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DISLOCATION CONTRIBUTION TO THE DAMPING PHENOMENA ACCOMPANYING RECRYSTALLIZATION IN Al

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Résumé - On a suivi les premières étages de la recristallisation de lames minces d' aluminium par observations de frottement intérieur,module élastique, metallographie et X.R.D.. Les résultats sont interpreté en termes d'émission des dislocations par les joints de grains,associé a la nucleation.

Abstract - The initial recrystallization stages of cold rolled Al sheets have been followed by internal friction,elastic modulus,metallographic and X-ray diffraction observations.The results are interpreted in terms of dislocation emission from the grain boundaries,connected with nucleation.

I -INTRODUCTION

Many authors/1/ have observed Q^{-1} maxima accompanying recrystallization. Different behaviours of the modulus have been observed in correspondence of the Q^{-1} maxima, either a drop or a minimum. In general the various results have been related to dislocations;in particular Isoré et al./2/ refer the increase of internal friction to a high mobility degree of the dislocations in the freshly recrystallized domains, behind the migrating grain boundary.

Questions remain open,in particular on the contribution of nucleation to these relaxation phenomena. Hence internal friction and dynamic modulus measurements have been made by us during the recrystallization of cold rolled Al sheets,togheter with metallographic observations and analyses of the X-ray diffraction line profiles, in particular in the initial recrystallization stages. The results are discussed also with reference to the possibility of grain boundary sliding contributions,given that in experiments with increasing temperature the recrystallization peaks present correspondence with the so called grain boundary peaks/3/.

II - EXPERIMENTAL

Observations and measurements were carried out on sheets of Al 99.9%,obtained by cold rolling with 90% reduction.

Internal friction and elastic modulus were measured directly during different isotherms,in vacuum. The vibrations were flexural,vibration frequencies ca. 500 Hz, amplitudes < 10^{-6}. The elastic modulus was derived from the resonance frequencies. Errors reported in the results are inclusive of the scatter between subsequent measurements. The metallographic observations and the X-ray diffraction analyses were made not directly,during isothermal heating,but on different samples of the same material,each heated for given times and then cooled for examinations.
Fourier analyses of the diffraction line profiles were made with the Warren-Averbach

[(1)] Gruppo Nazionale di Struttura della Materia method on some specimens before the thermal treatments.

III - RESULTS

Isothermal behaviour of Q^{-1} and dynamic modulus Gd (expressed by the ratio over Go, modulus before heating) are considered first. As shown in fig.1 two pronounced peaks, P1 and P2,maxima of Q^{-1} vs time appear. The ratio between the heigths of P1 and P2 decreases by increasing temperature. At all temperatures a relatively small peak,P0, is appreciable,preceding peak P1. The dynamical modulus presents in general relevant progressive decreases at the lower times before the peak P1,with some changes in trend referable to P0; after this initial trend a saturation level is reached with shallow minima in correspondence of peaks P1 and P2;measurements errors of Gd were particulary high in the range corresponding to the maxima of such peaks,as due to instabilities during the measurements. The continous line diagram in fig.1 represents the corresponding recrystallization behaviour;two stages are distinguished :in the first one,left of the arrow,the increase in average grain dimensions is mainly due to the increases of the zones where recrystallization is evident;in the recrystallized zones the grain sizes remained approximately constant during this stage. In the second stage the grains present uniform increases. Peak P1 covers the whole first recrystallization stage whereas peak P2 appears at the beginning of the second stage of recrystallization. In fig. 2 the logarithms of time vs inverse temperature are reported for all the peaks examined; apparent activation energies,derived from the average slopes are indicated in the figure; the apparent energy is higher for P0 (=0.5 eV);for the other peaks the energies are lower =0.3,0.2 eV.

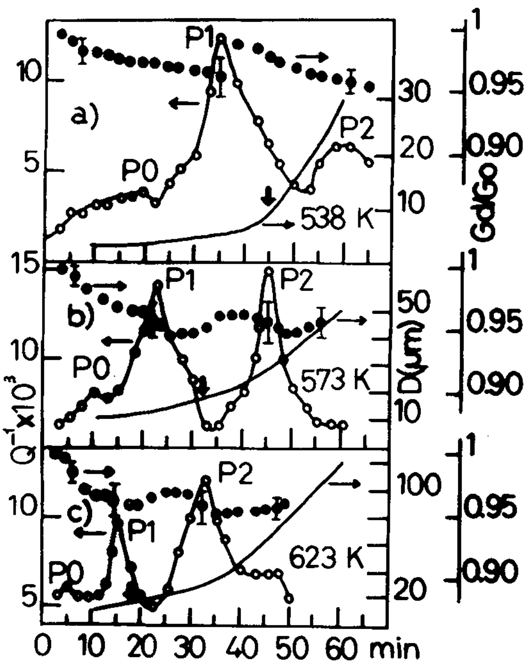
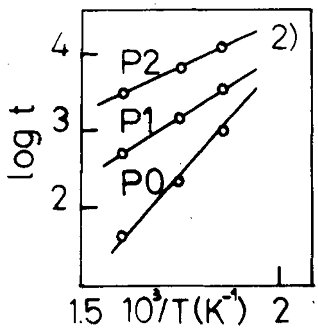


Fig. 1a-b-c) - Internal friction coefficient (-o-), dynamic modulus Gd (in the fraction over initial modulus Go) (●●●), and average grain dimension, D (——) during isothermal heating, at the temperatures indicated, of cold rolled Al sheets.

With particular attention to dislocation contributions X-ray diffraction line spectra have been examined on the same specimens used for the metallographic observations. Widths of the (220) lines are shown in fig.3,with the Q^{-1} behaviour reproduced for comparison.

The internal friction maxima correspond to well pronounced maxima of the line widths. Fourier analyses of the diffraction line profiles have shown that,in particular after the initial recrystallization stage,the contribution of the average quadratic strains,i.e. the contribution of the dislocations prevails over the one connected with grain or subgrain dimensions.



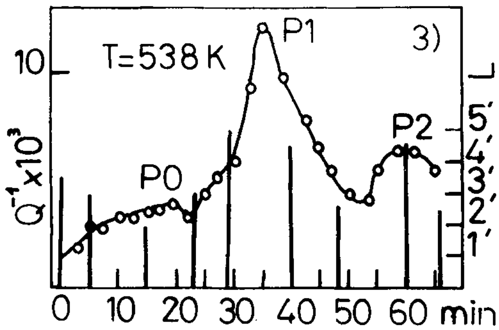


Fig.2 - Arrhenius plot of the times of peak maxima.
Fig.3 - The vertical lines represent the half heigth width of the X-ray diffraction line (220) after isothermal heating at 538 K for the times in abzissa. For comparison the corrispondent behaviour of Q^{-1} is reported(—).

Other authors have considered also isochronal recrystallization behaviour. Analogous measurements have been made also by us; in this respect reference is made to results reported in a previous paper/4/,showing the development of an internal friction peak during recrystallization by increasing temperature;for the frequencies used this peak lies in the temperature range of the peak attribuited by many authors to grain boundary sliding.

IV - DISCUSSION

The Q^{-1} increases,occurring during isothermal recrystallization,as well as those of modulus decrement,Go Gd,and of diffraction line width,L,are all consistent with dislocation damping,due either to dislocations already present and passing to relaxed conditions because of increases of the free lengths of vibration,or to new dislocations,as might be dislocations emitted from the grain boundaries.
Recrystallized grains are in general considered free from dislocations as well as from polygonization walls;so the attribution of the relaxation phenomena observed to dislocations emitted from the grain boundaries seems more reliable for peak P2, which appears after fullfillment of the first recrystallization stage,when the whole volume is occupied by recrystallized grains of the first stage.
For peak P1 analogous phenomena of dislocation emission are probably involved not only from grain boundaries but also from subboundaries,polygonization walls,preliminar to the coalescence phenomena observed by many authors/5/.
Of course the Q^{-1},Go/Gd, L decreases after the maxima,can be due not only to the disappearance of the dislocations emitted but also to their grouping in dislocation walls. This introduces us to the question of nucleation,since Bollman observed nuclei in part with large angle-,in part with low angle-boundaries/5/.

In this respect it is worth recalling also the observations of many authors, indicating that new grains do not nucleate uniformely in the volume but only in preferential sites, mainly on grain boundaries and triple points /5/.

Consistently with all these observations as well as with the results discussed here it seems reasonable to assume that nucleation is connected with the emission of dislocations from grain and sub-grain boundaries.

Other indications may be drawn from the X-ray diffraction results, on the possibilities of other mechanisms. As mentioned, the recrystallization peak coming about by increasing temperature can be observed in correspondence of the so-called grain boundary peak. It might be thought thus that the recrystallization peak depends on damping phenomena connected with grain boundary sliding, with possible contributions also to modulus relaxation. However, the observed maxima of the diffraction line widths seem hardly referable to g.b. sliding; hence this possibility is neglected.

Further, equivalent contributions to internal friction and modulus relaxation can be obtained with short dislocation segments in high densities or with long dislocation segments in low densities. The increases of the X-ray diffraction line widths present evidence in favour of the first alternative, i.e. of dislocations in large densities.

The activation energies derived from the isotherms (fig. 2) are rather low. Of course they are only apparent; higher energies would be obtained by a suitable choice of the initial conditions. In this respect more valid appears the value relating to the shallow maximum P0, for which more reliable is the reference to zero time for the beginning of the processes involved, and this energy can be related to diffusion in grain boundaries.

V - ACKNOWLEDGEMENTS

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