§1. Kapitza Conductance Estimation of an Oxidized Copper Surface in Saturated He II

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The heat transfer from a metal to He II is determined by Kapitza conductance at the interface. Surface temperature estimation of the metal is used for the study of Kapitza conductance. The surface temperature is usually extrapolated from the temperature gradient in the metal. In the case of the metal with a coated layer, however, it is difficult to estimate the surface temperature. The similar case is applied for the superconductor of the helical coil of Large Helical Device (LHD). The copper surface is chemically treated by the oxidation in order to improve the heat transfer characteristics in He I. It is planed that the helical coil will be cooled by He II in the phase II upgrade. The Kapitza conductance of the conductor has to be estimated for a stability analysis. Therefore, the heat transfer from the oxidized copper surface to the saturated He II has been measured using an oxygen free copper cylinder. However, the thermal resistances related to the oxidation layer have not been considered. In order to study the Kapitza conductance of the oxidized copper surface, it is essential to estimate the thermal resistances. In the present study, we are concerned by the thermal resistances. The Kapitza conductance of the oxidized copper surface is discussed.

A diagram of the present sample for heat transfer measurement is shown in Fig. 1. The sample, which is an OFC cylinder with 70 mm in length and 20 mm in diameter, was mounted in a stainless steel vacuum can. The exposed surface was facing upward to the saturated He II bath. In order to minimize the heat leak to the bath via the can, the cylinder was attached to a fiber reinforced plastics (FRP) flange, and then assembled to a stainless steel flange which is part of the can. The heat transfer measurements can be separated into two stages. First, heat transfer measurements of the oxidized and the polished copper surfaces were conducted. The Kapitza conductances of the surfaces are compared with results of other studies. Then, two coating surfaces were prepared in order to estimate the resistances related to the oxidation layer: a) coated with Stycast 1266; b) coated with Stycast 1266 on the chemical oxidation layer. The measurements were conducted at 1.78 K in saturated He II.

Fig. 2 shows experimental results of the polished and the oxidized surfaces. The term of "surface temperature" is defined as the estimated temperature from the temperature gradient within the copper cylinder. The polished surface has consistent results with other studies.1)2) The oxidized surface has higher surface temperature than the polished surface, which contradicts the results from Kashani and Van Sciver.1) The inconsistency might be caused by the different surface preparation during oxidation. Experimental results for the polished and the oxidized surfaces with Stycast coating are also shown in Fig. 2. The surfaces with Stycast coating have almost the same heat transfer curve and have higher surface temperature than the polished and the oxidized surfaces.

The surface temperature difference between the two surfaces with the Stycast coating is 0.2 K at 5000 W/m^2. With the series resistance assumption, the surface temperature difference is due to the relations, ($R_{Cu\text{-}Oxidation}$ + $R_{Oxidation}$ + $R_{Oxidation\text{-}Stycast}$) - $R_{Cu\text{-}Stycast}$. The temperature gap at the Cu-Stycast interface is about 0.5 K using the resistance of epoxy instead of Stycast. Assuming a variable of $R_{Oxidation\text{-}Stycast}$, it is expected that the maximum resistance for the sum of $R_{Oxidation}$ and $R_{Cu\text{-}Oxidation}$ is 1.4x10^{-4} m^{2}K/W at 4.9 K. It is assumed that the surface temperature difference between the two surfaces with Stycast coating is associated with the Cu-oxidation interface resistance and the thermal resistance of the oxidation layer. The temperature of the chemically oxidized surface seems to be dominated by the influence of resistances.

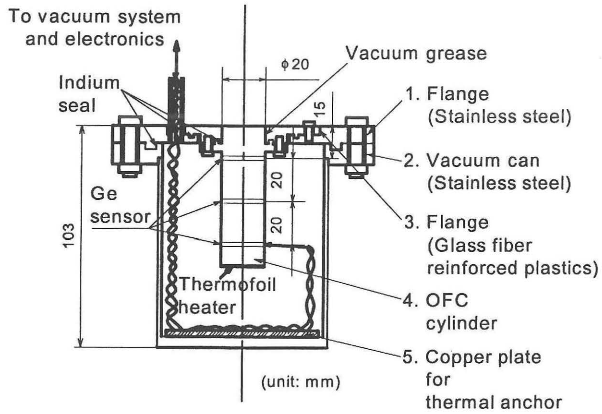

Fig.1. Schematic illustration of the sample

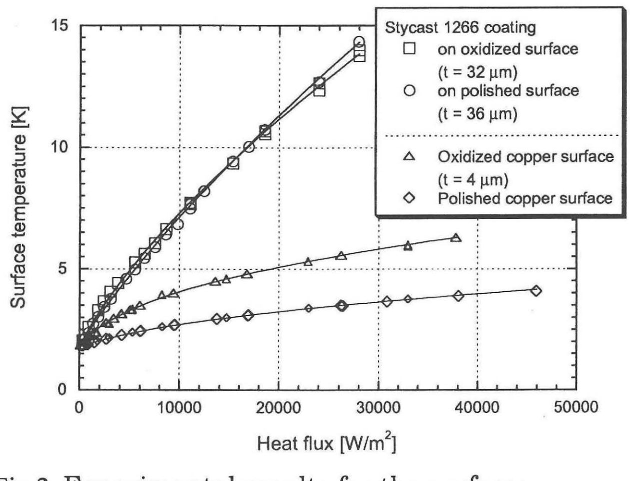

Fig.2. Experimental results for the surfaces

Reference

1) Kashani, A., et al., Cryogenics **25**, (1985)238

2) Claudet, G., et al., Adv. Cry. Eng. **27** (1981)441