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PRECIPITATION AND RECRYSTALLIZATION IN Al Mn ALLOYS

C. Diallo, M. Mondino and W. Benoit

Institut de génie atomique, Swiss Federal Institute of Technology, Écouless, CH-1015 Lausanne, Switzerland

Abstract.- Low frequency internal friction has been used to study precipitation and recrystallization in Al Mn alloys. It is found that the first stages of precipitation are characterized by an increase of the I.F. background and that the presence of precipitates gives rise to a relaxation peak located at 440K. Recrystallization is characterized by a rapid decrease of the I.F. background with a strong diminution in dislocation density. Observations performed after different thermomechanical treatments allow to conclude about the characteristics of the interaction between both phenomena.

1. Introduction.- The recrystallization kinetics and therefore the recrystallized structure of aluminium alloys containing a dispersion of a second phase is sensitive to several parameters. Doherty and Martin (1,2) and Mould and Cotterill (3) studied the case of particles formed before deformation and stable during the annealing treatments leading to recrystallization. On the other hand, Hornbogen (4) and Küster (5) considered the decomposition of the solid solution during recrystallization leading to a dynamic situation where recrystallization conditions can be strongly influenced by the precipitation.

Because its sensitivity to dislocations pattern evolution, to the formation and presence of precipitates the I.F. can become a useful tool to the analysis of such phenomena. In the present case the I.F. will be used to study the interaction between precipitation and recrystallization. It has to be pointed out that the precipitates existing in the alloy before deformation as well as the evolution of the solid solution after deformation are important parameters for the recrystallization.

2. Results and Discussion.- Both binary (Al 1% and 2% Mn) and commercial (Al 1,0% Mn .5% Fe) alloys have been used. In figure 1 a and b the I.F. of commercial alloys after 90% cold rolling is shown.

Two stages characterize the I.F. evolution. The first one is seen in fig.1a and corresponds to the increase of the I.F. background which may be accompanied by the appearance of a relaxation peak masked in this figure by the high I.F. background. The second one is the strong diminution of the I.F. background after the annealing at 650K. Figure 1b clearly shows this stage. Above 600K the I.F. rapidly decreases. This second stage of the I.F. evolution is accompanied by a character-
lSoChmMl treatments o after 10' at 473K v- - 553K x- - 650K

Fig. 1a

Fig. 1: I.F. and Frequency spectra of 90% cold-rolled samples of commercial alloy 1a) resulting from isochronal treatments
1b) during direct heating up to 650K (curves a and a') and during cooling after 1 hr annealing at 650K (curves b and b')

Fig. 1b

istic behaviour of the frequency (curve a', fig.1b).

The first stage has been interpreted [6] as due to the unpinning of dislocations by Mn atoms leaving the solid solution to form precipitates. Confirmation of this is obtained from the behaviour of undeformed direct-chill-cast binary alloy (fig. 2).

Fig. 2: I.F. and frequency of undeformed sample of direct-chill-cast binary alloy (Al 2% Mn) resulting from isochronal treatments.
curve a): after 30 mm annealing at 473K
curve b): after 30 mm annealing at 523K
curve c): after 30 mm annealing at 770K

Since in this case there is no recrystallization, only precipitation occurs, the increase of the background and the onset of the peak observed after 30 mm annealing at 523K are due respectively to this precipitation and to the presence of precipitates in the alloy. According to Hausch et al [7], after this treatment,
the G1 metastable precipitates are present. Annealing at higher temperature, 770K, leads to the disappearing of the peak connected with the transformation of G1 phase into the stable precipitates Al6Mn (7).

For the analysis of the second stage observed in the evolution of the I.F. background (I.F.B.), one has to recall that I.F.B.(A: dislocations density and \( \lambda \) = dislocations loop length). Since the loops length are very sensitive to precipitation, the dislocations density A is essentially affected by the recrystallization. The second stage is then explained by the decrease of A when recrystallization takes place. Optical microscopy observations show that after the diminution of background recrystallization has occurred (8).

The I.F. spectrum of a binary alloy after 90% deformation presents (fig.3) the same type of behaviour as the commercial alloys: i.e. the G1 precipitation precedes the recrystallization.

\[ \text{I.F. spectrum}\]

Fig. 3: I.F. and Frequency spectrum of 90% deformed sample of binary alloy.

3. Effect of iron in recrystallization. It is known (7) that in AlMn alloys the presence of Fe reduces the Mn solubility and therefore accelerates the precipitation.

In order to precise the influence of precipitation on the recrystallization in the frame of the present work, two Al alloys, containing 1% Mn .5% Fe and .8% Mn, .03% Fe respectively, were prepared. The cast material was 60% cold-rolled, annealed 16 hrs at 823K and again 90% deformed. The I.F. results are presented in figure 4.

The sample with the higher Fe content shows a more rapid increase of background and a lower recrystallization temperature. This means that the acceleration of the precipitation by the presence of Fe leads to the formation of a larger volume fraction of precipitates with a consequent reduction of Mn on the dislocations and therefore an increase of the dislocation mobility.

From this one concludes that Mn atoms in solid solution have a retarding effect on the recrystallization or/and the precipitates, existing in the alloy before deformation, are favourable sites for the nucleation of recrystallization.
Confirmation of these two points is given by the behaviour of different samples of commercial alloys annealed for 16 hrs at 723K, 823K, 888K and 913K and then cold-rolled by 90%. In this way one can vary the Mn content in solid solution; for instance in the sample treated at 913K most of the Mn is in solid solution, while in the one treated at 723K most of the Mn has already formed the precipitates of \( \text{G}_1 \) phase, the other two samples correspond to intermediate states.

The temperature of the rapid diminution of I.F., which has been associated with the recrystallisation temperature, is presented in figure 5 for the different annealing temperatures before deformation.

The changes in the recrystallization temperature confirm then the stabilization of the cold-worked structure by the Mn atoms in solid solution or/and the efficiency of preexisting precipitates for the nucleation of recrystallization.

This observation has important consequences for the obtaining of an optimal grain size, in particular a small grain size should be obtained in a material containing precipitates before deformation to enhance the nucleation of recrystallization and Mn atoms in solid solution to avoid the growth of the new grains.
4. Conclusion.- The present results show that I.F. can become an important tool for the study of precipitation (characterized by an increase of the I.F. background and the appearance of a relaxation peak) and recrystallization (characterized by a rapid decrease of the I.F. background).

The observations on samples with different thermomechanical history allow to conclude that:

i) The first stages of precipitation always precede the recrystallization.

ii) The presence of precipitates before deformation accelerates the recrystallization i.e. highly distorted regions around precipitates are effective sites for nucleation of recrystallization.

iii) Mn atoms in solid solution retard the recrystallization, i.e. they are efficient pinners on the subboundaries.

iv) To obtain a given grain size the ratio between the volume fraction of precipitates and the Mn in solid solution must be carefully controlled.

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