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CRITICAL-CURRENT OSCILLATIONS AS A FUNCTION OF THE EXCHANGE FIELD AND THICKNESS OF THE FERROMAGNETIC METAL (F) IN AN S-F-S JOSEPHSON JUNCTION (BUZDIN AI; BULAEVSKII LN; PANYUKOV SV (1982))

The first magnetic superconductors with a regular sublattice of magnetic atoms have been discovered in 1976. This generated a lot of interest to the problem of the coexistence between superconductivity and magnetism. In singlet superconductor the Cooper pairs comprise the electrons with the opposite spins and a very strong internal magnetic field in the ferromagnet (so called exchange field) acts on the electrons on the way to align their spins. This leads to the destruction of the Cooper pairs and explains while practically all know magnetic superconductors are antiferromagnets, where the averaged (on the scale of the Cooper pair) internal magnetic field is zero. Only recently (after 2000) the first three ferromagnetic superconductors where discovered and without any doubts they are triplet superconductor, where the Cooper pairs are formed from the electrons with parallel spin orientation.

As the coexistence between the singlet superconductivity (S) and ferromagnetism (F) occurred to be impossible in the bulk compounds, it was natural to address a question what will be the proximity effect near the S/F interface? Namely this problem was addressed in the referred article [1]. The authors where the first to discover the damping oscillatory behavior of the superconducting wave function in the ferromagnet and predicted the realization of the "π" state in S/F/S Josephson junctions. In such a "π" junction in the ground state the sign of the superconducting order parameter is opposite on the banks of the junction (the phase difference is "π", which explain the name of such a junction).

The analysis performed in the referred paper corresponded to the clean ferromagnet, where the electron transport is ballistic. The subsequent studies demonstrated that the oscillatory behavior of the superconducting wave function is a very general phenomenon, which is robust toward the scattering on the impurities and then it is present in all type of the ferromagnetic junctions – ballistic or diffusive. In fact these oscillations of the order parameter are in some sort the manifestation to the non-homogeneous superconducting Larkin-Ovchinnikov-Fulde-Ferrell (LOFF) state [2,3]. LOFF state was predicted to occur in the clean superconducting ferromagnet. Due to the incompatibility of ferromagnetism and singlet superconductivity it is not easy to verify this prediction on experiment. However in the S/F systems the Copper pairs penetrating inside the ferromagnet occur to be in the situation similar to that considered by Larkin, Ovchinnikov and Fulde, Ferrell. Moreover the damping oscillatory behavior of the superconducting wave function in the ferromagnet must be present in both clean and dirty limits.

The S/F/S "π" junctions have been subsequently realized on experiment [4]. The "π" junctions incorporated into the superconducting circuits serve a source of the phase shift and generate the non-dissipative current. The recent experimental studies demonstrated that the "π" junctions permit to realize a "quiet" superconducting qubit – a building block of future quantum computer [5].

The current interest to the S/F/S systems is also stimulated by the perspectives they open for the emergence of the superconducting spintronics.

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