High-quality NbN-MgO-NbN SIS junctions and integrated circuits for THz applications

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Superconductor - insulator-superconductor (SIS) mixers based on NbN films are considered as a promising replacement for conventional Nb SIS mixers for realization of low-noise heterodyne terahertz receivers due to high gap frequency of up to 1.4 THz. In order to realize wideband and low-noise mixers, high current density and high-quality SIS junctions as well as extremely low-loss transmission lines are required.

New technique for fabrication of high-quality SIS tunnel junctions based on epitaxial NbN films with MgO barrier has been developed. NbN films have been deposited on single-crystal MgO substrates placed on the water-cooled substrate-holder. The NbN films are dc magnetron sputtered from a 5-inch diameter high purity Nb target in a reactive mixture of argon and nitrogen, leading to good thickness uniformity on 3-inch diameter substrates. Since deposited NbN films has cubic lattice structure with a lattice constant very similar to those for single-crystal MgO substrates it was possible to obtain single-crystal NbN films even at deposition at ambient temperature [1, 2]. The single-crystal NbN films deposited on an MgO single-crystal substrate in this work show a high transition temperature (T_c = 16.1 K) and reasonably low resistivity (ρ = 80 μОм*см).

The tunnel barrier was created by oxygen plasma oxidation of extremely thin Mg layer (d = 1.5 nm) deposited on the NbN electrode by DC sputtering. The plasma oxidation process is similar to well-known nitridization process that was successfully used for fabrication of high current density NbN-AlN-Nb SIS junctions [3]; such process provides both better current density control compare to traditional rf sputtering of the MgO target [1, 2] and perfect junction quality. As a result the NbN/Mg-MgO/NbN junctions with gap voltage V_g = 5.2 mV and quality barrier parameter R_j(2mV)/Rn > 40 have been fabricated. Such junction parameters are very promising for development of the Josephson oscillators and superconducting integrated receivers [4] for frequencies well above 1 THz.

To design integrated circuits one should know the parameters of the films composed the integrated circuits (e.g. - London penetration depth, the effective dielectric constant, etc.). Comprehensive studies of the electrical parameters of superconducting microwave structures made with different materials of the wiring electrode (Nb, Al, NbN, and NbTiN) have been performed and compared to numerical calculations in order to determine the various microwave parameters of these integrated structures.

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