Effects of magnetic fluctuation on 0-\(\pi\) transition in a superconductor-ferromagnet-superconductor junction

MICHIFASU MORI, SHIN’ICHI HIKINO, SABURO TAKAHASHI, SADAMICHI MAEKAWA, Tohoku University — There has been growing interest in a superconductor-ferromagnetic-metal-superconductor (SFS) junction, in which the Josephson critical current, \(I_c\), shows a cusp as a function of thickness of ferromagnetic-layer, \(d\), and/or temperature, \(T\). Such a non-monotonous behavior, which is in marked contrast to \(I_c\) in a conventional Josephson junction, originates from the fact that the current-phase relation is shifted by \(\pi\). This is called \(\pi\)-state. We study the influence of magnetic fluctuation on \(I_c\) in the SFS junction by a tunneling Hamiltonian approach. An analytical formula of \(I_c\) is given in the fourth order perturbation theory as regards the tunneling matrix element. Electrons propagate diffusively in the FM due to non-magnetic- and magnetic scatterings. The \(I_c\) exhibits the damped oscillatory dependence on \(d\), and shows the transition between 0- and \(\pi\)-states. When the superconducting transition temperature is comparable to the ferromagnetic Curie temperature, the period of oscillation is elongated by increasing \(T\) due to the magnetic fluctuation, which plays an important role in the 0-\(\pi\) transition, in particular, with \(T\). Our results present an appropriate combination of a superconductor and a ferromagnetic metal to control the 0- and the \(\pi\)-states.