THERMOACTIVATED CREEP AND STRESS RELAXATION IN Cd + 0.08 at% Sn SINGLE CRYSTALS

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The activation area of plastically deformed Cd + 0.08 at% Sn single crystals was determined from differential creep test and stress relaxation at temperatures 78 K, 200 K and 295 K. The activation area \( A \) depends on the resolved shear stress, \( \tau \), \( A* \sim \tau^{-r} \) where \( r \) is dependent on temperature and the testing method used. For temperatures above 0.3 \( T_m \) recovery during stress relaxation should be considered.

1. INTRODUCTION

Defects in crystalline solids control the dislocation motion. If obstacles are not too large, the motion of dislocations through a crystal is controlled by thermally activated processes. In order to identify the thermally activated mechanism of plastic deformation, it is necessary to determine the activation parameters such as the activation energy and the activation area and to compare them with the thermodynamic properties of theoretical models. Values of the activation area can be determined from the differential creep tests as well as from the stress relaxation experiments.

In the differential creep tests the specimens is deformed with a constant stress to a given strain. Then the stress is changed. Due to an increase of the shear stress, \( \Delta \tau \), a change of the strain rate from \( \dot{\alpha}_1 \) to \( \dot{\alpha}_2 \) occurs. The activation area can be estimated according to equation

\[
A* = \left(\frac{kT}{b}\right) \frac{\ln (\dot{\alpha}_2/\dot{\alpha}_1)}{\Delta \tau}
\]

where \( b \) is the Burgers vector, \( k \) is the Boltzmann constant and \( T \) is the temperature.

In the stress relaxation experiments \([1]\), crystals are deformed to a certain stress \( \tau_R \) and then allowed to relax by stopping the crosshead of the tensile machine. The stress drop during relaxation, \( \Delta \tau_R \), as a function of time \( t \) can be described by

\[
\tau_R - \tau(t) = \Delta \tau_R = s \ln (t + t_0) - s \ln t_0
\]

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where $t_0$ is a constant and $s$ is the slope of the plot $\Delta\tau_R$ against $\ln (t + t_0)$. The activation area can be derived from the stress relaxation curves using the relation

$$A^* = \frac{kT}{bs}.$$  

The aim of the present paper is to compare the values of the activation area determined from these two methods.

2. EXPERIMENTAL PROCEDURE

The single crystals of Cd + 0.08 at% Sn were grown from the melt in a glass tube using a modified Bridgman method [2]. The samples having 20 to 25 mm in length and 4 mm in diameter were annealed in vacuum of about $1.3 \times 10^{-3}$ Pa at 473 K for 6 hours, and then cooled to room temperature. Specimens with the orientation allowing only basal slip were used.

The measurements were performed at temperatures 78 K, 200 K and 295 K. Temperatures of 78 K and 200 K were obtained by means of liquid nitrogen and in a dry ice alcohol mixture, respectively.

For the determination of the activation area in creep experiments the incremental loading method was used [3]. The samples were gradually loaded with increments in constant time interval. The elongation was measured using a linear variable differential transformer. The output of the transformer was continuously recorded during the creep tests. At the end of each time interval a small stress increment $\Delta\tau \approx \tau/100$ was added for 60 s and then $\Delta\tau$ was removed. The strain rate change resulting from the adding the stress increment was measured and the activation area was determined according to the relation (1).

The stress relaxation experiments were conducted in a Polanyi testing machine. The specimens were deformed in tension at an initial strain rate of $5 \times 10^{-4}$ s$^{-1}$. The duration of each relaxation period was 300 seconds. The decrease in load was recorded on chart paper and then the resolved shear stress was calculated using the usual formulas for single glide. The activation area was estimated using relation (3).

3. EXPERIMENTAL RESULTS AND DISCUSSION

Experimental results obtained by both methods are shown in figs. 1, 2 and 3. There are shown the dependences of the activation area, $A^*$, on the resolved shear stress in lg-lg plot for different temperatures. The average of values obtained by adding or removing the stress increments was considered to be the resultant value of the activation area. No important differences of these values were found. Experimental values lie in the interval shown in figs. 1 to 3. It is seen that the values of the activation area determined by both methods are coincident only at 78 K.