SUPERCONDUCTING PROXIMITY EFFECT IN Nb/KG COMPLEX FILMS

Yoshiko Ohashi

Department of Instrumentation Engineering
Keio University, 3-14-1 Hiyoshi
Kohoku-ku, Yokohama 223 JAPAN

INTRODUCTION

When a superconducting material and a normal conductor (and/or a semiconductor) are in intimate contact, the superconducting proximity effect will be expected. That is to say Cooper pairs in a superconducting material leak out to the normal conductor. As a result of this pair electron leakage, superconducting region appears inside the normal conductor near the boundary, where the density of superconducting pair electrons decreases with increasing depth from the boundary. The soaking length of superconducting electron pairs into a normal conductor is called coherence length, ξ_N, which is comparable to the extent of the wave function of a superconducting electron pair. ξ_N has a specific value depending on materials.

The superconducting proximity effect causes decreasing the superconducting transition temperature of the whole sample composed of a superconductor and a normal conductor, T_c^*, with increasing thickness of the normal conductor, d_N. The value of ξ_N can be determined experimentally from the relation between T_c^* and d_N. Namely, the thickness of a normal conductor at which the decrease of T_c^* disappears corresponds to ξ_N.

The expression of ξ_N in the dirty limit ($l_N << \xi_N$, where l_N is mean free path of the normal conductor) was derived by de Gennes[1] as follows:

$$\xi_N = (\hbar D/2\pi k_B T)^{1/2}, \tag{1}$$

where $\hbar$ is Planck's constant, D, diffusion constant in the normal conductor, k_B, Boltzmann's constant, and T, temperature. Using free-electron-gas model, ξ_N can be expressed by Seto and van Duzer [2] as

$$\xi_N = (\hbar^3 \mu / 6\pi e k_B T m^*)^{1/2} (3\pi^2 n)^{1/3}, \tag{2}$$

where μ, e, m^* and n are the carrier mobility, electron charge, effective mass of carriers, and carrier concentration of the normal conductor, respectively. On the other hand, in the clean limit ($l_N >> \xi_N$), ξ_N can be written as

$$\xi_N = (\hbar^2/\pi k_B T m^*) (3\pi^2 n)^{1/3}. \tag{3}$$

It should be noted that, in any case, the value of ξ_N can be controlled by the electron properties of the normal conductor. It suggests that, using semimetal graphite as a normal conductor, the superconducting proximity effect will give us some feature peculiar to the anisotropy of graphite structure.

EXPERIMENTAL

Each sample used in this work was composed of a niobium (Nb) film as a superconductor and a kish graphite (KG) film as a normal conductor. The method of preparing KG films was the same as that described before [3]. In order to make an intimate contact between a KG film and a Nb film, the KG film mounted on quartz substrates were cleaned by Ar^+ ion beam irradiation of energy 50 and 100 eV with current 0.7mA for 2 minutes before deposition of Nb. Nb films were deposited on the KG films and the quartz substrates by electron beam evaporation in a deposition chamber, which was evacuated to a base pressure of around 2×10^{-9}Torr, and was kept 2×10^{-7} Torr during deposition. Therefore, each sample consists of two regions, one of which is a complex Nb-KG film and the other is a simple Nb film on a quartz substrate. They were worked into a bridge type for measuring the electric resistivity by means of a conventional four points probe technique as mentioned in the previous conference [4]. The superconducting transition temperature, i.e. $T_{cNb\text{-}KG}$ for the complex Nb-KG films and T_{cNb} for the Nb films, were taken as the midpoint temperature at which the film resistance reached one-half of full restoration of the normal state resistance with a current density of 100 A/cm^2. Resultant superconducting critical temperature T_c^* defined as $T_{cNb\text{-}KG}/T_{cNb}$ was estimated for each sample.

RESULTS AND DISCUSSION

Figure 1 shows T_c* versus thickness of the KG films treated with and without Ar^+ ion beam irradiation for the fixed Nb thickness of 40 nm. As shown in Figure 1, the tendency toward decreasing T_c* with the film thickness is steeper with cleaning than without cleaning. It means that the cleaning with Ar^+ ion irradiation is effective for confirming the intimate contact of Nb on KG films, hence the superconducting pair electron leakage through the boundary of this contact grows.

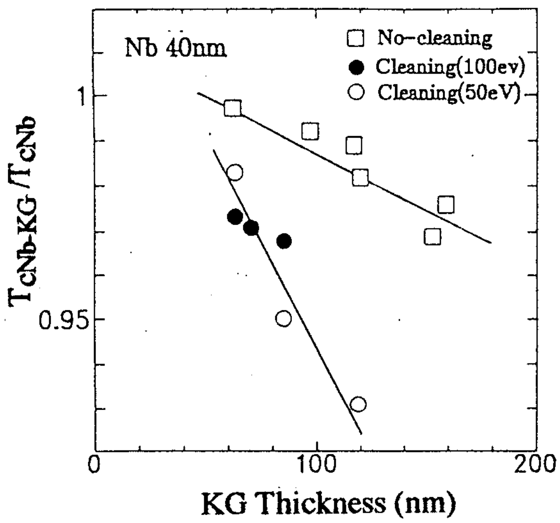

Figure 1 - T_c* vs. thickness of the KG films for a fixed Nb thickness of 40 nm with and without cleaning before deposition.

T_c* versus thickness of the KG films is shown in Figure 2 for various thicknesses of Nb films. KG thickness is ranging from 50 to 350 nm, and Nb thickness is 40 and 70 nm. Though a saturation in decrease of Tc* versus KG thickness was not observed within the limit of this study, it was found that the coherence length of KG, namely ξ_N, seems to be longer than 200 nm.

Now, it should be noted that the coherence length given by the equations (1), (2) and (3), seems to be related with anisotropic parameters of graphite structure. That is to say, l_N, D, μ and m* should correspond to their c-axis components, l_{Nz}, D_z, μ_z and m_z* respectively. According to the experimental results with use of these parameters,

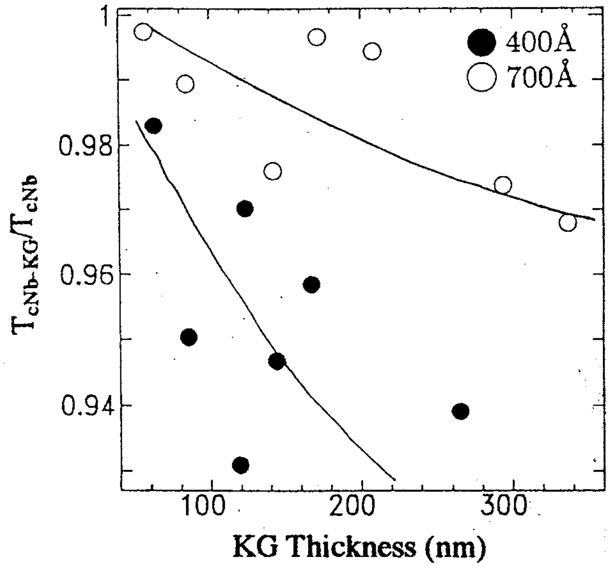

Figure 2 -Tc* as a function of KG thickness for the thickness of Nb film of 40 and 70nm.

l_{Nz} may be larger than several hundred nanometers at the rough estimate.

CONCLUSIONS

(1) Tc* decreased with increasing KG thickness.
(2) The coherence length of graphite was found to be larger than 200 nm.
(3) The c-axis component of mean free path, l_{Nz}, seems to be larger than 200 nm.

ACKNOWLEDGEMENT

The author wish to thank Mr. T. Ise for his assistance in operating the electron beam sputter-deposition apparatus to prepare Nb films.This work was partially supported by The Iketani Science and Technology Foundation.

REFERENCES

1. P. G. de Gennes, Rev. Mod. Phys. 36 225 (1964)
2. J. Seto & T. van Duzer, Proc. 17th Internat. Conf. on Low Temp. Phys. 328 (1972).
3. Y. Fujibayashi, J. Phys. Soc. Japan, 34 989 (1972).
4. Y. Ohashi, Proc. 21st Biennial Conf. on Carbon, Buffalo, 647 (1973).