B R I E F C O M M U N I C A T I O N S

ELECTRON-MICROSCOPE STUDY OF THE DISLOCATION STRUCTURE IN MgO CRYSTALS

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Electron-microscope investigations of dislocation structures in MgO crystals have been reported in a number of papers [1-7]. However, further study in this area is necessary since the dislocation structures in MgO crystals display a number of important features, the careful analysis of which is required for understanding the processes of plastic deformation.

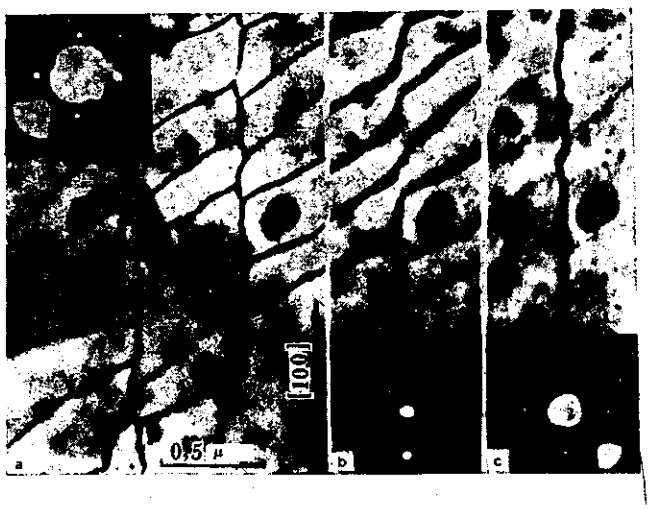

Fig. 1. Dislocation pattern in MgO crystals in one (001) plane. Reflex images are (a) $\bar{2}2\bar{0}$; (b) $0\bar{2}0$; and (c) $22\bar{0}$.

Figure 1 shows an example of the dislocation networks which are observed in deformed MgO crystals. Spectral stereoscopic investigations have established that similar patterns, by and large, are planar; although some special disposition of dislocations is possible, it is not fundamental. Figure 1 displays the results of diffraction analysis of this structure, which indicates that it is the result of the interaction of dislocations with Burgers vectors $\frac{1}{2}[\bar{1}\bar{1}0]$ and $\frac{1}{2}[01\bar{1}]$ in two slip systems $(\bar{1}10)$ and (011).

Two features of the structure of these networks demand attention.

1. It can be seen that when the dislocation reaction

$$\frac{1}{2}[\bar{1}\bar{1}0] + \frac{1}{2}[01\bar{1}] = \frac{1}{2}[\bar{1}0\bar{1}]$$

is realized, the recombination zone of the reacting dislocations is a 45° dislocation oriented along [100], and does not lie along the line of intersection $[11\bar{1}]$ of the slip surface of the two interacting dislocations, as is usually assumed [8].

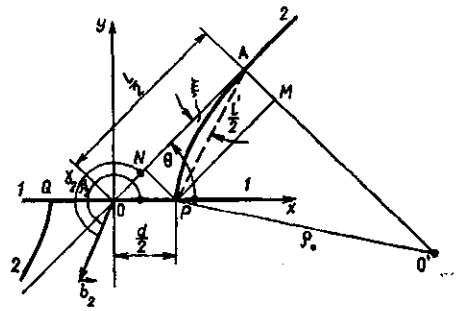

Fig. 2. Diagram illustrating the formation of a recombination zone and planar pattern in the {001} planes in MgO crystals.

2. The realization of the above-indicated dislocation reaction does not occur only under conservative motion of the dislocations, but also under their active slip in the cubic plane (001). The virtual slip surface of the dislocation segment, corresponding to the recombination zone, is not $(\bar{1}2\bar{1})$ but (010), i.e., the plane in which slip of the recombination zone is possible. Therefore, the strength of the seam between dislocations in this case will be determined not by the fixing of the recombination zone, but by the spatial construction of the dislocation structure.

In light of the above, data on the relative resistance to motion of the dislocations, the mean starting stress or the force of static friction $\tau^0_{(001)}$, becomes of great interest; this remains unknown at present. Knowledge of this characteristic is also important from the standpoint of evaluating the efficiency of transverse slip when a slip band is developed in the MgO crystals by a double transverse slip. Usually such estimates using electron-microscope data are made on the basis of the degree of curvature of the dislocations. However, the use of this method is associated with great inaccuracies.

One can propose a different method which gives substantially more reliable results. Inasmuch as after the formation of the recombination zone the whole system is maintained at equilibrium by the forces of resistance to the motion of the individual components of the dislocation structure in the cubic plane, the structure and its dimensions should be functions of the level of friction between dislocations in these planes. For practical purposes of finding the coupling between the parameters of the dislocation structure and the level of the force of friction, there are two possibilities. One possibility lies in the fact that since there should be a coupling between the size of the recombination zone and the displacement zone (Fig. 2) of the form [9]:

$$\frac{l}{d} = \cos\theta + \sqrt{\sin\theta\left[\frac{\rho}{d} - \sin\theta\right]},$$

where $\rho = \frac{0.5\,Gb}{\tau^0_{(001)}}$, G is the shear modulus, and b is the Burgers vector; for determining $\tau^0_{(001)}$ two quantities must be measured: the size of the recombination zone d and the ratio of the length of the displacement zone to the recombination zone l/d. However, it is frequently difficult in electron micrographs to establish the position of the point where the displacement of the reacting dislocations begins. Therefore, the determination of the quantity l, and thus $\tau^0_{(001)}$, is associated with large inaccuracies. Estimates of the force of friction by this method show that the level of resistance to the motion of dislocations in the {100} planes in MgO is in the range of 9 to 20 kg/mm^2.

Another method of estimating the force of friction gives substantially more reliable results. It is based on the fact that the size of the recombination zone, determinable by the maximum gain in the energy of the system in the formation of the recombination zone, is also determined by the level of friction between dislocations. Then $\tau^0_{(001)}$ can be found from the solution of the variational equation $\delta(E-E')=0$, where

$$(E-E')/D = \frac{d}{2}\,\nu(\cos^2\gamma - \cos^2\gamma_1) + \frac{1}{2}(l-l') + \frac{\nu}{2}\,l'(\cos^2\gamma_2' - l\cos^2\gamma_2),$$

$$D = \frac{Gb^2}{4\pi(1-\nu)}\ln\frac{R}{r_0},$$

ν is the Poisson coefficient, R is the size of the crystal, r_0 is the radius of the nucleus of dislocation, and the γ's are the angles between the dislocations and their Burgers vectors. Unprimed quantities refer to the situation before the reaction occurs, and the primed refer to after the reaction. In this case for finding the level of the friction between dislocations it is sufficient to know only the size of the recombination zone, which can be determined to a high degree of reliability, especially if the formation of the image is realized in certain more convenient reflexes (Fig. 1b). A histogram of

the distribution of the size of the recombination zone d is shown in Fig. 3. It is seen that the distribution of zone length is rather sharp, with a maximum in the region of 0.25 to 0.3 μm. Knowing this quantity, by using the functional dependence of the size of the recombination zone on the level of friction between dislocations in the {100} plane for maximum energy gain (Fig. 4), one can determine the level of friction between dislocations in the {100} planes in MgO crystals.

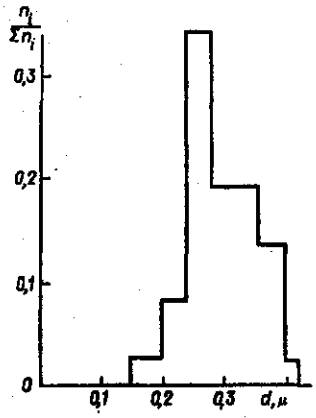

Fig. 3

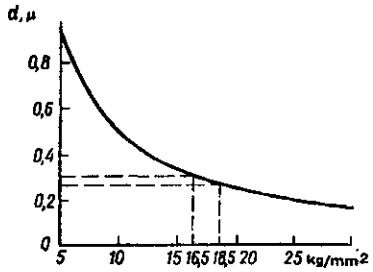

Fig. 4

Fig. 3. Histogram of the distribution of the recombination zone dimensions oriented along <100> in MgO crystals.

Fig. 4. The dimension of the recombination zone formed as a result of the dislocation reaction in MgO crystals as a function of the level of resistance to the motion of the dislocations in the {100} planes.

Using the most probable value of d, one obtains for $\tau^0_{(001)}$ the value 18.5 kg/mm^2, while the mean gives 16.5 kg/mm^2. It is noticeable in Fig. 3 that the distribution of d is nonsymmetric, being somewhat broadened on the side of larger d. This broadening can be connected with the slipping of reacting screw dislocations (the portion AP of the dislocations in Fig. 2) in the (001) plane, as a consequence of which there should be additional enlargement of the recombination zone. There is thus a preference for the value $\tau^0_{(001)}$ = 18.5 kg/mm^2 determined from the mode of the d distribution. It is interesting to compare the data obtained for the resistance to the motion of the dislocations in the planes of the cube with the corresponding values for the easy slip surfaces. In [3], for a value of the force of friction found from the curvature of the dislocations in pure MgO, the value 6.28 kg/mm^2 was derived. It was also indicated in [4] that in MgO the dislocations begin to move at 7 kg/mm^2.

Thus, the data obtained show that the frictional stress of dislocations in the {100} planes of MgO are about 2.5 times larger than in the {110} planes, and 1.5 times larger than the macroscopic yield limit; this seems physically reasonable.

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