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STUDY OF DISLOCATION MECHANISMS IN ALUMINIUM AT 0.5T_m BY ANELASTIC RELAXATION

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INTRODUCTION

The exact mechanism that controls the U₂ (1.2 eV) creep in aluminium (around 0.5T_m) is still controverted today. It has been variously attributed to the cross-slip /1/ formation of kinks on the non-compact planes such {100} /2/ or the climbing governed by the pipe-diffusion/3/.

A study was therefore undertaken to understand the basic mechanisms which control the initiation of the movement of the dislocation around 0.5T_m in the c.f.c. materials (e.g. aluminium) by the technique of internal friction using torsion pendulum. This technique permits us to separate every thermally activated anelastic relaxation and it provides the advantage of working at low stress amplitude (10⁻⁴μ). The latter advantage implies that the dislocation motion is not greater than few interatomic distances and that the microstructure is unvarying during the course of the experiments. Further, these measurements performed as a function of temperature and frequency enable us to obtain enthalpies of activation with good precision.

MODEL TESTS AND INTERNAL FRICTION BEHAVIOUR

- Cross-slip at a triple node :
If one considers a node of dislocations, two dislocations can slip on one plane {111} but the movement of the third requires a cross-slip such it moves simultaneously in two planes {111}
- Slip on {100} :
If we consider a set of 3 families of dislocations which satisfies the Frank criterium (two of the 3 families are at 60° and the third is a screw). As a consequence the screw dislocation motion is operating in a non-compact glide plane {100}. The slip can occur by creation of only one kink on the dislocation.
- Dislocation climbing :
The motion of a dislocation having a sessile jog, is governed by a self-diffusion mechanism producing an emission or an absorption of vacancies by the jog.
By considering each of the above models we can make the following prediction on the anelastic behaviour of the samples :
- The mechanisms of cross-slip and the climbing of a dislocation predict a diminution of the relaxation maximum as a function of the maximum stress amplitude as σ_m⁻² and σ_m⁻¹ respectively. On the contrary in the case of the slip on {100} this dependence does not exist.

- In the case of a model for the movement by climbing or slip on {100} of a dislocation, the application of static stress superposed on a dynamic stress amplitude should not have any effect on the internal friction spectra since the centre of oscillation is only shifted. But on the case of the cross-slip model a superposed static stress produces the cross-slip and the ulterior dislocation motion is elastic leading to the disappearance of the relaxation.
- In the case of cross-slip and slip on {100} models, we can predict an important relaxation for polygonized microstructure, for instance after creep.
- The activation parameters involved are :
ΔH (cross-slip) ≈ 0 (Orowan stress)
ΔH ({100}) ≈ U(recombination) + E_L ≈ 0.9eV
ΔH (climb) ≈ 1.1eV (pipe-diffusion)
≈ 1.4eV (self-diffusion)
The activation volumes are the same for the three models and near of 1000b³.

COMPARISON WITH EXPERIMENTAL RESULTS

We have studied the spectrum of internal friction between 0.3T_m and T_m on samples of zone refined 99.9999% (6N) and 6N aluminium doped with 10ppm of silver or copper. The deformed state provides around 0.5T_m a relaxation which we called P₁. The study of the evolution on this P₁ peak maximum (δ_M) as a function of the dynamic stress amplitude implies that δ_M passes through a maximum. On the other hand, a static torsional stress superposed on the oscillating stress has no effect on the internal friction spectra. Finally, the values of the activation energy and the time of relaxation obtained are as follows : 1.1eV from 6N aluminium, 1.3 and 1.5eV from doped aluminium.

In the case of creep, the relaxation P₁ disappears but if the sample is strongly deformed it reappears. We have analyzed the corresponding microstructures in the deformed and crept states. While the former case the dislocations form the deformation cells with tangled dislocations, in the latter case they constitute a set of well organized subboundaries.

We could therefore think that the unique mechanism compatible with all the experimental results is the slip of the dislocations controlled by the climb movement of sessile jogs on screw dislocations
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