§86. Thermal Conductivity and Phonon Scattering in AlN-Stycast Composites

Noto,K.,Takahashi,T.(Faculty of Engin. Iwate Univ.)

Yamaguchi,S.

Ninomiya,A.(Seikei Univ.)

Sato,T.(Faculty of Sci. Nagoya Univ.)

Thermal conductivities of pure AlN, Stycast-70%AlN, Stycast-60%AlN, and pure Stycast have been measured in the wide temperature range from 10 to 150 K by using GM type cryocooler. Thermal conductivity of the AlN-Stycast composites is 10-15 times larger than pure Stycast. The measured thermal conductivities in these composites were analysed by standard law of mixtures and it turned out that there are significant difference between measured data and analysed values. Phonon scattering mechanisms were studied in the thermal conductivity of pure AlN and it was revealed that the phonon scattering by dislocations is dominant in this material.

Thermal conductivity, κ, was measured by a standard steady state heat flow method by using a GM type cryocooler.

$$\kappa = \frac{\dot{Q}}{\Delta T} \cdot \frac{\ell}{S} \qquad [\mathrm{W/cm \cdot K}] \qquad (1)$$

, where Q[W], ΔT[K], S[cm^2], and ℓ[cm] denote heat flow, temperature gradient, sample cross section, and distance between thermometers, respectively. Figure 1 shows the block diagram of the full-automatic thermal conductivity measuring system[1].

Figure 2 shows the results of temperature dependence of thermal conductivity in our four samples. As can be seen in this figure, thermal conductivity of two Stycast-AlN composites is about 10-15

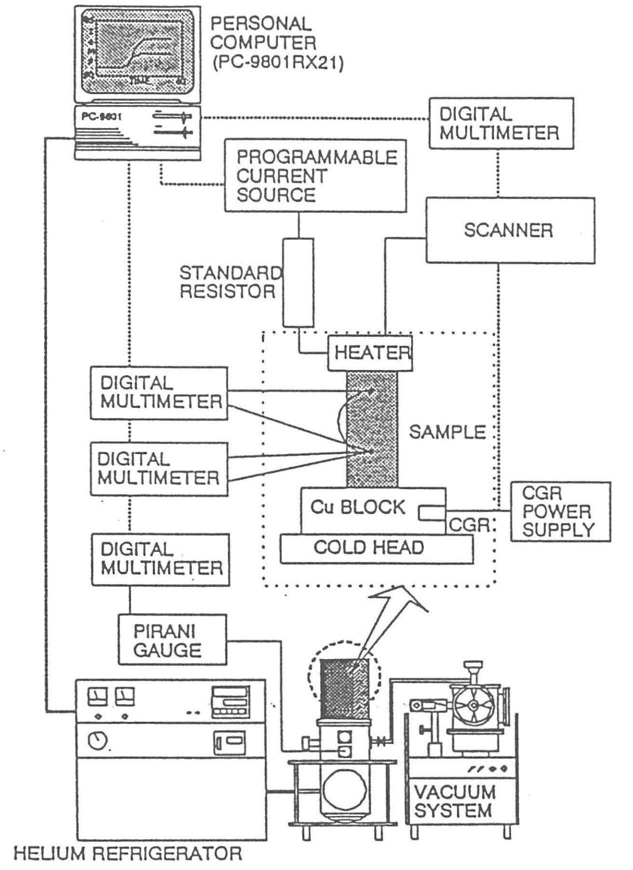


Fig.1. Block diagram of the full automatic thermal conductivity measuring system.

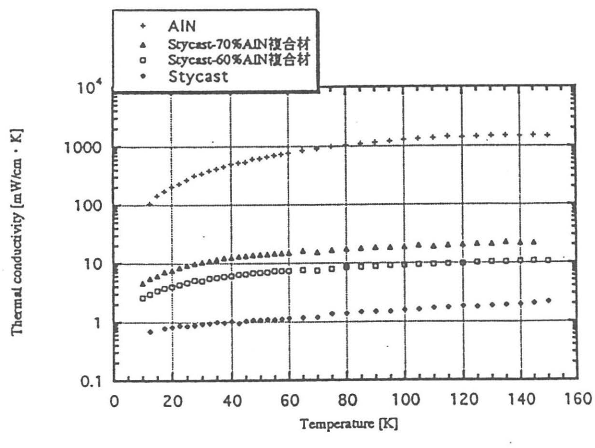


Fig.2. Temperature dependence of thermal conductivities for the studied four samples.

times larger than pure Stycast.

The upper and lower bound of thermal conductivity in two Stycast-AlN composites were calculated by a standard law of mixtures;

upper bound: $$\kappa = \kappa_A S_A + \kappa_S S_S \quad (2)$$

lower bound: $$\frac{1}{\kappa} = \frac{1}{\kappa_A} S_A + \frac{1}{\kappa_S} S_S \quad (3)$$

, where κ_A, κ_S, S_A, and S_S denote κ of AlN, κ of Stycast, fraction of AlN cross section, and fraction of Stycast cross section, respectively. The calculated bounds are compared with the measured results as shown in Figs. 3 and 4. As can be seen in these figures, there are considerable differences between both bounds and measured results.

Next, we analyse scattering mechanisms of phonons in pure AlN sample. Phonon thermal conductivity is given by the following expression in the relaxation time approximation,

$$K_g = At^3 \int_0^{\theta/T} \frac{x^4 e^x}{(e^x - 1)^2} \cdot \frac{1}{1 + B(tx)^2 + C(tx)^4 + Et^4 x^2} \quad (4)$$

, where A, B, C, and E are parameters denoting scattering by boundaries, dislocations, point deffects, and umklapp process, respectively. Figure 5 shows the results of analyses. The solid line is the best fitted curve by least square method in terms of eq.(4). The values of best fitted parametes are A=0.8, B=200, C≒0, and E≒0, respectively. From these results, it can be concluded that the phonon scattering by dislocations is dominant in pure AlN.

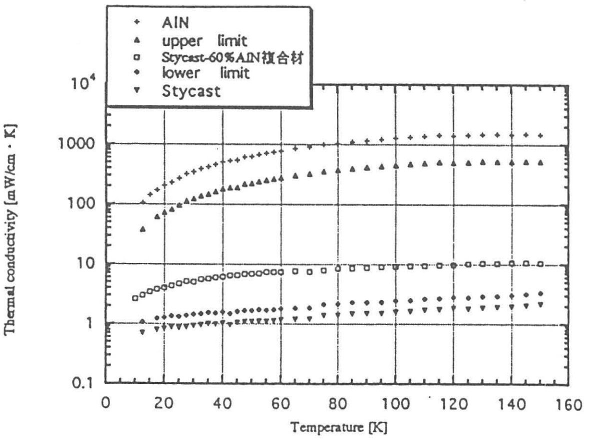


Fig.3. Comparison with the law of mixtures for Stycast - 60% AℓN composites.

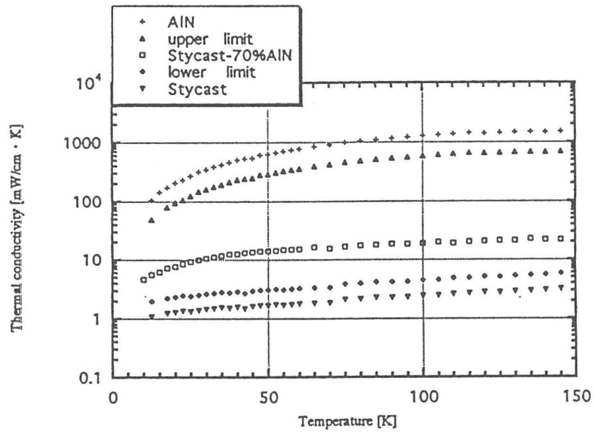
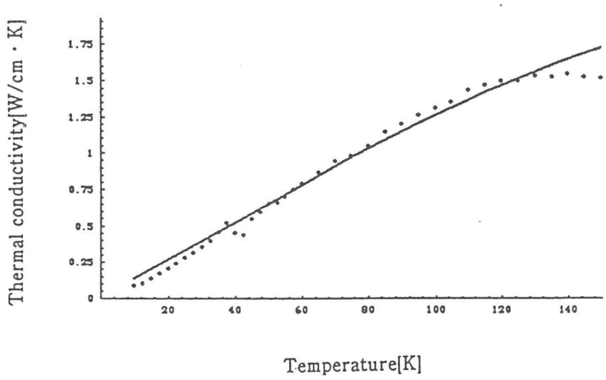


Fig.4. Comparison with the law of mixtures for Stycast - 70% AℓN composites.



$A=0.8 \quad B=200 \quad C \cong 0 \quad E \cong 0$

Fig.3. Comparison with the analyses on scattering mechanisms based on eq.(4) for pure AℓN.

References

1)Hobara,N. et al,A Fully Automated Measurement System of Thermal Conductivity Using a Helium Refrigerator:Cryogenic Engineering 28(1993)688.

2)Takahashi,T. et al:Abstract of Spring Meeting of Cryogenic Engineering Society of Japan(1997)83p(in Japanese)