PROXIMITY EFFECT OF Cu CLAD Nb AND Cu CLAD NbTi WIRES
Y. Oda, G. Fujii, H. Nagano

To cite this version:

HAL Id: jpa-00217756
https://hal.archives-ouvertes.fr/jpa-00217756
Submitted on 1 Jan 1978

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
PROXIMITY EFFECT OF Cu CLAD Nb AND Cu CLAD NbTi WIRES

Y. Oda, G. Fujii and H. Nagano
Institute for Solid State Physics, University of Tokyo, Roppongi, Minato-ku, Tokyo 106, Japan

Abstract.—The Meissner screening length in Cu of Cu clad Nb and Cu clad NbTi wire has been measured over temperature range from T down to 25 mK. The temperature dependence of the screening length is expressed by \((T+T_c)^{-1/2}\) from about 1.5 K to the minimum temperature. The length becomes 12 \(\mu\)m for Cu clad Nb and 7 \(\mu\)m for Cu clad NbTi wire at 25 mK. The measurement has been also done for Cu clad fine multiple NbTi wire. In this case, the screening length shows a drastic increase above 1 K, and the slope becomes remarkably small below 1 K. Some comments for application are also presented.

Normal metal N contacted with a superconductor S shows superconducting properties. In low magnetic field, Meissner effect is observed in the normal metal /1-2/. We have measured the temperature dependence of the screening length in Cu of Cu clad Nb and Cu clad NbTi wire, which are available for the superconducting magnet /3/. The mutual inductance due to the wires were measured by mounting them parallel to AC magnetic field in measuring coil /4/. The mutual inductance due to the wire changes suddenly at superconducting transition temperature \(T_c\) of Nb or NbTi core. As temperature is lowered, the mutual inductance increases. This is attributed to the increase of the screening length \(\rho\) in Cu, which is the distance, from the N/S interface, to which magnetic field penetrates freely in N. Experimental \(\rho\) was calculated by

\[
\rho = r \left(1 + \frac{\Delta M(T)}{\Delta M(T_c)}\right)^{-1/2} - 1
\]

(1)

where \(r\) is the radius of the core, \(\Delta M(T)\) is the mutual inductance change below \(T_c\), \(\Delta M(T_c)\) is the inductance change due to the transition of the core /4/. The measurements were made at several frequencies from 20 to 700 Hz. The features of the temperature dependence did not change in this region. The temperature dependence at 70 Hz for Cu (0.35mm\(\phi\)) clad Nb (0.25mm\(\phi\)) and Cu (0.1mm\(\phi\)) clad NbTi (0.07mm\(\phi\)) wires.

A theoretical calculation of the screening length was made by Deutscher and de Gennes /1-2/.

\(\rho\) is smaller than the coherence length \(\xi_N\) in N, \(\rho\) is given by

\[
\rho = \xi_N \left(1 - \log(1/K(0)) - 0.116\right)
\]

(2)

where \(K(0)\) is the Ginzburg-Landau parameter in N at the interface. In the dirty limit, \(\xi_N\) for \(T>T_{CN}\) (transition temperature of N) is given by

\[
\xi_N(T) = \left(\frac{\hbar v_F^2}{3kT}\right)^{1/2}
\]

(3)

where \(K(0)\) is independent of \(T\) at low temperatures, \(T^{-1/2}\) dependence is derived from this equation /2/. Equations (2) and (3) mean that \(\rho\) does not include any parameters depending on S. This equation gives a close value to the experimental result. But the \(T^{-1/2}\) dependence can not be obtained by this
equation. T has been found to be 73 mK for Cu clad Nb and 57 mK for Cu clad NbTi. Electron-electron interaction in Nb may be needed to give T term.

The measurement was also made for Cu clad fine multiple NbTi wire /5/. In this case, the mutual inductance change below Tc was very drastic above 1 K. The temperature dependence of the mutual inductance is given in figure 2 against 1/T.

![Figure 2](image)

**Fig. 2**: Temperature dependence of the mutual inductance below T due to the Cu (0.12 mm$^2$) clad fine multiple NbTi (0.009 mm$^2$×78) wire.

One possible explanation of this temperature dependence above 1 K is the overlapping of the screening range from each interface. From figure 1, $\rho$ should be about 1 µm at 1 K. This is about same value as the distance between the cores. Then all cores may be included in a superconducting sheath below 1 K.

One application is to use these wires for thermometry down to mK region. It gives much larger inductance change than that of CMN. Moreover, better thermal contact with metal can be easily achieved. On the other hand, our results imply that Cu clad superconductor are not suitable as a flux transformer or a magnetic pick up coil, for instance, for SQUID measurements.

References


/3/ Vacuum Metallurgical Co., LTD., Japan.


/5/ The Furukawa Electric Co., LTD., Japan.