Two Types of Grain Boundary Migration in High-Purity Aluminum

by Paul A. Beck and Philip R. Sperry

A TECHNIQUE has been recently developed¹ for studying grain-boundary migration in aluminum and for ascertaining the **direction** of the migration. Successive positions of the grain boundaries are indicated by etch markings at the specimen surface. The latest set of boundaries are identified by the difference in color between the areas on the two sides of each boundary. Each color area corresponds to a certain lattice orientation. Electrolytic etching is used to form a thin oxide layer on the specimen surface. The crystal orientation of the oxide is related to that of the aluminum grain on which it formed. The optical anisotropy of the aluminum oxide gives rise to the color effects with polarized light.

Paul A. Beck is acting head, Depart. of Metallurgy, University of Notre Dame, and Philip R. Sperry is metallographer at the University of Notre Dame. This work was supported by the office of Naval Research, U. S. Navy, Contract No: N6 ori-165, T.O. 1.

This means of studying grain boundary migration allows clear distinction between the two types of grain boundary migration occurring in high purity aluminum. Fig. 1 shows two sets of grain boundaries resulting from continued annealing at 600°C of material which is essentially strain free, having been previously annealed at that temperature. Observing the direction of migration at the specimen surface, it is noted that almost all boundaries are moving in a direction **toward their centers of curvature**. The driving force of grain boundary migration in essentially strain-free aluminum is the surface energy associated with the grain boundaries. The observed direction of movement is in conformity with that expected with this type of grain boundary migration according to the investigations of Harker and Parker,² C. S. Smith,³ and J. E. Burke.⁴

Fig. 2 shows successive grain boundary positions of migrating boundaries in a specimen of high purity aluminum annealed for four successive periods at 500°C after a rolling reduction of 7.5 pct. In this instance, where the driving force of the boundary movements is the strain energy stored in the deformed grains, the direction of the boundary migration is opposite to that required by surface energy considerations: the boundaries move **away from their centers of curvature**. The surface energy which has to be supplied in order that this type of grain boundary migration may proceed, is provided by the strain-energy gained when the deformed grains are gradually replaced by strain-free grains.

Fig. 1—In grain growth, boundary surfaces migrate toward their centers of curvature. Boundaries in high purity aluminum, after annealing 2 min. at 600°C (1), and after an additional anneal of 30 sec at 600°C (2). Magnification 75X.

Fig. 2—In recrystallization (grains C, D and E) boundary surfaces migrate away from their centers of curvature. Strain induced growth of grain A at the expense of grain B. High purity aluminum annealed 90 min at 600°C, rolled 7.5 pct [heavily outlined straight boundaries (1)], annealed successively 5 sec (2), 5 sec (3), 15 sec (4) and 7 sec (5) at 500° C. Magnification 75X.

The sharp distinction possible between the two types of grain boundary migration discussed justifies the continuation of the familiar differentiation between surface tension induced boundary migration or grain growth, and strain induced boundary migration or recrystallization. A somewhat more detailed description of the latter process is given in a recent publication.⁵

References

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