Tunable $0 - \pi$ Josephson devices with ferromagnetic insulator barrier: the role of spin-orbit interaction and lattice impurities

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Abstract

Josephson π-junctions (π-JJs) are currently subject to intense research activity [1-4] due to their applicability in superconducting circuits [1,3], spintronics [4] and quantum computing devices [2]. In particular, the possible integration of π-JJs in quantum circuits for superconducting qubits is quite promising [2], in view of the increased robustness against noise induced by magnetic field sources and a more compact design [1,2,4], paving the way to scalable and self-biased devices [2]. Superconductor-ferromagnet-superconductor JJs (SFS JJs) are promising platforms to implement π-JJs [1,2,4], and have been widely studied, being proven to exhibit temperature induced $0-\pi$ transitions. Much less is known when the ferromagnetic layer is insulating and more suitable for circuital applications, due to its low dissipation. In this work we investigate the transport properties of ferromagnetic-insulator barrier junctions (SFIS JJs) [1] with particular attention to the temperature behavior of the critical current ($I_C(T)$), that may be used as a fingerprint of the junction. One of the most challenging issues is to find an effective way of controlling the $0-\pi$ transitions in SFIS JJs, through a direct action on their $I_C(T)$ [1,3,4]. We study the specific role of impurities as well as of spin mixing mechanisms, due to the spin orbit, in this kind of task [1,3,4]. $0-\pi$ transitions can be properly tuned, thus achieving stable π -JJs over the whole temperature range [1], that may be possibly employed in superconducting quantum circuits.

References

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Figures

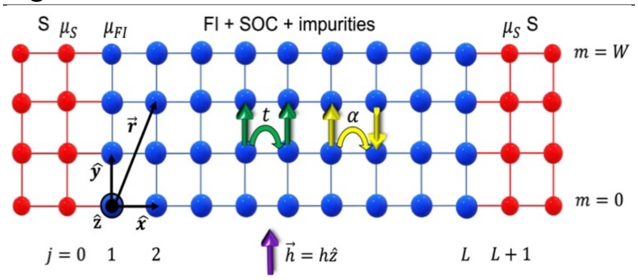

Figure 1: 2-D lattice scheme of the SFIS JJ. Exchange field h, spin-orbit α, hopping t, chemical potentials of FI barrier μ_{FI} and superconducting leads μ_S are shown [1].

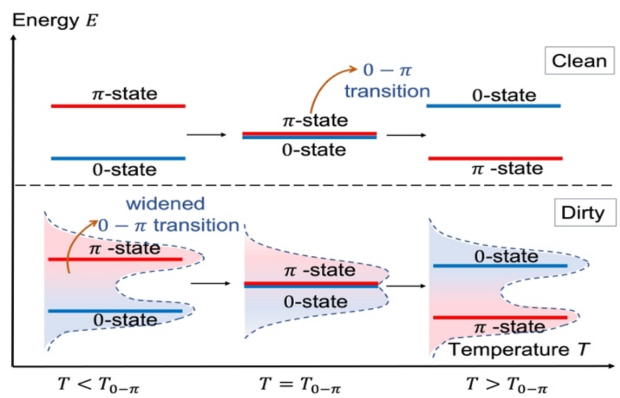

Figure 2: Schematic picture of 0 and π energy levels undergoing a $0-\pi$ transition in the absence (above, clean regime) and presence (below, dirty regime) of lattice impurities [1].