Contribution ID: **170** Type: **Oral Presentations**

Nonreciprocal transport in Josephson junctions made of d-wave superconductors through ferromagnetic layer in the presence of interfacial Rashba spin-orbit coupling

Wednesday 9 July 2025 12:45 (15 minutes)

We have studied theoretically the effect of interfacial Rashba spin-orbit coupling (SOC) on the Josephson effect between two d-wave superconductors with ferromagnetic layer in between, based on the Bogoliubov-de Gennes approach, extended McMillan's Green function formalism, and generalized Furusaki-Tsukada treatment. If both time-reversal and space-inversion symmetries are broken, Josephson junction can exhibit Josephson diode effect (JDE) characterized by nonreciprocal behavior in the critical supercurrent in two opposite directions, as well as finite current at zero phase difference known as anomalous Josephson effect (AJE). We found that the appearance of the JDE and AJE are conditioned by the simultaneous presence of interfacial Rashba SOC, nonzero component of magnetization out of junction plane, and asymmetric orientation of two d-wave superconductors. This is in accordance with symmetry analysis of global Hamiltonian of junction. We found that high diode efficiency in this kind of junctions can be realized by tuning the orientations and magnitudes of relevant ingredients. The cumulative ground state of junction is not pure 0 or π because the different transverse channels have different phase differences. We predict that phase transition between 0-like and π-like states can be achieved by modulating the strength of the interfacial Rashba SOC. Temperature dependence of JDE is shown and the possibility of a temperature 0-π-like crossover is predicted.

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Session Classification: Condensed Matter, Materials and Applied Physics

Track Classification: S03 –Condensed matter, Materials and Applied Physics