BII-7 Grain Boundary Sliding in Zinc and Zinc-Copper Bicrystals

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This investigation was undertaken to determine what effect solute additions would have on the process of grain boundary sliding (G.B.S.). It was expected that this would help to gain an understanding of the process of G.B.S. and its relation to other forms of deformation. The investigation was performed primarily by means of creep tests on bi-crystals of both pure and alloyed zinc along with several other types of experiments.

Pure zinc was used to investigate the effect of specimen configuration on the behavior of the grain boundary. Tensile specimens with the grain boundary at 45° to the tensile axis were used. Previously[1] shear type specimens were used. The present results confirm and extend the previous findings[1] that the amount of G.B.S. after 200 hours is directly related to the maximum resolved shear stress on the active slip system. Although the grain boundary always had a higher shear stress than the slip plane there were no observations that the grain boundary slid off without slip deformation reaching it. In some cases the component crystals deformed in such a way that very little deformation reached the grain boundary and these specimens had less G.B.S. than companion specimens. Grain boundary migration in the tensile specimens assisted in clarifying the role of stress in G.B.S. in that the grain boundary must be stressed in order to slide.

An activation energy for the process of G.B.S. was computed using the equation

$$\frac{G.B.S.}{t} = A\tau e^{-\frac{Q}{RT}}$$

where G.B.S. - grain boundary sliding
T - time
Q - Activation Energy for G.B.S.
T - Abs. Temperature
τ - maximum resolved shear stress
A & R - constants

The measured activation energy for pure zinc was found to be 11.3

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Kcal/mole.

The G.B.S. experiments on the alloys showed that they behaved quite similarly to the pure zinc. It was found that the amount of G.B.S. decreased with increasing solute content if the test condition were held constant. It was also found that the stress required to cause a given amount of G.B.S. in a given time increased with solute content. There was a large increase in critical resolved shear stress with solute content at the strain rates that were used, but calculations indicate that the critical resolved shear stress of the alloy specimens should be near that of the pure zinc at strain rates approaching those used in the creep tests. The microhardness of the alloy specimens showed nearly the same percent increase with solute content as does the G.B.S.

The decrease in G.B.S. measured on the alloy specimens cannot be attributed to segregation of the solute to the grain boundary. All of the alloys were of single phase in the temperature range used. Microhardness measurements, and relative energy calculation(2), indicate that there should be no segregation. Rather, the effect of the solute is to harden the matrix there by reducing the glide rate and hence the amount of G.B.S.

Internal friction experiments were run to determine if there was a correlation between the relaxation peak due to grain boundaries and the G.B.S. measured in the bicrystalline tests. There were indications of two peaks in the internal friction experiments, one for zinc and a second for the zinc alloys as Weinig and Machlin(3) found for copper and copper alloys. This suggests that there is a separate relaxation process for the grain boundary for the alloy as measured by the internal friction method. There was no indication of a different behavior for the alloy specimens as measured in the bicrystalline tests. There was also no indication of viscous sliding of the grain boundary in the G.B.S. experiments but the model proposed for the internal friction results is based upon a viscous grain boundary concept. Therefore, there does not seem to be a correlation between the two types of experiments.

Fine grained polycrystalline specimens were tested to correlate the results of the G.B.S. experiments on bicrystals with the overall creep behavior. A correlation between the steady state creep rate of the alloy polycrystalline specimens and the amount of G.B.S. for the alloy bicrystal specimens was observed. This implies that the rate controlling process for G.B.S. in the alloys as well as in the pure zinc must involve the deformation of the component crystals. The results on pure zinc indicate that there is no increase in the activation energy for creep of polycrystalline specimens near 200°C, contrary to Tegart and Sherby's(4) findings. The activation energy was found to be dependent upon the history of the sample. The creep rates in this investigation were less than 3 x 10^{-4}in./in./hr while Tegart and Sherby

used creep rates as high as 0.5 in./in./hr.

The profiles of the G.B.S. vs position along the grain boundary measured at the completion of the tests are not regular and suggest that local variations influence the process of G.B.S. The data from the profiles do not confirm the Mullendore and Grant(5) model of slip induced sliding that predicts a variation of sliding with distance along the grain boundary.

The process of G.B.S. must be the gradual shifting of the atoms at the grain boundary; much the same as in the movement of a dislocation. The deformation of the component crystal must contribute to, as well as control the process of G.B.S. The alloying element which is in solid solution must simply strengthen the matrix and thereby influence G.B.S.

REFERENCES

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