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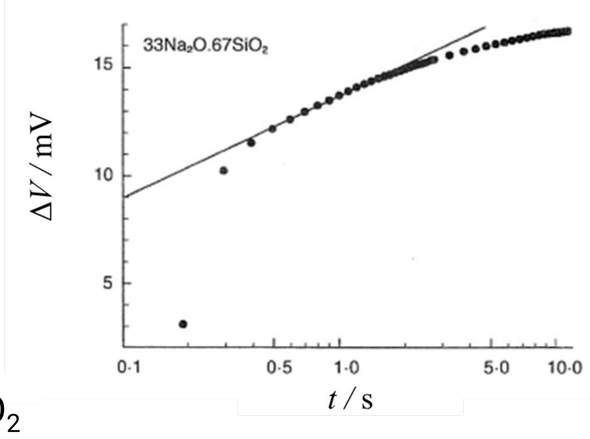
Thermal conductivity measurement of molten Na_2O-SiO_2 slags by non-stationary hot-wire method

Tomoaki Hashimoto[1], Masahiro Susa[1] , Miyuki Hayashi[1]
1. Tokyo Institute of Technology

1 INTRODUCTION



In steel refining and continuous casting, the thermal conductivity of slag melts is important for improving energy efficiency and product yield. However, it is difficult to measure the thermal conductivity in the molten state at high temperatures, and various thermal conductivities are often reported for the same composition. For example, the results of measurements of simple systems such Na_2O-SiO_2 vary widely.[1-4)] This problem is thought to be due to not being able to correctly estimate the effects of specific heat and convection. In this study, we measured the thermal conductivities of KNO_3 and Na_2O-SiO_2 melts using the non-stationary hot-wire method. In order to eliminate the influence of convection, we focused on the short-time region and investigated the influence of specific heat on the behavior of the short-time region from actual measurement results.

2 METHODS

Non-stationary hot wire methods

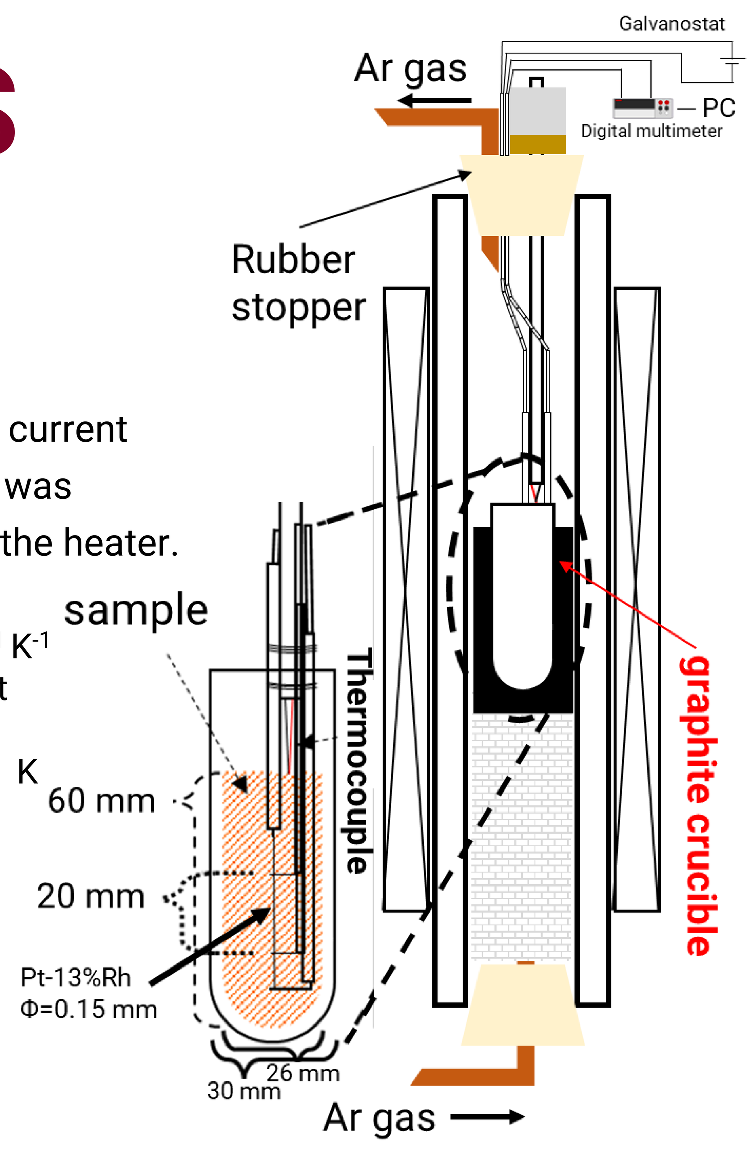
Joule heat was generated by passing an electric current through a thin metal wire, and thermal conductivity was calculated from the temperature increasing rate of the heater.

$$\lambda = \frac{Q}{4\pi\left(\frac{d\Delta T}{d\ln t}\right)}$$

λ : Thermal conductivity W m^{-1} K^{-1}
Q : Heat generation rate per unit length W m^{-1}
ΔT: Heater temperature change K
t : time s

Sample

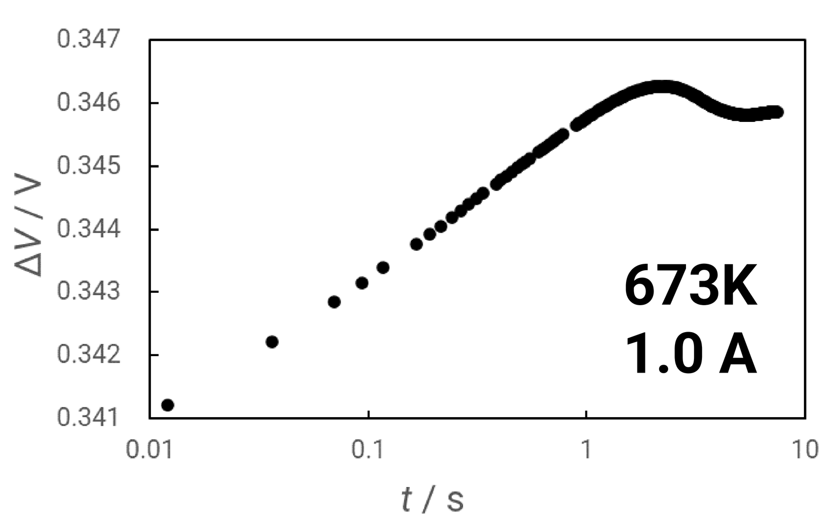
✓ KNO_3 for confirming measurement accuracy
✓ 33.3Na_2O- 66.7SiO_2 (mol%)



3 RESULTS

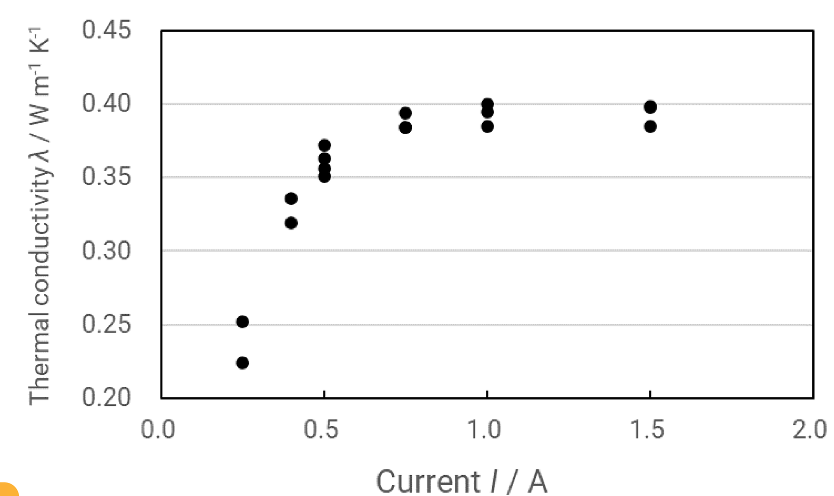
Measurement results at KNO_3

In the region of about 1 second or more, deviations from the linear relationship were observed due to the influence of convection. A good linear relationship was obtained in the region of 1 second or less.



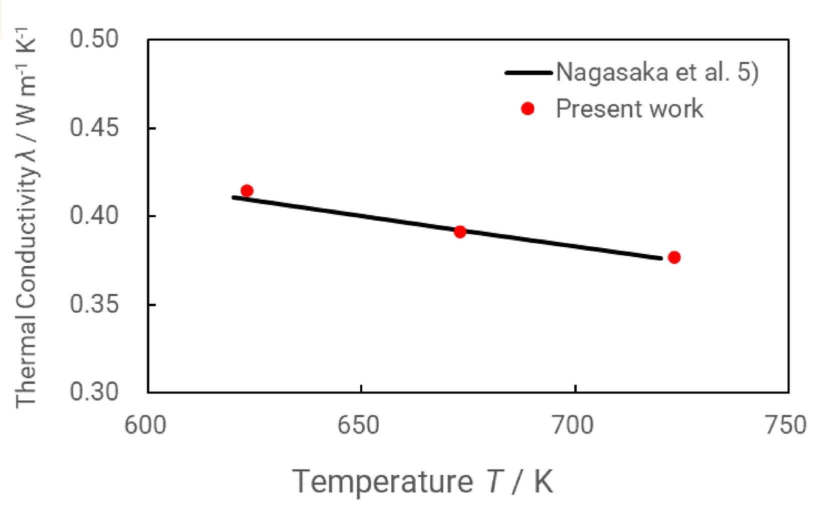
Current value dependence

The figure on the right shows the dependence of thermal conductivity on current value at 673K. A decrease in thermal conductivity was observed on the low current side. Thermal conductivity was almost constant above 0.75A.



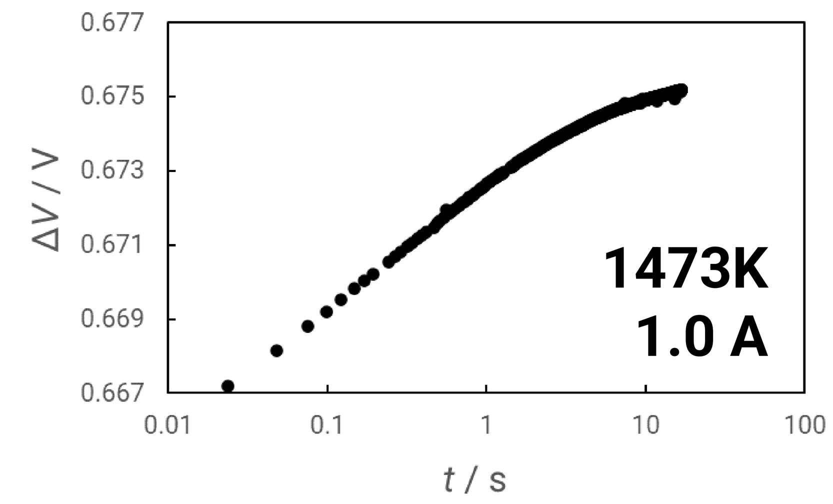
Comparison with previous research

The black line ——— is the recommended value of KNO_3 shown by Nagasaka et al.[5)] This measurement result agreed with sufficient accuracy. Thermal conductivity of the Na_2O-SiO_2 system was measured using a similar measurement method.



Measurement results at Na_2O-SiO_2

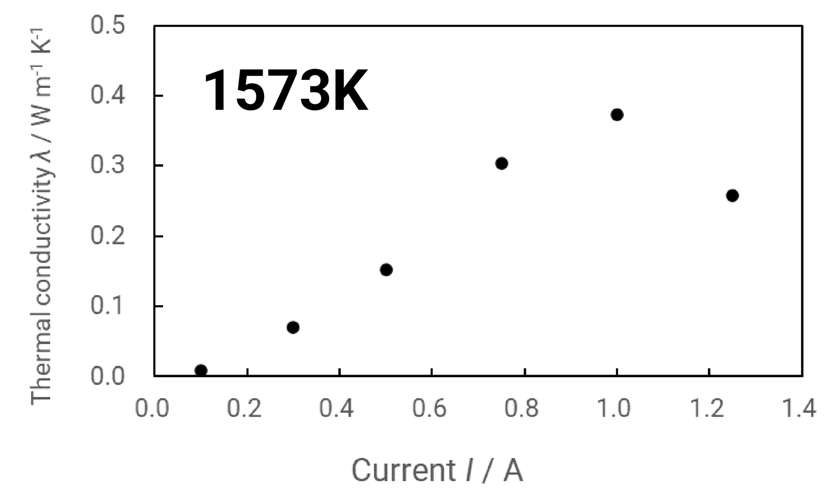
In the region of about 1.5 second or more, deviations from the linear relationship were observed due to the influence of convection. The linear relationship does not deviate significantly because the viscosity is higher than that of KNO_3. A good linear relationship was obtained in the region of 1.5 second or less.



4 DISCUSSION

Current value dependence

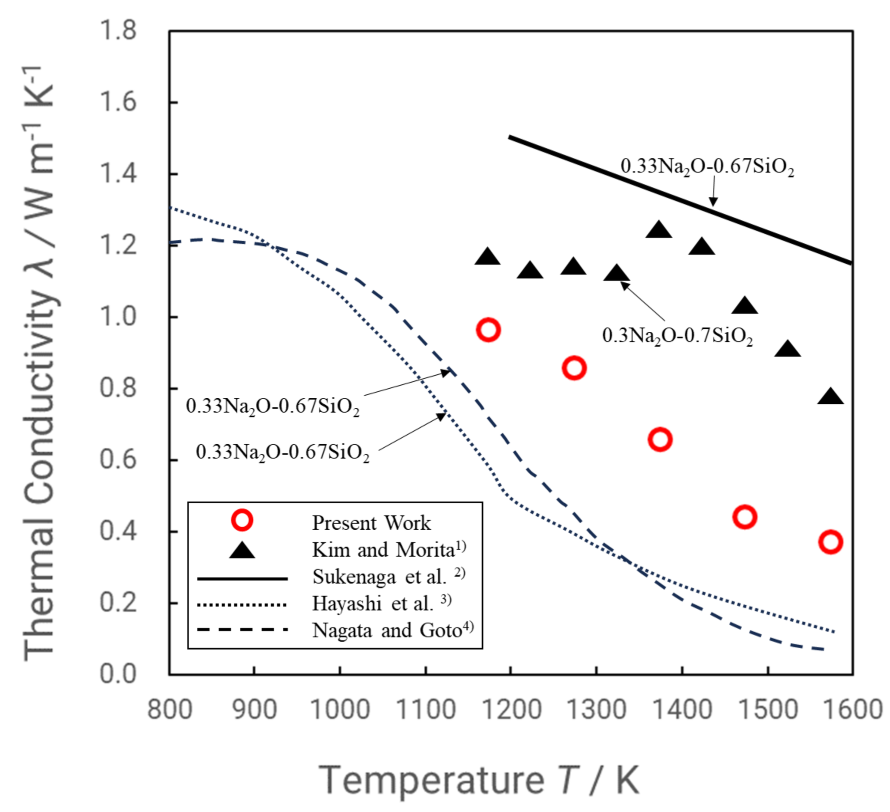
Similar to KNO_3, the thermal conductivity is estimated to be small on the low current side due to the influence of specific heat. On the high current side, the rise in temperature of the heater caused a rise in the temperature of the sample, resulting in a decrease in thermal conductivity.



In this measurement, the thermal conductivity was defined as the point where it became constant.

Thermal Conductivity of Na_2O-SiO_2

○ is the measurement result in this measurement. Reasons for the low thermal conductivity may include a delay in heating due to the specific heat of the thin heater wire itself, and may be related to the rise in temperature of the sample due to the use of a high current value. On the other hand, the reason why the thermal conductivity is high is that in the case of molten samples, a linear relationship is derived within the range that includes the influence of convection.



5 CONCLUSIONS

1. To measure thermal conductivities accurately, an appropriate current should be used: the usage of too small current leads to the effect of the specific heat of the thin heater on the measurement values. The usage of too large current may yield the effect of convection on the measurement values, and/or cause us to obtain the thermal conductivities at higher temperatures than expected because the wire is overheated by the large current.
2. The thermal conductivities of 33.3Na_2O- 66.7SiO_2 (mol%) melts were measured over the temperature range between 1173 K and 1573 K : 0.9 W/mK at 1200 K and 0.4 W/mK at 1500 K.

REFERENCES

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