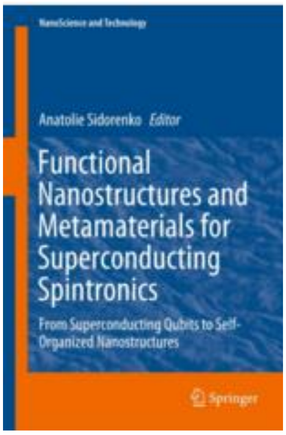

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Compact Josephson φ-Junctions

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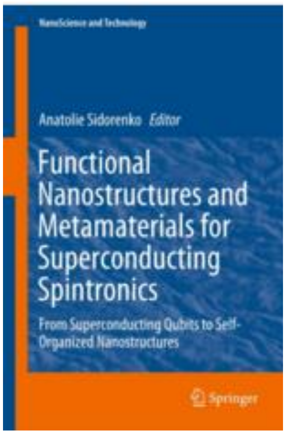
Abstract

This chapter is devoted to the study of controllable proximity effects in superconductors (S), in terms of both fundamental aspects and applications. As a part of the work, theoretical description was suggested for a number of structures with superconducting electrodes and multiple interlayers with new physics related to the proximity effect and nanoscale φ-junctions. They are Josephson structures with the phase of the ground state φ_g , $0 < \varphi_g < \pi$ φ-junctions can be created on the basis of longitudinally oriented normal metal (N) and ferromagnetics (F) layers between superconducting electrodes. Under certain conditions, the amplitude of the first harmonic in the current-phase relation (CPR) is relatively small due to F layer. The coupling across N layer provides negative sign of the second harmonic. To derive quantitative criteria for realization of a φ-junction, we have solved two-dimensional boundary-value problem in the frame of Usadel equations for overlap and ramp geometries of different structures with NF bilayer. This chapter is focused on different geometries of nanoscale φ-structures of the size much less than Josephson penetration depth λ_J . At the same time, φ-state cannot be realized



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in conventional SNS and SFS sandwiches. Proximity effect between N and F layers limits minimal possible size of φ-junction. In the case of smaller junctions, NF bilayer becomes almost homogeneous, φ-state is prohibited, and junction exists in 0- or π-state. The conditions for realization of φ-junctions in ramp-type S–NF–S, overlap-type SFN–FN–NFS, and RTO-type SN–FN–NS geometries are discussed in the chapter. It is shown that RTO-type SN–FN–NS geometry is most suitable for practical realization. It is also shown in this chapter that the parameter range of φ-state existence can be sufficiently broadened. It allows to realize Josephson φ-junctions using up-to-date technology. By varying the temperature, we can slightly shift the region of 0-π transition and, consequently, we can control the mentioned phase of the ground state. Furthermore, sensitivity of the ground state to an electron distribution function permits applications of φ-junctions as small-scale self-biasing single-photon detectors. Moreover, these junctions are controllable and have degenerate ground states +φ and –φ, providing necessary condition for the so-called silent quantum bits.