Microplasticity in ordered and disordered Mg_3Cd

The alloy Mg_3Cd has an hcp structure and is capable of showing long range order [1]. In the disordered state, the material is brittle showing only planar slip whereas in the ordered condition, multiple slip is observed leading to considerable ductility. This note reports observations of the microplasticity of this alloy in both ordered and disordered states, the system providing an opportunity of studying the effect of slip on the microstrain behaviour without a change in chemical composition.

Specimens with a gauge length of 50 mm and a diameter of 6 mm were machined from extruded rod. These were annealed at 250° C for 1 h in air, giving a grain size of 0.06 mm. Disordered material was produced by quenching from 180° C, this being above the critical temperature of 153°C. Ordering was achieved by cooling from 180°C to room temperature at a rate of 10°C h^{-1}. The specimens were chemically polished for metallographic observation using a mixture of 2 parts methyl alcohol with 1 part of concentrated nitric acid. All the specimens were stored at 0° C prior to tensile testing. Chemical analysis of the alloy showed that there was only a 3% deviation from stoichiometry, which it is felt would not significantly affect the order-disorder behaviour.

Tensile testing was carried out on ordered and disordered specimens at 0° C and the stress-strain curves are shown in Fig. 1. These curves confirm that the respective treatments gave rise to brittle and ductile materials. Microscopic observation of specimen surfaces after stressing revealed that only planar slip occurred in the disordered material all the way to fracture whereas the more ductile ordered alloy showed a profusion of cross-slip.

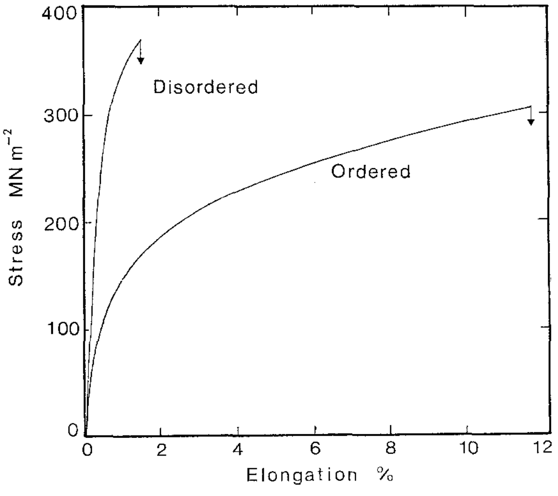

Figure 1 Stress-elongation curves to failure for ordered and disordered Mg_3Cd.

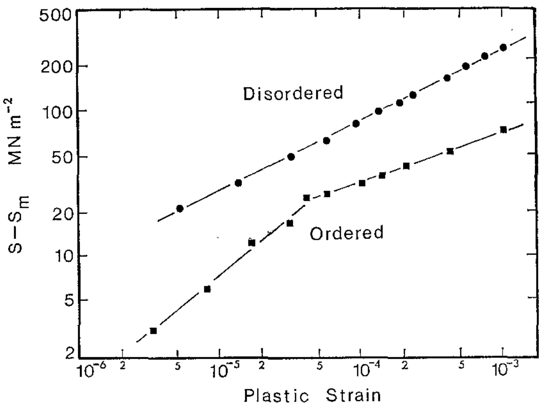

Figure 2 Log ($S - S_m$) against log (e_p) for ordered and disordered Mg_3Cd, where S is the stress, S_m the microyield stress and e_p is the plastic strain.

Microstrain measurements were made on both types of material at a strain sensitivity of 10^{-6} using metal foil strain gauges. The microyield stress (taken as the stress to produce 10^{-6} plastic strain) for the ordered alloy was 21 MN m^{-2} and that for the disordered alloy was 85 MN m^{-2}. Fig. 2 is a plot of the stress in excess of the microyield stress, $S - S_m$, against plastic strain for both the ordered and disordered materials. It can be seen that whereas the disordered alloy shows a single straight line over the strain range from 10^{-5} to 10^{-3} plastic strain, the ordered alloy shows two straight line portions with a discontinuity at about 5×10^{-5} plastic strain. Assuming that the materials in the microstrain region obey a relationship of the form $(S - S_m) = k(e_p)^n$, where S is the stress, S_m the microyield stress, e_p is the plastic strain and k and n are constants; the values of the constants were obtained from the plots in Fig. 2. For the disordered alloy, the k value was 4.1×10^3 MN m^{-2} and the n value was 0.49. The corresponding values for the ordered alloy were 7.6×10^4 and 0.80 for the first part of the plot and 5.7×10^2 and 0.32 for the second part.

In general, for ordering systems, Young's modulus increases with the degree of order but in most cases the effect is only 3 to 10% [1]. This means that changes in the mechanical properties with ordering can be ascribed to changes in slip behaviour between ordered and disordered states.

The results agree in principle with those obtained by the authors in a study of the microplasticity of magnesium-lithium alloys [2]. It was found that an alloy with an hcp structure, in which the slip was planar, behaved in a way very similar to the disordered alloy in this experiment (which again showed only planar slip) in that a plot such as shown in Fig. 2 was a single straight line. In contrast, an alloy with a bcc structure, showing a large amount of multiple slip behaved in a way similar to the ordered material in this experiment (which showed profuse cross-slip) in that the plot in Fig. 2 showed two straight line regions with a sharp discontinuity.

In experiments on beryllium, Bonfield and Li [3] found a two stage behaviour in the stress-strain curve in the microstrain region. By means of electron microscopy studies they concluded that the transition coincided with appearance of multiple slip in the material. The experiments conducted here lend considerable support to the findings of Bonfield and Li and indicate that the microstrain behaviour of materials depends to a large extent on the number of slip systems which can operate.

References

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R. E. LEE
Department of Metallurgy
and Materials Science,
University of Nottingham

W. J. D. JONES
Department of Mechanical Engineering,
University College London

Cyclic stress-induced grain-boundary migration in polycrystalline zinc

During the course of fatigue tests on polycrystalline zinc at room temperature, it was found that considerable grain-boundary migration often occurred, and some tests were carried out to observe this effect more closely.

Polycrystalline zinc, 99.95% pure, with a grain size after annealing of 0.15 mm was subjected to rotating bending fatigue at 3000 Hz. The surface of a specimen examined after 3.8×10^6 cycles (10% of the expected life at 35 MN m^{-2}, and occupying 17 h) showed a marked degree of grain-boundary migration. Almost every boundary had moved, the largest movement being 0.04 mm. The migrated boundaries were very irregular in appearance, often with microcracks running along the new boundary. A typical example of this is shown in Fig. 1. The migration led to a new network of boundaries giving a larger overall grain size, with many small grains being annihilated. Fig. 2 is a histogram of the angular distribution of the orientations of the migrated boundaries with respect to the principal stress axis, and shows clearly a peak in the region of 45°. This indicates that the stress cycling leads to a re-orientation of the grain boundaries to positions parallel to the planes of maximum shear in the specimen.

The surface regions through which the boundaries migrated were often marked by pitting of the type shown in Fig. 3, where pits formed rows behind the advancing boundary. A smaller proportion of grains showed pitting of a more random nature. Fine slip lines were seen in a

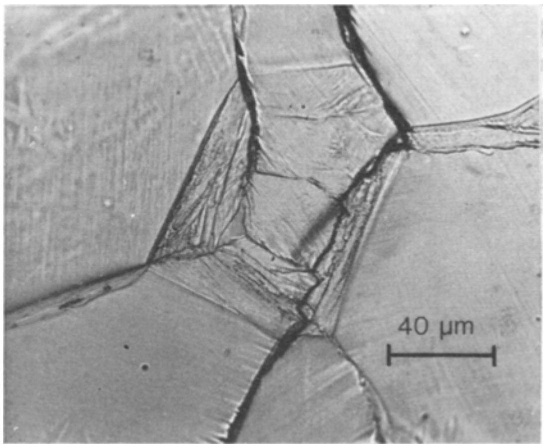

Figure 1 A typical example of the damage produced in polycrystalline zinc after cycling for 17 h at a low stress.