PECULIARITIES OF DISLOCATION GENERATION
BY BLOCK BOUNDARIES IN ALKALI HALIDE
CRYSTALS DURING ULTRASONIC VIBRATIONS

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The generation of dislocations by block boundaries in alkali-halide crystals under the action of ultrasound was investigated making use of a computer defect modeling method. Ultrasonic vibrations were excited in a double piezoelectric oscillator at the frequencies 60 and 73 kHz. Specimens of KCl and KBr with $\theta = 0^\circ$ and $\theta = 30^\circ$, where $\theta$ is the angle between the fourfold axis and the propagation direction of the ultrasound, were investigated. The change in the dislocation structure was determined from the volt-ampere characteristics. It was established that the dislocation sources located near the block boundaries started to operate at stress values one third of those at which other sources operated. Modeling showed that the existence of boundaries had a significant effect on the operation of small-size sources. The experimental estimate of the reduction of the critical stress exceeds the theoretical one.

It has been established before [1, 2] that the initial stage of plastic deformation of alkali-halide crystals under the action of ultrasound can be controlled through the generation of dislocations by sources localized at block boundaries or near them. The role of these sources decreases in the series KCl, KBr, NaCl, and LiF, i.e., it correlates with the tendency of the dislocations in these crystals to cross slip; we note that the difference between KBr and KCl is negligible. For a given material, the sources in the block boundaries are more active in "rigid" specimens with a high yield point. As a rule, the sources were activated in the boundaries with a linear density $\rho = 10^3 \text{ cm}^{-1}$ [2].

The present paper is concerned with further investigation of dislocation generation under the action of ultrasound making use of a computer defect modeling method.

Ultrasound strain was generated in a double resonance piezoelectric oscillator [3] at the frequencies 60 and 73 kHz. The change in the dislocation structure and in the specimen properties during the action of ultrasound was determined from the volt-ampere characteristics of the composite oscillator [4]. The dislocations were exposed by selective chemical etching. Specimens of KBr and KCl of two orientations with $\theta = 0^\circ$ and $30^\circ$ were investigated; $\theta$ is the angle between the fourfold axis and the direction of vibrations in a standing ultrasonic wave set up along the oscillator. Specimens with $\theta = 0^\circ$ were split along the cleavage planes, while those with $\theta = 30^\circ$ were sawed with a filament saw.

In specimens with $\theta = 0^\circ$ the ultrasonic wave creates equal shear stresses in eight of the twelve easy slip systems of the type $\{110\}<110>$ (Schmid factor $m = 0.5$). In the cross slip systems of the type $\{100\}<110>$ there are no shear stresses. In eight $\{111\}<110>$ systems the shear stresses are also the same ($m = 0.41$), but they are weaker than in the easy slip systems.

In specimens with $\theta = 30^\circ$ shear stresses exist in all easy slip planes, but they differ for each pair of planes (correspondingly $m = 0.37, 0.25, 0.13$). Shear stresses appear in eight $\{100\}<110>$ systems ($m = 0.31$) and in all $\{111\}$ planes ($m = 0.49, 0.37, 0.37, 0.26, 0.12, 0.08$).

The tests showed that in specimens of both orientation dislocations were generated by sources localized in block boundaries. The distribution of sources along the specimens is in agreement with the stress distribution in the standing ultrasonic wave. The density of dislocations generated by sources near the block boundaries attained a value $\sim 10^{11} \text{ m}^{-2}$. The mean length of slip bands was approximately the same at different boundaries and lay between 100 and 150 $\mu$m. The linear density of dislocations at the block boundaries was thereby pre-


0038-5697/84/2703-0213$08.50 $1984 Plenum Publishing Corporation 213
Fig. 1. Slip bands generated by sources in the boundary of block AA' of KBr, $\Theta = 0^\circ$, $f_p = 60$ kHz.

Fig. 2. Volt-ampere characteristics of a composite oscillator with a KCl specimen obtained in successive tests (1-4, respectively), $f_p = 73$ kHz.

Examples of slip bands generated by sources localized at a block boundary in a KBr specimen with a static yield point of 1 MPa for $\Theta = 0^\circ$ can be seen in Fig. 1. The dislocation density at the given stage of plastic deformation was relatively small, which facilitated the analysis of the slip band structure at the block boundary by the successive etching method. The boundary section AA' in Fig. 1 where the sources operated is oriented at an angle of 45° to the direction of the ultrasonic vibrations. The shear stress in the slip plane in which the bands are formed was 3 MPa. The dislocation density in the boundary was $2 \cdot 10^3$ cm$^{-1}$, it remained constant through successive etchings up to a depth of 100 μm. The slip bands, as seen in Fig. 1, extend on both sides of the boundary; they consist of loops stretched mainly along the crystal surface. The characteristic loop dimensions varied from 2.5 to 25 μm along the surface and from 4 to 14 μm perpendicular to the surface. It was established that larger loops were stretched along <110>. It is noteworthy that loops which make up the slip bands do not lie in a plane.

Specimens with $\Theta = 30^\circ$ are of interest because gradual increase of the stress amplitude allows the successive introduction into action of planes belonging to the easy slip systems [5]. Figure 2 shows the volt-ampere characteristics of a fourfold test in a KCl specimen with $\Theta = 30^\circ$ (corresponding to curves 1-4). The relocation of the volt-ampere characteristics 1, 2, 3, 4 indicates that in each test the specimen is being hardened. The yield point was not reached in the four tests. The stress amplitude responsible for the beginning of the massive multiplication of dislocations was taken as the dynamic yield point (points C, C', C'' on curves 1-3 of Fig. 2). Etching of the specimen performed after the first test revealed the development of slip bands at the block boundaries in planes of the type {110} with $m = 0.37$. The stress amplitude corresponding to point C on curve 1 was 0.88 MPa. This stress amplitude can be taken as the critical amplitude for the beginning of the operation of sources localized near the block boundaries. In repeated tests (curves 2 and 3) slip bands appeared in the same planes ($m = 0.37$), but they were located not only near the block boundaries. The stress amplitude corresponding to points C and C' were 2.56 and 3.05 MPa.

Let us mention another distinctive feature of specimens with $\Theta = 30^\circ$. In the planes of the easy and cross slip the shear stresses can be similar (see the Schmid factor $m$ presented below), i.e., the cross slip is facilitated in comparison with specimens of zero orientation. According to [6], this is a favorable condition for intense dislocation generation under alternating load. In specimens with $\Theta = 30^\circ$ the dislocation density in the slip bands proved to be four times higher than in specimens with $\Theta = 0^\circ$.

To analyze the operation of a dislocation source near a block boundary, a computer modeling method of the elementary act of dislocation multiplication developed in [7, 8] was used. It is not possible to follow experimentally the elementary act of dislocation multiplication at ultrasonic frequencies of $10^6$-$10^8$ Hz; therefore, the modeling method is more convenient.

A test dislocation segment with two pinned ends was placed in the field of a block boundary and the phase of its motion under the action of an alternating stress was modeled. The stress amplitude was chosen in such a way that during one half-period a closed dislocation loop was formed. For the simplicity of calculation, the