Temperature and Magnetic Field Dependent Optical Properties of Superconducting MgB_2 Thin Film

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We investigated the temperature (T = 5 ~ 40 K) and magnetic field dependent (H = 0 ~ 17 T) far-infrared properties of a MgB_2 thin film, whose thickness and T_C are about 50 nm and 33 K. In the superconducting state without external H-field, we obtained the superconducting gap value $2\Delta \sim 5$ meV and $2\Delta/k_BT_C \sim 1.8$. Although the value of $2\Delta/k_BT_C$ was half of the BCS value, the 2Δ seemed to follow the temperature dependences of the BCS formula. Under external H-field, the superconducting state became suppressed. Optical properties of this mixed state can be model with the Maxwell-Garnett theory, which assumed that the normal metallic region be imbedded in a superconducting background. Using this theory, the optical conductivity spectra could be explained quite well. Quite interestingly, the normal state area fraction increased abruptly at a low H-field and increased rather slowly at a higher H-field. It did not follow the H-dependences predicted for a s-wave superconductor (i.e. a linear dependence), nor for a d-wave superconductor (i.e. $H^{1/2}$ dependence). It seems that there are two different regimes for the mixed states, which suggested the anomalous vortex dynamics and/or a complex gap nature of the MgB_2 superconductor.

keywords : Far-infrared, MgB_2 superconductor, complex gap nature