METALLURGY

Recrystallization and Grain Boundary Sliding in a Magnesium Alloy

DURING tensile deformation of magnesium and its dilute alloys in the temperature range 100°–350° C, cells form preferentially close to the grain boundaries¹. Afterwards irregular boundary migration occurs and evidence has been presented for the grain boundaries being pinned at their intersections with the cell walls². This migration results in an increase in grain boundary area and thus the driving force must arise from the difference in stored energy between neighbouring grains. It is unlikely that sliding can occur to any appreciable extent at these irregular boundaries and in these circumstances it is probable that the shearing forces in the vicinity of the grain boundaries are accommodated by increases in the degree of misorientation across the cell walls. Eventually the irregular migration leads to primary recrystallization³⁻⁶ along the old grain boundaries and an example is illustrated in Fig. 1.

Fig. 1. Specimen deformed to failure at a rate of 0.1 per cent/h at 200° C. A network of new grains has formed along the old grain boundaries ($\times c. 270$)

Stacey^{3,4} has suggested that the observed increase in tensile ductility with decreasing strain rate of a magnesium/0.8 wt. per cent aluminium alloy at 150° C is due to such primary recrystallization. On the other hand, Greenwood *et al.*⁷ and Brookes *et al.*⁸ attribute similar increases in ductility to non-basal slip systems becoming operative preferentially at the slower rates.

Primary recrystallization is *per se* a recovery process and its occurrence would relieve stress concentrations at the original grain boundaries. In addition, ductility may be improved by sliding occurring at the new grain boundaries; it was to test this latter possibility that these experiments were carried out.

A 0.06-in. thick sheet specimen of a magnesium/0.8 wt. per cent aluminium alloy was polished chemically, deliberately scratched using 6 μ diamond paste and then pulled to fracture at a rate of 0.1 per cent/h in air at 200° C. As a consequence of continuous migration and recrystallization during deformation there was no clear evidence for sliding at the new grain boundaries. Accordingly, a mixed strain-rate test was carried out. A similar specimen was polished and scratched as before and then deformed 15 per cent at a tensile rate of 18 per cent/h and a further 10 per cent at a rate of 180 per cent/h at 300° C. The initial slow deformation had resulted in a network of new grains being formed along the original grain boundaries and the subsequent rapid rate was used to minimize boundary migration during the second part of the test.

Fig. 2. Mixed strain-rate specimen deformed at 300° C. Where the fiducial lines cross the location of the old grain boundary two distinct steps are seen, for example at A ($\times c. 1,070$)

Evidence for sliding at the new grain boundaries is presented in Fig. 2. Where the fiducial lines cross the locations of the old grain boundaries they show two distinct steps, for example at A (Fig. 2). This result lends support to the suggestion that primary recrystallization leads to improved tensile ductility.

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¹ Suiter, J. W., and Wood, W. A., *J. Inst. Met.*, **81**, 181 (1952–53).

² Harris, J. E., and Partridge, P. G., *Proc. Berkeley Conf. Properties of Reactor Materials and the Effects of Radiation Damage*, 359 (Butterworths, 1962).

³ Stacey, R. D., *Metallurgia*, **58**, 125 (1958).

⁴ Stacey, R. D., *J. Inst. Met.*, **89**, 399 (1960–61).

⁵ Harris, J. E., Haddrell, V. J., and Rickards, G. K., *J. Nucl. Mat.*, **6**, 144 (1962).

⁶ Byrne, J. G., *Trans. A.S.M.*, **56**, 68 (1963).

⁷ Greenwood, J. N., Miller, D. E., and Suiter, J. W., *Acta Met.*, **2**, 250 (1954).

⁸ Brookes, P. E., Kirby, N., and Burke, W. T., *J. Inst. Met.*, **88**, 500 (1959–60).

A Method of Determining the Stress Effective during Lüders Band Propagation

In materials which exhibit a well-defined yield-point drop followed by non-uniform yielding at a nearly constant stress, this stress is given by the Petch equation¹ as:

$$\sigma_y = \sigma_t + k_y d^{-\frac{1}{2}} \quad (1)$$

where σ_y is the lower yield stress, σ_t is the friction stress, k_y is a term originally thought to be associated with an unlocking stress and $2d$ is the grain diameter. It is desirable to have an accurate value of the macroscopic stress, σ_y , in order that the slope of the lower yield stress vs. grain size curve, k_y , be as meaningful as possible. In addition, the dependence on temperature of the lower yield stress is an important property in theoretical considerations. Difficulties may arise, however, in determining what value of the lower yield stress to use in such situations. This communication describes a method which can be used to determine, at least in an approximate manner, whether the magnitude of any corrections to the nominal yield stress is sufficiently large to warrant consideration.

One source of error is that due to the change in cross-sectional area as one proceeds from the yielded to unyielded material in a specimen. The magnitude of this effect can be rather large for a small grain size² or at low temperatures³. Change in area can be taken into account by using the value of the Lüders strain to calculate the area behind