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THE INVESTIGATION OF DISLOCATION PHOTODAMPING IN NaCl WITH F-CENTERS

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Abstract. - The mechanism of dislocation photodamping in NaCl with F-centers is investigated by means of simultaneous measurements of the amplitude dependent internal friction and the dislocation charge. The dislocation photodamping is confirmed to arise from light-induced generation of pinning points, and the pinning points nature and conditions of their formation are studied. On the base of the experimental data the model of the dislocation photodamping is proposed.

1. Introduction. - As it is known [1], the illumination of coloured alkali halides with dislocations leads to the dislocation photodamping, i.e. to the additional hindering of the dislocation movement. The dislocation photodamping is shown to arise from the light-induced generation of the pinning points. However, the exact mechanism by which this occurs and the nature of the pinning point is still uncertain. The purpose of this research is to investigate this problem using simultaneous measurements of the dislocation charge and the amplitude dependent internal friction, the latter being strongly dependent on the number of pinning points on dislocations and, also, on the binding energy between a dislocation and a pinning point.

Experimental procedure. - The amplitude dependent dislocation damping, modulus defect and dislocation charge were measured by the four-component piezoelectric resonator, operating at 100 KHz. The description of the apparatus and measuring procedure are given elsewhere [2]. It should be noted, that the idea of the dislocation charge measurement here is based on the fact, that oscillating charged dislocation induces on the opposite specimen faces an alternating voltage, which is proportional to the dislocation charge [3,4]. The specimens used were NaCl single crystals, Y-irradiated up to the doses of 10^6-10^7 Rad. Fresh dislocations were introduced into the irradiated crystals in dark in a four-point bending rig. The radius of the curvature was ~0.7 m, that corresponds to the introduction of about 10^7 cm^-2 edge dislocations. The experiments were
conducted in the temperature range from 200 to 300 K.

**Fig. 1:**

a) The amplitude dependences of $\delta$ and $\Delta m/m$ of the same specimen after F-light exposures of the different duration. The measurements were done 30 minutes after the light was switched off. 1-before the exposure, 2-the F-light exposure - 1 min, 3-the F-light exposure - 9 min.

b) The amplitude dependent decrement $\delta$ and modulus defect $\Delta m/m$ versus the illumination time.

**Experimental results.** - As it is seen from Fig.1(b), the illumination of the plastically bent specimens leads to the sharp decrease of the amplitude dependent decrement $\delta$ and modulus defect $\Delta m/m$. When the light is switched off, $\delta$ and $\Delta m/m$ partly recover, the time of this recovery being about 1-2 minutes at room temperature. One can see from Fig.1(b), that the change of $\delta$ and $\Delta m/m$ during recovery is small as compared to the total change of $\delta$ and $\Delta m/m$ after the illumination. Thus, one can think that a light exposure of the plastically bent coloured crystals leads to the formation on the dislocation line of two kinds of photopinners, transient ones, that disappear after the illumination is stopped, and permanent ones, that are preserved for a long time after the illumination is stopped. To establish the nature of the photopinners, it is necessary to know how the photopinning strength depends upon the illumination time.

Such experiments were conducted in the following way. The specimen was subjected to the F-light exposure of some duration, then the illumination was stopped, and the amplitude dependent decrement $\delta$ and modulus defect $\Delta m/m$ were measured 30 min after the light was switched off. The latter is done to preserve the permanent pinners only. Fig.1(a) shows the amplitude dependences of $\delta$ and $\Delta m/m$ after the F-light exposures of the different durations. One can see, that the longer the duration is, the stronger $\delta$ and $\Delta m/m$ decrease.
To determine the binding energy between the permanent photopinners and dislocations and the photopinner density on the dislocation line, the amplitude dependences of $\delta$ and $\Delta \gamma^\alpha\beta\gamma$ were measured at different temperatures. At first, the unilluminated specimen was measured, then the same specimen was illuminated during 1 min, and the amplitude dependences were measured again.

It is found, that the amplitude dependences of both unilluminated and illuminated crystals are thermally activated in the temperature range used. It allows one to use the Indenbom-Chernov theory [2] of the thermally activated dislocation breakaway from pinning points for the interpretation of the results obtained. It should have been expected that during illumination the preexisting pinners would become stronger, that should lead to decrement decrea-se. However, the consideration of the experimental data in terms of the Indenbom-Chernov theory shows that, in fact, the additional pinning points were created during illumination. The binding energy between dislocations and a new pinning point calculated on the base of the Indenbom-Chernov theory gives $W \sim 0.35$ ev. It should be noted, that the binding energy of the preexisting pinning point with a dislocation proves to be practically the same.

In order to establish the nature of photopinners it is very important to understand the role of dislocation charge in the photopinner formation. That is why the simultaneous measurements of the amplitude dependent $\delta$ and dislocation charge $q$ were performed at $T \sim 240$ K. The temperature chosen was low enough to exclude any diffusion-controlled processes which are shown to play an essential role in the formation of the dislocation charge [2]. Apart from that, the recovery of the amplitude dependent damping after illumination is suppressed at these temperatures.

The results of simultaneous measurements of $\delta$ and $q$ during illumination are shown in Fig.2. It is seen, that the decrement decrease is accompanied by an increase of the negative dislocation charge magnitude. As seen, the dependences of $\delta$ and $q$ upon the illumination time are rather similar. Both curves change monotonously and reach the saturation values simultaneously within 1-2 min after the light is switched on. As the saturation values are reached, both $\delta$ and $q$ do not vary in spite of the fact that the illumination still goes on and there is a great number of F-centers in the bulk of the crystal. By comparing the dislocation charge change $\Delta q$ caused by illumination with the corresponding change of the photopinner density on dislocation line $\Delta C$, defined in terms of the Inden-
bom-Chernov theory \cite{5}, one can show, that $\Delta C \sim \Delta q$ (Fig. 3). Thus, the number of photopinners correlates well with the dislocation charge during illumination. It should be emphasized that the photopinner generation occurs only in the case that the negative dislocation charge grows in value.

**Discussion.** - As it is shown recently \cite{2} the dislocation charge growth to the large negative values during the illumination of NaCl coloured crystals at 240 K is associated with the capture of photoelectrons by the empty traps on a dislocation line. The anion vacancies on the dislocation line are the most probable traps. The concentration of the anion vacancies in the vicinity of an edge dislocation is much higher than in the bulk, because the edge dislocations are the sinks for the anion vacancies. The photoelectrons are trapped by the anion vacancies to form F-centers and, therefore, the F-centers concentration near the dislocation is also higher, than that in the bulk. The F-center concentration increase leads to their coagulation and to conversion into some other color centers near the dislocation line. From that one can propose a model to explain the dislocation photodamping process. The F-light exposure of the irradiated NaCl specimen with dislocations causes the F-center coagulation near the dislocation line and the photolytic precipitation of Na colloids, which effectively pin the dislocation down. It is supposed, that the permanent centers are the final product of the F-center coagulation, whereas the transient centers are intermediate products of this process. In fact, the properties of the permanent pho-
topinners are much similar to those of very small colloidal particles. So, the permanent photopinners are very stable at room temperature and cannot be decomposed by light at this temperature, as it is in the case of the small Na-colloids in NaCl [6]. Supposing, that the permanent pinning points are the small Na-colloids, one can estimate their seize on the base of the following assumptions. Assume, that all the electrons trapped by the dislocation, take part in the colloidal particle formation and each electron trapped corresponds to a Na-atom in the colloidal particle. Then η = Δq / ΔC is an average number of Na-atoms in the colloidal particle. Our experimental results yield η = 10 ± 100 (Fig. 2, 3). The knowledge of a mean colloid size permits one to roughly estimate, using the Friedel model [7], the binding energy between a dislocation and a colloidal particle. Treating the colloidal particle as a coherent inclusion consisting of about 50 atoms and situated at a distance of 3b from the dislocation one obtains W ~ 0.5 ev. This value is in good agreement with the value of W ~ 0.35 ev obtained from the present experimental data.

References