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INTERNAL FRICTION DAMPING IN A RAPIDLY SOLIDIFIED Al-Fe-Ce POWDER METALLURGY ALLOY

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Abstract - The low frequency internal friction behavior of a rapidly solidified Al-8.6Fe-3.8Ce powder metallurgy alloy was investigated over the temperature range of 77 K to 700 K and frequency range of .6 to 1.5 Hz. The alloy has a large high temperature background damping curve as well as a small internal friction peak at about 475 K with an activation energy of 150 KJ/mole (36 kcal/mole) which is believed to be related to a grain boundary relaxation phenomenon. Aging of this alloy for up to 100 hours at 400°C increases the magnitude of both the high temperature background and the 475 K peak as well as causing another possible peak to appear. These aging effects as well as changes in modulus as calculated from measured frequency changes are discussed and possible mechanisms are proposed.

INTRODUCTION

Several new types of dispersion strengthened aluminum alloys made from consolidated amorphous powders have been developed recently for use at high temperatures /1/. Of these new alloys, the Al-Fe-Ce alloys show the best overall mechanical properties including good high temperature strength and creep resistance as well as a higher elastic modulus than conventional ingot metallurgy aluminum alloys /1/.

These Al-Fe-Ce alloys are produced by rapidly solidifying a melt into a fine irregular powder by gas atomization followed by compaction of the powder. The rapid solidification along with the high liquid and low solid solubility of Fe and Ce in Al, as well as the low diffusivity of both alloying elements in Al produces a fine dispersion of intermetallic compounds which are primarily responsible for the good elevated temperature properties of this alloy.

The purpose of this work was to study the internal friction behavior and temperature dependence of the modulus for this alloy and to investigate the effect of high temperature aging on those properties.

EXPERIMENTAL

The alloy used was supplied by Alcoa Laboratories and had a composition of 8.6 w/o Fe and 3.8 w/o Ce with the balance being Al. The rapidly solidified powder had been hot pressed for consolidation and extruded into a rectangular bar. A rod 1.6 mm square by 76.2 mm long was cut transversely from the extruded bar for the internal friction and modulus measurements.

The internal friction and dynamic modulus were measured upon heating in a low-frequency inverted torsional pendulum machine. After repeating measurements at three frequencies, the sample was annealed at 400°C for 10 hours in a vacuum of 10^{-8} torr. Internal friction and modulus measurements were again taken and the sample was then annealed for an additional 90 hours (100 hours total) and the measurement sequence repeated.

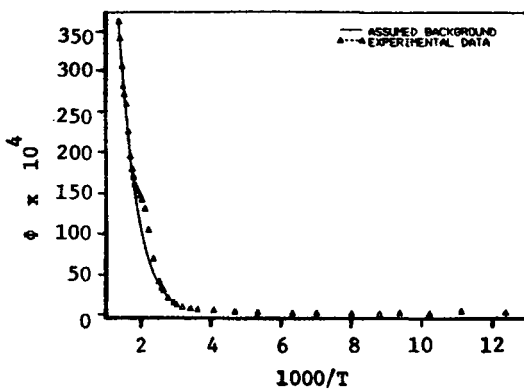


Fig. 1 - Internal friction curve for Al-Fe-Ce alloy at .8 Hz., 77 K - 700 K

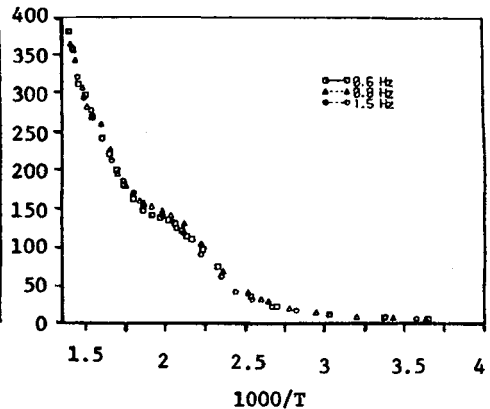


Fig. 2 - Internal friction curve for Al-Fe-Ce alloy at various frequencies, 250 K - 700 K.

RESULTS

The internal friction, ϕ , for the alloy was measured over the range 77 K to 700 K as shown in Figure 1. The background damping is very small at low temperatures, and there appears to be a very small peak at 90 K which was not investigated. The background damping increases sharply at high temperatures, and superimposed on the background damping is a peak at about 475 K. Figure 2 shows the total internal friction as measured at three different frequencies and Figure 3 which is this total internal friction minus the high temperature exponential background shows the shift in the peak with frequency. The activation energy of this peak was found to be 150 kJ/mole (36 kcal/mole) by plotting $\ln \omega$ vs. $1/T$.

Figure 4 shows the effect of annealing on the total internal friction at .8 Hz, and Figure 5 demonstrates how the net peak magnitude has changed. Note that after annealing for 10 hours at 400°C that the background damping has not changed significantly, but the peak has grown in magnitude with the possibility of a secondary peak appearing at a higher temperature. After 100 hours at 400°C, the background increased dramatically, but the 475 K peak did not change significantly. Again, however, it appears that a secondary peak has started to grow at around 560 K.

Modulus measurements as computed from the square of the measured vibration frequency are shown in Figure 6 for the sample in the original and aged conditions. The alloy decreases in stiffness with temperature in a smooth manner as shown and loses some of its elevated temperature stiffness after aging for 100 hours.

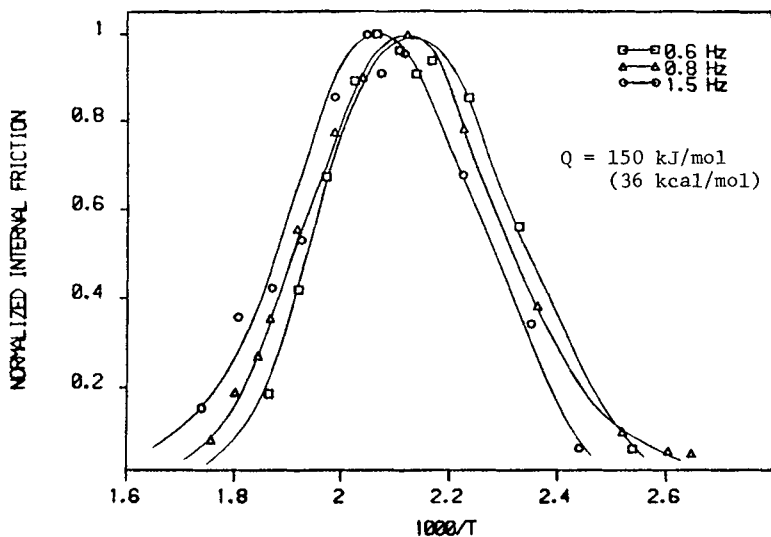


Fig. 3 - Normalized peak height vs. $1/T$ for the 475 K peak at three different frequencies.

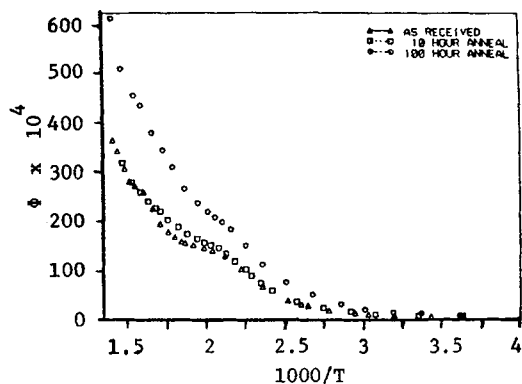


Fig. 4 - The effect of annealing on the total internal friction of the Al-Ce-Fe alloy.

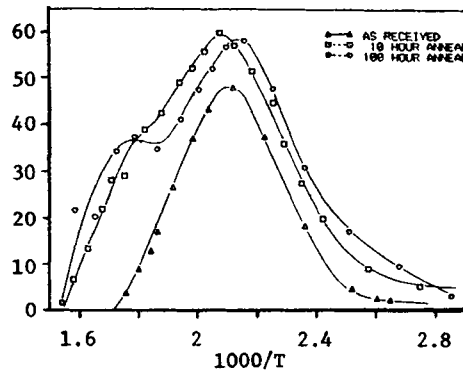


Fig. 5 - The effect of annealing on the net peak magnitude of the 475 K peak

DISCUSSION

Previous work done on pure polycrystalline aluminum at approximately the same frequency has shown that a large grain boundary peak with an activation energy of 34 kcal exists at 553 K /2/. It is thought that the 475 K peak in this investigation is also associated with grain boundary relaxation, but the peak has been lowered in temperature and greatly reduced in magnitude from that in pure aluminum. Previous work by others on the Zn-Pb /3/ and Cu - O /4/ systems has shown that similar effects can occur in grain boundary peaks when alloying elements are added. For this study, it is thought that the dispersed intermetallic compounds restrict the grain boundary sliding, thus also reducing the grain boundary damping. The good creep strength of this alloy is further evidence of such behavior.

The rise in the magnitude of the 475 K peak with annealing is attributed to the reduction of the dispersive strengthening effect as metastable and quenched-in structures form coarser equilibrium structures. This process is probably also responsible for the loss of elevated temperature rigidity with the 100 hour anneal. The growth of the secondary peak at 560 K may correspond to the pure aluminum grain boundary peak as this alloy begins to anneal to its equilibrium structure forming areas within the microstructure containing pure aluminum.

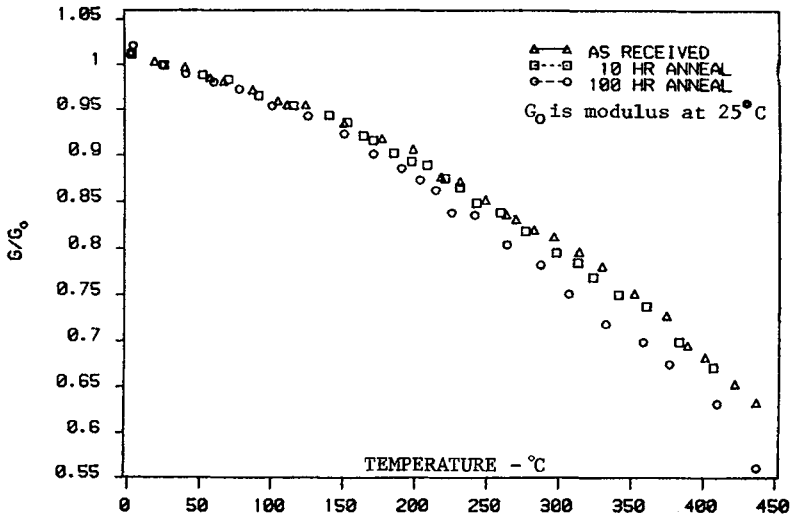


Fig. 6 - The effect of annealing on the modulus of an Al-Fe-Ce alloy.

CONCLUSIONS

The internal friction peak observed in this alloy at 475 K appears to be associated with a grain boundary relaxation phenomenon similar to that found in pure polycrystalline aluminum. The structures responsible for the dispersion strengthening in the alloy decrease the magnitude of this relaxation peak, increase the activation energy associated with it, and decrease the temperature at which the peak occurs at, as compared to pure aluminum. Aging of the alloy for 100 hours at 400°C causes the 475 K internal friction peak to increase in magnitude and a second peak which is coincident with the relaxation peak in pure Al begins to grow as well. These effects as well as the decrease in the high temperature modulus which occurs are thought to be related to the reversion of the microstructure to its equilibrium form.

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