component in F1. Moreover, the obtained data is in qualitative agreement with the microscopic theory, which, however, predicts a (not investigated) breakdown of the triplet spin-valve effect for dF1 smaller than 0.3 to 0.4 times the magnetic coherence length, ζF1.

http://dx.doi.org/10.3762/bjnano.7.88

Keywords

Heterostructures, Superconducting spin valve, Thin films, Triplet superconductivity