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To cite this version:
S. Kiss, F. Kedves, I. Harangozó. GRAIN BOUNDARY AND PRECIPITATION EFFECTS IN DIFFERENT AlMn ALLOYS. Journal de Physique Colloques, 1981, 42 (C5), pp.C5-963-C5-968. <10.1051/jphyscol:19815149>. <jpa-00221021>

HAL Id: jpa-00221021
https://hal.archives-ouvertes.fr/jpa-00221021
Submitted on 1 Jan 1981

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GRAIN BOUNDARY AND PRECIPITATION EFFECTS IN DIFFERENT AlMn ALLOYS

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Abstract.- Internal friction and dynamic elastic modulus investigations completed by optical microscopy and microhardness measurements were made on cold drawn and recrystallized AlMn alloys with 0.03 – 1.1 wt%Mn content. Primary and secondary recrystallization caused pseudopeaks on the spectra of the as drawn samples. Primary recrystallization was indicated by a sudden decrease in microhardness too and a well detectable grain growth was obtained due to secondary recrystallization. Both recrystallization temperatures increase significantly with the Mn content. The strength of the grain boundary relaxation decreases rapidly with the Mn concentration for the small and large grained samples as well. For higher Mn contents the peak shifted to higher temperatures. Investigating the effect of different precipitation heat treatments we found that the temperature of the occurring relaxation peak was lower for the less stable precipitates formed at lower temperatures.

1. Experiment.- Inverted torsional pendulum working from room temperature up to 650°C in the 0.2 – 2 Hz frequency range was used for the anelastic measurements. The amplitude of deformation was less than 5 x 10^{-5} for the 70 mm long and 0.8 mm thick wires. The grain sizes of the samples were determined after electropolishing and electrolytic etching in perchloric acid ethyl alcohol 1:5 solution. The measurement of grain sizes and microhardness was made using a metallic microscope Neophot-12.

2. Results and discussion

2.1. Recrystallization.- The background of the internal friction \( \text{i.f.} \) is determined by the grain size and dislocation structure of the sample which have been produced by the previous cold work and heat treatment. So the measurement of the \( \text{i.f.} \) can prove as a good tool for following the recrystallization. The recrystallization of AlMn alloys was already investigated and the appearance of the pseu-
dopeak on the spectra caused by recrystallization is also known [1]. The aim of our measurements on as-drawn samples was to collect further data on the recrystallization and the nature of pseudopeaks in AlMn alloys.

Measuring the i.f. spectra of the as drawn specimen with different Mn content $c_{\text{Mn}}$ at heating rates of 100-120 deg./hr. two asymmetric narrow peaks were found, and the peak temperature increased with $c_{\text{Mn}}$ /Fig. 1/. The dynamic modulus /d.m./ determined parallel with the i.f. increased rapidly within the range of abrupt decrease of i.f. /Fig. 2/. The first d.m. increases were extremely high, up to about 50%, for samples having been deformed heavily. These decreases of i.f. and anomalous increases of d.m. can be attributed to recrystallization. Optical microscopic determination of grain sizes supported this assumption. A couple of samples were heated with heating rates applied in i.f. measurements and samples were taken out of
the furnace each 10-20°C, quenched and the grain size measured. It was found that elongated small grains /several µm/ appeared near the temperature of the first peak and grains of about several tenth of mm appeared at about the second peak. The microhardness decreased significantly /up to 30-50%/ within the narrow /20-30°C/ temperature range of primary recrystallization [2].

The primary and secondary recrystallization temperatures \( T_{pr} \) and \( T_{sr} \) respectively/ determined through measuring the i.f. spectra for dilute alloys increased rapidly up to \( c_{Mn} = 0.2 \) wt% and changed more slowly above it /Fig. 3/. The whole shift in \( T_{pr} \) was 250°C and in \( T_{sr} 150°C. \)

**Fig. 3:** Concentration dependence of the temperature of primary /\( P/\) and secondary /\( S/\) recrystallization.

In order to find out the origin of the two peaks measurements were made on recrystallized samples too. It was found that the i.f. was always much smaller and the earlier peaks did not appear. They are probably caused by the sudden decrease of the background /decrease of dislocation density/. This statement is supported by measurements made at different frequencies /\( f = 0.5, 1.5 \) and 200 cps/ in which the peak heights decreased with increasing frequencies but the peak temperatures did not shift.

It was also found that the peak heights are lower for lower

**Fig. 4:** Effect of the heating in steps on the damping of Al-0.3 wt% Mn.
heating rates. This shows that the part of the damping measured at the peaks was a time dependent contribution during recrystallization. In order to find the origin of this behaviour heat treatment in steps were made /Fig. 4/. A rapid isothermal decrease of the i.f. was found in the recrystallization range supporting the above assumption.

2.2. Grain boundary relaxation.- The effect of Mn atoms on the GB migration can also be studied by measuring the strength of the GB relaxation on fine grained /nonrecrystallized/ and coarse grained samples with different c_{Mn}. For fine grained samples at low concentrations the evaluation is disturbed by the fact that the first pseudo peak overlaps the GB peak appearing at about 260°C for f = 0.5 Hz /see Fig. 1, curve for c_{Mn} = 0.2 wt%/ The peak height depends strongly on the previous degree of deformation, e.g. for 0.1 wt%Mn i.f. data between 500 to 2000 x 10^{-4} were obtained at the first peak but they reproduced well for identical previous history. The evaluation of results can be made easily for coarse grained /0.1 - 0.5 mm/ samples, the peaks are much lower /230 x 10^{-4} for 0.1 wt%Mn/ and are shifted 20-30°C higher /Fig. 5/. In both cases the peak heights decrease rapidly with increasing c_{Mn}. The GB migration for c_{Mn} = 1 wt% is hindered so very low relaxation peak can only appear and at the solubility limit no GB relaxation occurs. It must be noted that in cases of higher dissolved concentrations high temperature GB peak was not found above the original GB peak.

![Grain boundary relaxation peaks of coarse grained samples](image)

2.3. Effect of precipitations.- Theoretical results [3] and experimental study of other systems /AlCu/ [4] suggest that i.f. peak can only be expected in presence of precipitates with semicoherent phase boundaries. This statement is valid for several agehardenable alloys therefore it seemed to be interesting test the AlMn system too. The i.f. measurements were made on Al-1.1 wt%Mn samples homogeni-
zzed at 630°C for 2 hr and then precipitated at different temperatures. The homogenized sample showed a 25 x 10^{-4} high, wide GB peak at about 300°C at 0.5 Hz. After precipitating at 200°C when fitting to the matrix good enough precipitates are probably formed GB peak did not appear but a fairly wide and lower peak was found around 170°C /Fig. 6/. It was striking that after precipitation at higher temperatures a similar peak was found but much nearer to the original GB peak /Fig. 7/. It is known that at 400 and 500°C metastable G phase /Al_12Mn/ can be expected with semicoherent or incoherent interfaces and at 550°C and higher stable incoherent Al_6Mn phase occurs [2,5,6].

Discussing the results starting from the highest temperature of precipitation and going to lower temperatures the position of the peak suggests as if the original GB peak would be shifted towards lower temperatures. This should mean that the peak is caused in every case by relaxation of interfaces, but the boundaries of precipitates play now the role of GB-s. The better the fitting of precipitates in the host matrix the lower the peak temperature since relaxation takes place easier.
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