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The precipitation behaviour in a thermomechanically treated Al–Zn–Mg alloy

Much work has been done on thermomechanical treatments that involve the combination of plastic deformation and precipitation in aluminium alloys [1–6]. Usually, prior working of the alloy after a solution treatment and quenching operation, was followed by a heat treatment and ageing process. The resultant microstructural changes cannot be considered simply as a dislocation rearrangement plus precipitation. The interaction between lattice defects and the decomposition of the solid solution is characterized by a complex effect. A supersaturated solid solution will, in general, decompose during the ageing process by a multistage reaction path to give a number of intermediate transformation products before the equilibrium phases are established. Vacancies are always an important factor, which together with solute mobility, affect the transformation procedure. In alloys which are plastically deformed, even though new vacancies can be introduced by dislocation interaction, most vacancies can easily migrate to defects such as dislocation cell walls, boundaries and individual dislocations. Thus rapid nucleation and growth of precipitates are always observed on these defects [2, 4]. Holl [1, 2] studied the precipitation phenomenon during the ageing process, in connection with the existence of subgrains in an Al–Zn–Mg alloy. His results indicated that the presence of subgrain structure, produced by 2% tensile strain plus annealing at 450° C for 2 hours, seriously inhibited the hardening at an 165° C ageing temperature. Only coarse, lath-shaped η-phase precipitates were observed at subgrain boundaries and on individual dislocations within subgrains. However, recrystallized specimens which were aged at the same temperature for the same period, produced a dense distribution of fine precipitates within every grain, together with a characteristic precipitate-free zone adjacent to grain boundaries. Holl's work demonstrated the effect of subgrain structure on the precipitation, but further work is necessary to investigate the effects of cold work, annealing temperature and time, since the subgrain formation is directly affected by pre-strain and annealing.

In this letter, an investigation of the precipitation process in an Al–Zn–Mg alloy, for various ageing times at 165° C, is reported. The chemical composition of the Al–Zn–Mg alloy chosen for this experiment is as given in Table I.

Samples in the fully annealed condition were first treated with solution at 465° C followed by water quenching to room temperature and cold rolling to a 50% reduction of area. Subgrains were produced by an annealing process at 400° C for five minutes, and the specimens were aged at 165° C immediately after the annealing treatment. The microstructure of the aged alloy was determined by a TEM thin foil technique, for ageing times up to seven days. Precipitates were found at subgrain boundaries, and on individual dislocation lines inside the subgrains after four hours ageing, as shown in Fig. 1. Most of the precipitates grew to a lath-shaped η-phase ($MgZn_2$). At this stage, no homogeneously distributed small precipitates were

TABLE I

Element	Zn	Mg	Mn	Fe	Si	Cu	Ti	Zr
wt%	4.20	1.55	0.30	0.28	0.14	0.07	0.04	0.13

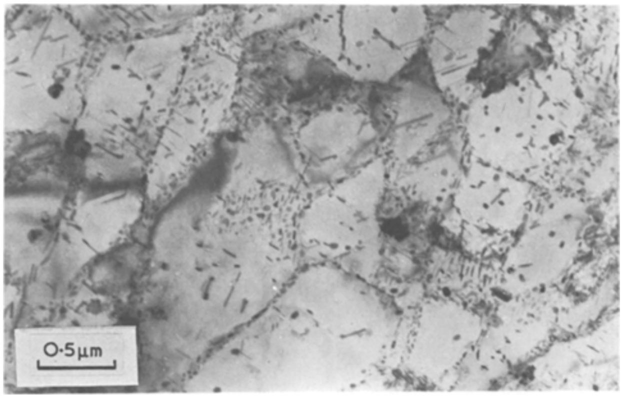

Figure 1 η-precipitates on sub-boundaries and on individual dislocations within subgrains. The specimen was solution-treated at 465° C, water-quenched, then cold rolled to a 50% reduction in area and annealed at 400° C for 5 min, followed by water quenching and then ageing immediately at 165° C for 4 h.

observed within the subgrains. With ageing times of eight hours or longer, most of the subgrains inside the material disappeared and a very dense, homogeneously distributed precipitate was found as shown in Fig. 2, although it is clear that a small fraction of subgrains still existed after ageing for eight hours.

Preliminary interpretations of the influence of subgrains on precipitation behaviour in Al–Zn–Mg alloys have been given in earlier papers [1, 2]. The precipitates were formed due to the nucleation of solute clusters that were affected by the concentration of vacancies quenched-in after the solution treatment. The sub-boundaries serve vacancy sinks, such that the concentration of vacancies inside the subgrains is reduced and the solute mobility inside [7, 8] the subgrains is also reduced. It is known that a lower annealing temperature and short annealing time always correlates with higher concentration of vacancies left behind inside the subgrains. This indicates that although a dense, homogeneously distributed precipitate was not found in Holl's work, they do appear with longer ageing periods inside the subgrains as shown in Fig. 2. The subgrains disappear as the ageing process proceeds and vacancies become uniformly distributed within the grain, with consequent uniform precipitation.

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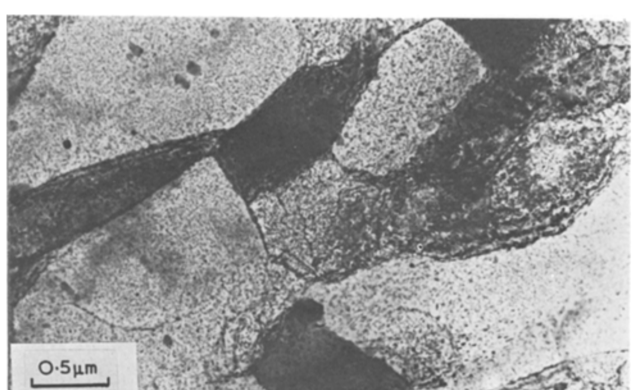

Figure 2 Almost uniformly distributed precipitates within subgrains. The specimen was solution-treated at 465° C, water-quenched, then cold rolled to a 50% reduction in area and annealed at 400° C for 5 min, followed by water quenching and ageing immediately at 165° C for 8 h.