§27. Evaluation Technique on Thermal Impedance between Dissimilar Solids

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In the heat transfer process between dissimilar materials, temperature discontinuity is resulting in thermal impedance at the interface. It can be observed clearly at cryogenic environment. Many researches have been conducted,1,2) and the impedance is considered to be caused by scattering of phonons at the interface. However, their experimental results do not agree with theoretical predictions because of the variation of experimental data. In order to help to understand the mechanism, it is important to improve the accuracy of the impedance measurement. In the present study, the measurement technique of thermal impedance at the interface has been developed based on the comparison between samples with different thicknesses. The sample was formed with a test material and a dummy thermal impedance. The technique is discussed according to the obtained information of the dummy thermal impedance.

The schematic illustration of the sample is shown in Fig 1. For the test material, 304-series stainless steel was chosen to compare with previous measurements. Its cross section is rectangular: 8.00 × 8.00 mm square. Three thicknesses were prepared: 5.00 mm, 8.00 mm and 10.00 mm. The stainless steel was sandwiched by oxygen-free copper (OFC) blocks, RRR=80±20. Stycast 2850FT was utilized for adhesive and for dummy thermal impedance between the stainless steel and the OFC blocks. In curing of Stycast, each sample was pressed on at 15.3 kPa to have the identical thickness of the Stycast layer. The average thickness of 60 μm was estimated from SEM photographs. A thermofoil heater was glued on one side of the sample and the other side was screwed on the sample holder which was connected to the second stage of a 4K-GM cryocooler.

In the sample, it is supposed that the thermal impedance of Stycast layer and the thermal resistance of stainless steel are combined in series. Two samples with different thicknesses of stainless steel: t_1 and t_2 were prepared and their apparent thermal conductivities were measured. Two equations are obtained:

$$\Delta T_{Total,1} = q_1 \cdot \left(2Z_{Stycast} + \frac{t_1}{\lambda_{SS}} \right) \quad (1a)$$

$$\Delta T_{Total,2} = q_2 \cdot \left(2Z_{Stycast} + \frac{t_2}{\lambda_{SS}} \right) \quad (1b)$$

where λ_{SS} is the thermal conductivity of the stainless steel and the subscripts 1 and 2 refer to the samples 1 and 2 correspond to t_1 and t_2. In the equations, λ_{SS} and $Z_{Stycast}$ are unknown. One variable is eliminated from the two equations, and λ_{SS} *and* $Z_{Stycast}$ are obtained:

$$\lambda_{SS} = \frac{t_1 - t_2}{\dfrac{\Delta T_{Total,1}}{q_1} - \dfrac{\Delta T_{Total,2}}{q_2}} \quad (2a)$$

$$Z_{Stycast} = 2 \cdot \frac{t_1 - t_2}{\dfrac{\Delta T_{Total,2}}{q_2} \cdot t_1 - \dfrac{\Delta T_{Total,1}}{q_1} \cdot t_2} \quad (2b)$$

Fig 2 shows the thermal impedance of the Stycast layer obtained by equation (2b). The thermal impedance is from ≈8×10^{-5} m^2-K/W at 250.2 K to ≈3×10^{-4} m^2-K/W at 15.0 K. On the other hand, the previous study has shown that the thermal impedance across copper-epoxy interface is ≈2×10^{-4} m^2-K/W around 4 K.3) The experimental result is comparable to that of the previous study. It was demonstrated that the method could evaluate the same order of magnitude as the previous study. The comparison between the samples with different thicknesses was one of the useful techniques to obtain the impedance.

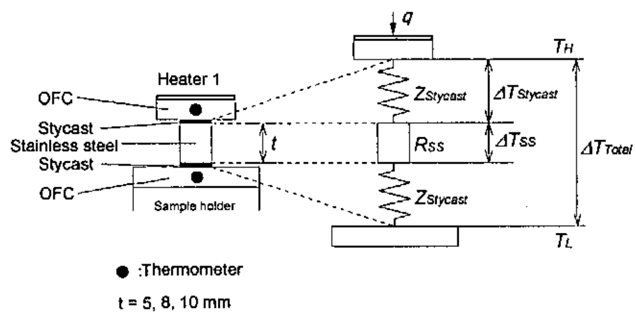

Fig.1. Sample detail and model of thermal resistance and impedance.

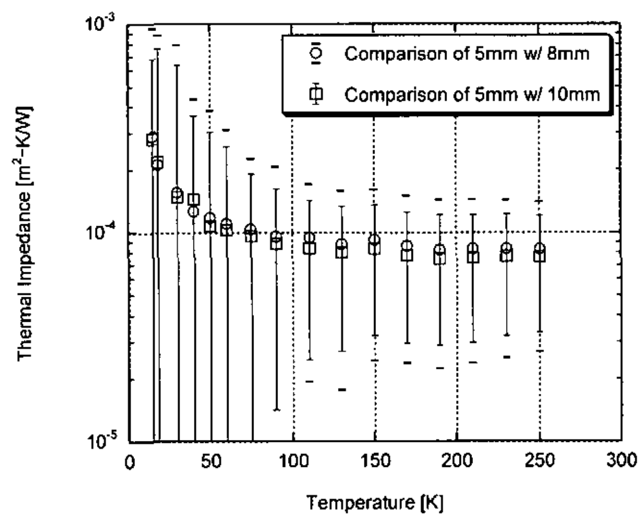

Fig. 2. Thermal impedance across Stycast 2850FT layer evaluated by equation (2b).

References
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3) Matsumoto, D. S., et al. *Physical Review B*, **6. 8**, (1977)3303.