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Optical and Tunneling Studies of Energy Gap in Superconducting Niobium Nitride Films

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We have prepared superconducting niobium nitride (NbN) films and NbN/AlN/NbN tunnel junctions to investigate the energy gaps by measuring the optical conductivity with time-domain terahertz spectroscopy and by tunneling spectroscopy, respectively. A 41-nm-thick NbN film was deposited on a 0.3-mm-thick single crystal MgO substrate by reactive dc magnetron sputtering. The critical temperature (Tc) and the dc resistivity at 20 K were 14 K and 69 micro-ohm-cm, respectively. The transmission spectra of the NbN film on the MgO substrate were measured at several temperatures from 6 K to 20 K. The experimental result at 6 K showed that the real part of the conductivity rises from a value near zero at about 1.2 THz (= 4.96 meV = 4.1kTc) which is the gap frequency of the film, where k is the Boltzmann's constant. With increasing the temperature, however, we found that the superconducting gap became ill-defined due to the broadening of the onset of absorption. This may be attributed to the finite quasi-particle lifetime in the NbN film. On the other hand, from the I-V curve measurement of the high quality NbN/AlN/NbN tunnel junction with the current density of 100 A/cm2 at 2.5-16 K by a dilution refrigerator, we observed large smearing of the gap voltage as the temperature increases. This also indicated the lifetime broadened superconducting density of state. The temperature dependence of the lifetime estimated from both results will be discussed.

Less than 5 years of experience since completion of Ph.D

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