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Development of ferromagnetic Josephson junction based on niobium nitride

In recent years, novel physics emerged in superconductor/ferromagnet (S/F) hybrid structures have been studied actively and their device applications have been considered. Among various novel phenomena in SC/FM structures, “pi state” appearing in ferromagnetic Josephson junctions (S/F/S) is attractive as a phase shifter for several superconducting devices based on macroscopic quantum effect [1]. In the present work, we have developed the ferromagnetic Josephson junction in order to realize a “quiet” superconducting flux quantum bit (qubit) with a pi junction [2,3]. The qubit with a pi junction can be operated without an external magnetic field which is a noise source, and thus good coherence characteristics is expected. Furthermore, zero magnetic field operation provides merits for realizing a highly-integrated system with many qubits. As the superconducting material of the junction, we adopted niobium nitride (NbN) with high superconducting critical temperature of ~16 K, which has a relatively smooth surface due to its epitaxial growth on a magnesium oxide substrate. We used copper nickel (CuNi) for the ferromagnetic barrier as a diluted weak ferromagnet, and fabricated the ferromagnetic Josephson junctions based on NbN electrodes with various junction sizes and CuNi thicknesses. We measured and analyzed the dependences of the Josephson critical current on the temperature and CuNi thickness.

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