NEUTRON IRRADIATION EFFECTS ON ANELASTIC AND MECHANICAL PROPERTIES IN Al-Mg-Si ALLOYS

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1. Introduction

Among the structural materials that could be selected for the first wall in fusion reactors, those based on Al-Mg-Si systems have received special attention.

In these alloys, microstructure and mechanical properties are known to change during irradiation. In experiments where service conditions are imposed to these materials, heavy irradiation doses lead to important drops in strength and ductility that could be correlated with electron microscopy observations showing drastic changes in microstructure[1]. These complex changes result from many processes induced by different components of the irradiation.

Under neutron irradiation, even at low and medium doses, changes in mechanical behaviour are still observable but those operated in microstructure are not easy to determine.

In the present work, the effect of small doses of neutron irradiation on mechanical behaviour is correlated with changes found in the internal friction spectrum of ther alloy after irradiation. As the mechanisms contributing to this spectrum have been previously investigated, these results are applied to evaluate microstructural changes due to neutron irradiation.

2. Experimental

The two alloys used were provided by ALUAR S.A. and their compositions are listed in Table 1. They differ not only in the amount of Si in excess but also in the nature of predominant precipitates on grain boundary. Samples M1 are hot extruded at a higher temperature so that the less soluble element, silicon in this case, precipitates on grain boundaries preferently; in samples M2, on the other hand, β-Mg_2Si particles predominate. Inside the grains, M1 has a lower Si content than M2, an effect due to a lower Si excess. In both cases the hardening phase β'' needles is finely dispersed in the matrix.

Internal friction measurements were carried out at low frequency (~2hz) and at a maximum deformation amplitude of about 2.7×10^{-4}. Tensil tests were made in an INSTRON 1123 machine, operated at room temperature and with cross head speed of 0.5 cm/min.

A neutron source was constructed bombarding a Pb target with 23 MeV electrons provided by the LINAC CAB-CNEA. Two increasing doses were achieved by irradiating at room temperature for 13hs (N1) and 44.5 hs (N2).

Internal Friction

The internal friction spectrum of these alloys shows a broad peak at about 480K (1hz). This internal friction peak has at least three components that can be detected as local maxima in the function $G(T) = \frac{dM}{dT}$, where M is the sample torsion modulus. These two higher components P_2 and P_3 were associated to mechanisms arising in β' precipitates and grain boundaries respectively.[2]

TABLE I

wt% →	Mg_2Si	Si exc.	Fe	Ti	T extrusion (K)
M1	0.85	0.05	0.17	0.17	740
M2	0.89	0.19	0.17	0.17	690

The grain boundary component P_3 decreases in height when β particles grow in the boundary but the effect of Si precipitates is opposite; peak height increases and shifts to lower temperatures.

The precipitate component P_2 depends on mobile dislocation density and on the mean dislocation loop length between β' rods. This component increases when the microstructure changes from the aged β'' precipitates to the overaged β' rods and when these particles coarsen.

Results and Discussion

Figure 1a shows the internal friction and frequency in samples M1 as a function of temperature and figure 1.b. the associated function G(T). In both cases, the states AR and after doses N1 and N2 are indicated. As can be seen from G(T), the effect of increasing doses is to decrease P_3 component and increase P_2 contribution.

Figure 2a and b shows the internal friction, frequency and function G(T) for samples M2 measured in identical conditions as in figure 1. For dose N1, both components behave as in M1, but for dose N2 contribution P_3 increases in magnitude and also shifts to lower temperature. Contribution P_2 behaviour is difficult to determine but it seems to remain almost unchanged.

Figure 3 shows the effect of dose N2 on the curve stress-strain for samples M1(a) and M2(b). In samples with Si on grain boundaries (M1) low doses increase their resistence to fracture, but in samples where β is predominant irradiation reduces ductility.

The relationship between P_3 peak height and ultimate tensile strain in non irradiated samples is shown in figure 4. Full symbols indicate high temperature extruded samples, while open symbols lower extrusion temperature. Different symbols are used for the two compositions investigated. Data corresponding to N2 doses are also included.

Internal friction results concerning P_3 suggest that the effect of low dose neutron irradiation on sample M1 is to enhance the precipitation sequence $Si \rightarrow \beta$ on grain boundaries. In the case of M2, the lower dose has the same effect on P_3 but dose N2 is now enough to induce nucleation of new Si particles.

The effect of irradiation on P_2 is less evident. It seems to grow for increasing doses in M1 and remain unchanged in M2 but careful investigation is necessary in macrocrystals to avoid P_2 contribution.

As the main effect of β particles in grain boundaries is on P_3 peak and that of Si particles is on ductility, the processes above described would lead to larger changes in ductility for small changes in peak height in sample M2 but larger changes in peak height with small variations in ductility in sample M1.

This behaviour is observable in fig. 4.

It is worth noticing that the abrupt softening exhibited by irradiated samples after the debut of plasticity is a repetitive effect that can not be

M1

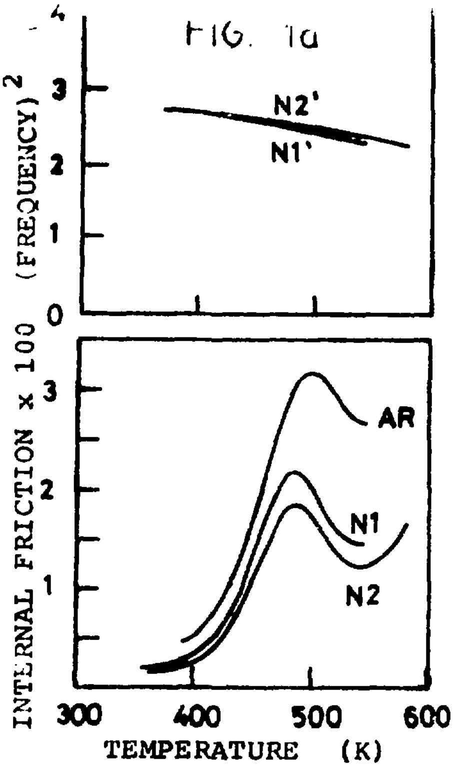
FIG. 1a

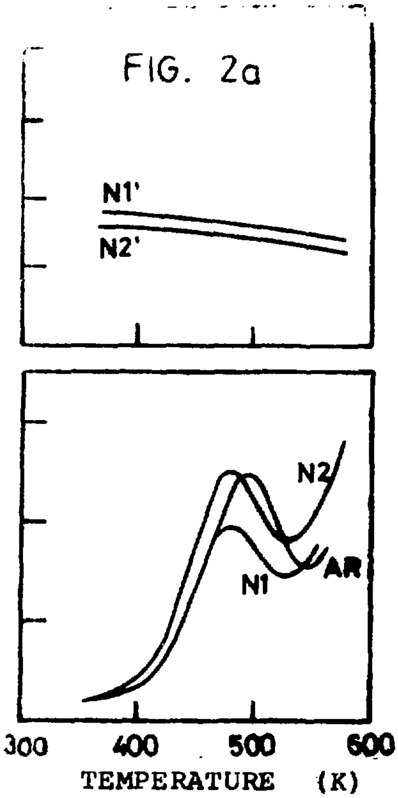
FIG. 2a

M2

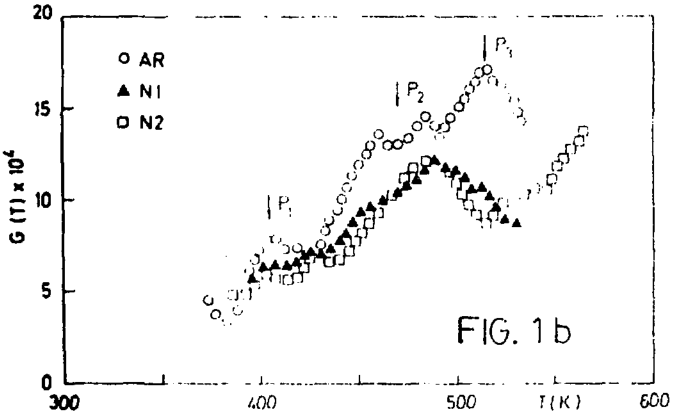
FIG. 1b

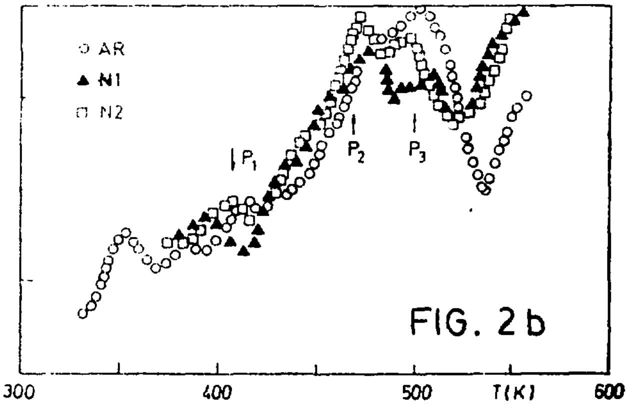
FIG. 2b

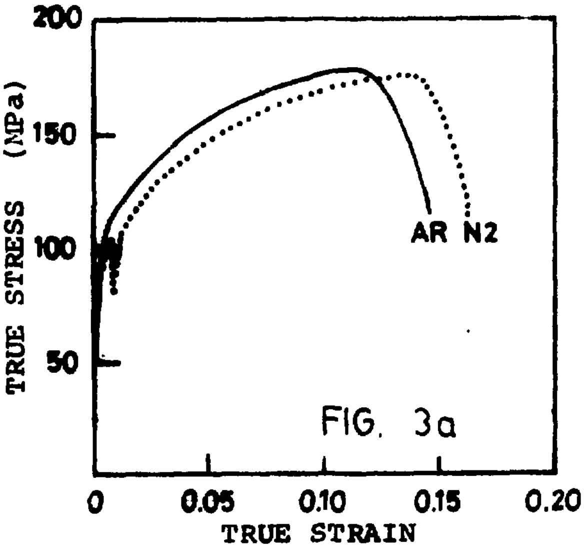
FIG. 3a

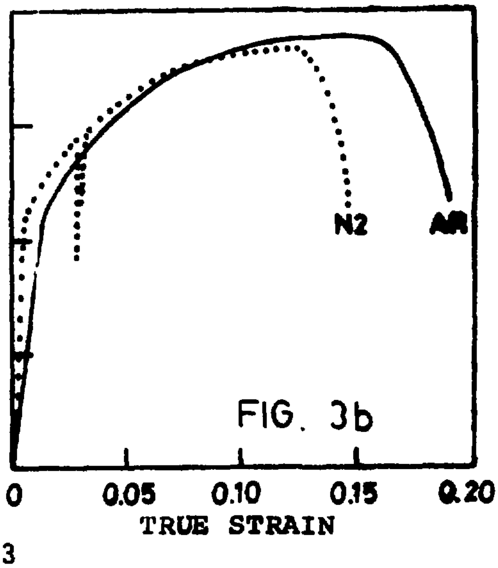
FIG. 3b

attributed to samples displacement during the test; microscopic examination of the grip zone showed no traces of such displacement.

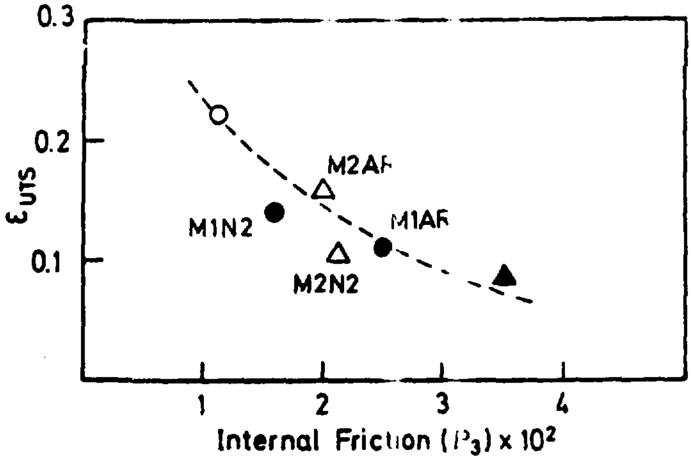

Figure 4: full symbols correspond to T extrusion = 740 K; open symbols, to T extrusion = 690K; o corresponds to 0.05%Si in excess and Δ to 0.19%Si excess.

Conclusion

The internal friction spectrum in this alloy is sensitive to microstructural changes induced by low doses of neutron irradiation.

Mechanical properties degradation seems connected with coarsening of hardening microstructure and enhanced silicon precipitation on grain boundaries.

References

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2. Urreta de Pereyra, S.E., Bertorello, M., and Ghilarducci de Salva, A.A., Phys. Stat. Sol. (a) 108, 577 (1988).