A NEW METHOD FOR DETERMINING THE VELOCITY OF DISLOCATION MOTION IN IONIC CRYSTALS

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Abstract

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A NEW METHOD FOR DETERMINING THE VELOCITY OF DISLOCATION MOTION IN IONIC CRYSTALS

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In works ($^{1-3}$) it was shown that, when a voltage pulse is applied to a photochemically colored ionic crystal, luminescence arises. In these works the dislocation mechanism for the occurrence of luminescence was proved. Dislocations moving under the action of an external stress release electrons located at trapping centers; recombination of these electrons with holes localized at luminescence centers excites the luminescence of these centers.

In the present work a new method is proposed for determining dislocation velocities, based on the study of the luminescence that arises during deformation of photochemically colored ionic crystals.

It is obvious that the number of light quanta emitted during deformation is directly proportional to the number of electrons released by dislocations from trapping centers. At the same time, if it is assumed that in the crystals under study the luminescence centers are distributed uniformly throughout the crystal, then the number of emitted quanta is proportional to the area swept out by the dislocations during loading. The number of emitted light quanta is equal to

$$I = Srn\eta,$$

where S is the area swept out by dislocations; r is the radius of interaction of dislocations with F-centers; n is the concentration of color centers; η is the quantum yield of deformation luminescence.

The quantity S can be represented as follows:

$$S = NlL,$$

where N is the number of mobile dislocations; l is the size of the crystal for a specimen $l \times l \times l$ cm^3; L is the average distance over which a dislocation moves under loading.

Fig. 1. Dependences of the velocity of dislocation motion v on stress, measured by deformation luminescence (1) and according to the data of (6) (2)

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Then $I = AL$, where $A = Nlrn\eta$.

Thus, from the number of light quanta emitted during deformation, one can determine the average path traversed by a dislocation. If the time of application of the voltage pulse t is known, then the averaged dislocation velocity is determined as follows:

$$v = I/At. \tag{1}$$

By studying the dependence, on stress, of the number of light quanta emitted during loading, $I = I(\tau)$, one can use formula (1) to determine the velocity as a function of the external stress, $v = v(\tau)$.

The investigations were carried out on KCl crystals. The crystals were colored by irradiation with Co^{60} γ-quanta. The optical yield stress of the specimens studied was $\tau_t = 100$ g/mm^2. The specimens were deformed by voltage pulses of duration from 30 to 50 μsec, with a rise time of 10 μsec. To obtain the voltage pulses, a new method of loading crystals was developed, using as the deforming element a magnetostrictive transduce-

This method has certain advantages (constant loading rate; pulse shape; load magnitude; the possibility of obtaining a rectangular pulse) over the traditional pulse-loading technique used in the works of other authors—the technique of striking the crystal under study against a massive anvil (4, 5).

To find the velocity of dislocation motion it is necessary to determine the values of the quantities entering formula (1). This was done as follows. The concentration of color centers was determined from the contour of the F-absorption band using Smakula' s formula. The values of the quantum yield of deformation luminescence and the radius of interaction of dislocations with F-centers were determined in (3). The dislocation density was determined from etch figures. The determination of the velocity of dislocation motion was carried out on the assumption that all dislocations revealed during etching are mobile.

Fig. 1. Dependences of the velocity of dislocation motion v on stress, as measured from deformation luminescence (1) and according to the data of (6) (2)

In Fig. 1 (curve 1) the dependence of the dislocation velocity $v = v(\tau)$ is presented for KCl crystals. In the same figure (curve 2) the dependences $v = v(\tau)$ for KCl crystals ($\tau_t = 100$ g/mm^2), obtained by the etching technique (6), are shown.

It is clear from the figure that the dependence $v = v(\tau)$ obtained by us differs substantially at low stresses from the analogous dependence obtained in (^{6}).

The dislocation velocities obtained by measuring the number of light quanta emitted during deformation of the crystal depend only weakly on the magnitude of the load and are practically insensitive to the presence of impurities. Such a sharp difference in the results is due to the difference in the experimental conditions under which dislocation motion is observed in these two cases. In our experiments the average velocity of bowing of dislocations between stoppers is measured, i.e., the velocity of micromotion.

On the other hand, when the dislocation velocity is determined by the etching technique, what is actually determined is the velocity of the end of a dislocation loop emerging onto the surface of the crystal. In addition, the etching technique makes it possible to determine the velocity of dislocation motion only in the case when the displacement of the end of the dislocation loop is $> 1\mu$ (this quantity is determined by the resolving power of the microscope). In this case

$$v = L/(t_\mathrm{d} + t_\mathrm{s}),$$

where t_d is the time of dislocation motion; t_s is the time of delay of dislocations at stoppers.

The velocity of dislocation motion determined by the method proposed in the present communication can be represented in the form

$$v = L/t_\mathrm{d}.$$

Comparison of these two expressions makes it possible to estimate the ratio of the time of delay of dislocations at stoppers to the time of motion. This ratio varies from 10^8 at $\tau = 50$ g/mm^2 to zero at $\tau = 130$ g/mm^2.

It should be noted that our results are in qualitative agreement with the results of determinations of dislocation velocity obtained from measurements of the damping decrement in LiF (^{7}) and KBr (^{8}) crystals.

Thus, in the present work a new method has been proposed for determining the velocity of dislocation motion which, in combination with the etching method, makes it possible to obtain more complete information about the nature of the physical processes occurring during deformation of a crystal. In addition, this method makes it possible to determine the time of dislocation delay at obstacles.

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