

# Investigation of the nature of optically induced drag of dislocations in NaCl crystals containing $F$ centers

M. A. Golosovskii and Ya. M. Solfer

*Institute of Solid-State Physics, Academy of Sciences of the USSR, Moscow*

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An investigation was made of the mechanism of an optically induced drag of dislocations in NaCl crystals containing  $F$  centers. This was done by simultaneous measurements of the amplitude-dependent internal friction and of the dislocation charge. It was found that the photodrag of dislocations was due to optical generation of pinning centers. Such centers formed when photoelectrons arrived at dislocations and when dislocations had empty traps (anion vacancies). A model of formation of the pinning centers was proposed. It was concluded that these centers were colloidal particles of metallic Na formed as a result of coagulation of the  $F$  centers near dislocations. The experimental results were used to estimate the size of these colloids and the energy of their coupling to dislocations.

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## INTRODUCTION

An optically induced drag of dislocations in alkali halide crystals containing  $F$  centers represents a reduction in the dislocation mobility when these crystals are illuminated with light of wavelengths corresponding to the photoionization of the  $F$  centers.<sup>1</sup> This photodrag effect is usually manifested by an abrupt change in the deforming stress in the course of plastic deformation<sup>2</sup> or by a reduction in the amplitude-independent internal friction of dislocation origin.<sup>3</sup>

It has been established that the photodrag effect is due to the appearance of new pinning centers at dislocations as a result of photoionization of the  $F$  center.<sup>3,4</sup> Some properties of these centers have been described<sup>2</sup> and suggestions have been made about their nature and conditions of formation.<sup>4</sup> In particular, a hypothesis has been put forward that the presence of electric charges on dislocations plays a significant role in the formation of these photoobstacles.<sup>5,6</sup> However, available experimental data on the photodrag of dislocations are insufficient to draw the final conclusion on the nature of photoobstacles. One needs fuller information on the conditions of formation of photoobstacles and their main characteristics, as well as on the role of dislocation charges in the formation of photoobstacles.

With this in mind we investigated the photodrag effect by simultaneous measurements of the dislocation charge and of the dislocation-controlled amplitude-dependent internal friction, which was governed by the detachment of dislocations from pinning centers and was very sensitive to the changes in the numbers of such centers and their energy of coupling to dislocations.

## EXPERIMENTAL METHOD

Simultaneous measurements of the amplitude-dependent damping decrement, modulus defect, and dislocation charge were made by the method of a four-component piezoelectric vibrator.<sup>7</sup> This method could be used to determine the dislocation charge because vibrations of charged dislocations produced an alternating potential  $U$  between the opposite faces of a sample.<sup>8</sup>

The relationship between  $U$  and the dislocation charge  $q$  can be established as follows. The displacement of a dislocation by an applied stress gives rise to a dislocation strain  $\varepsilon_{\text{dis}} \sim Nb\xi$ , where  $N$  is the density of mobile dislocations,  $b$  is the Burgers vector, and  $\xi$  is the average displacement of the dislocations. The displacements of charged dislocations give rise also to a polarization  $P \sim Nq\xi$ , where  $q$  is the linear charge on a dislocation. Thus, a potential difference  $U \sim q\varepsilon_{\text{dis}}/b$  appears between the opposite faces of a sample. The magnitude of  $\varepsilon_{\text{dis}}$  may be found using the model of dislocation-controlled internal friction<sup>9</sup> in terms of the measurable quantities  $\delta$ ,  $\Delta\mu/\mu$ , and  $\varepsilon$ , where  $\delta$  is the damping decrement,  $\Delta\mu/\mu$  is the modulus defect, and  $\varepsilon$  is the strain amplitude. The method for determining  $q$ ,  $\delta$ , and  $\Delta\mu/\mu$  is described in detail in Ref. 10.

The experiments were carried out as follows. Samples of  $3 \times 3 \times 21$  mm dimensions were cleaved along  $\{100\}$  planes from NaCl single crystals with impurity concentrations in the range  $<10^{-3}$  at.%. Special measures were taken<sup>11</sup> to avoid increasing the dislocation density in the process of reaching the required frequency ( $\sim 100$  kHz). Silver electrodes were deposited on these samples and then they were irradiated with gamma rays in doses of  $(1-5) \times 10^6$  rad, corresponding to introduction of  $10^{16}-10^{17}$  cm<sup>-3</sup> of the  $F$  centers. Samples containing these color centers were then deformed at room temperature in darkness by the four-point method to a radius of  $\sim 0.7$  m, which corresponded—according to Whitworth<sup>12</sup>—to introduction of  $\sim 10^8$  cm<sup>-2</sup> of excess edge dislocations.

The amplitude dependences of the internal friction and modulus defect were determined in the temperature range 200–300 °K a day after the introduction of dislocations. Storage for a day at 300 °K was quite sufficient to stabilize the dislocation structure produced by the deformation. Throughout the investigated range of temperatures the resonance frequencies of the samples and quartz components differed by no more than 0.3%.

The  $F$  centers were photoionized by illumination with

the  $F$ -active light ( $\lambda = 465$  nm) for a selected time interval. The source of light was a tungsten incandescent lamp of 170 W power in combination with optical filters or a DKSSh-500 lamp in combination with an SPM-2 monochromator. The investigated samples obeyed the condition  $\alpha d < 0.3$ , where  $\alpha$  is the optical absorption coefficient and  $d$  is the thickness of the sample. The reduction in the light flux intensity due to its passage through the sample was therefore not very great.

## RESULTS AND DISCUSSION

It was found that the photoionization of the color centers with the  $F$ -active light reduced significantly the amplitude-dependent internal friction  $\delta$  and the modulus defect  $\Delta\mu/\mu$  (Fig. 1b); after the end of illumination, these two quantities recovered partly in several minutes and then did not change for a long time at 300 °K. A study of changes in the amplitude dependences of the internal friction, recorded at 10–30 min after the end of exposure to light when the partial recovery already took place, gave the results shown in Fig. 1a. It is clear from this figure that long exposures to light could reduce practically to zero the amplitude-dependent  $\delta$  and  $\Delta\mu/\mu$ .

Since the dislocation-controlled amplitude-dependent  $\delta$  and  $\Delta\mu/\mu$  were due to the detachment of dislocations from their pinning centers, we concluded that the reduction in  $\delta$  and  $\Delta\mu/\mu$  due to exposure of a crystal to the  $F$ -active light was caused by an additional pinning of dislocations, which was largely retained after the end of illumination.

In the experiments involving illumination it is very important to separate the optical effect of light from the heating unavoidably associated with the absorption of light. An important advantage of the acoustic methods is the ability to separate these two effects. The additional pinning of dislocations increased the resonance frequency of a sample because of a reduction of the dislocation contribution to the elastic moduli. Heating caused by the absorption of light should increase the

length of a sample because of thermal expansion and should alter the elastic moduli, in such a way as to reduce the resonance frequency of a sample (this was true in the case of alkali halides). Illumination of our samples with the  $F$ -active light increased the resonance frequency. This showed that the change in the resonance frequency because of the heating was slight and the main component of the change was due to the additional dislocation pinning.

Since illumination altered also the modulus defect  $\Delta\mu/\mu$  (which was governed entirely by the concentration of obstacles), we concluded that illumination produced additional obstacles to dislocation motion: these were of temporary nature which disappeared after several minutes at 300 °K or of permanent nature retained for many days after the exposure to light. The exposure to light of wavelengths  $\lambda = 700$ –2000 nm also failed to destroy these permanent obstacles. We concentrated our attention on the permanent obstacles especially as the changes in  $\delta$  and  $\Delta\mu/\mu$  due to the temporary obstacles were considerably less (Fig. 1b) than those due to the permanent pinning centers.

The amplitude-dependent  $\delta$  and  $\Delta\mu/\mu$  of alkali halide crystals are governed, at  $T \sim 300$  °K, by the usual thermally activated detachment of dislocations from their pinning centers. We determined the characteristics of the interaction of dislocations with obstacles formed as a result of illumination by recording the amplitude dependences of  $\delta$  and  $\Delta\mu/\mu$  before and after illumination exposure at various temperatures. The exposure took place at 300 °K and the measurements were started 10–30 min after the end of exposure, i.e., the permanent obstacles were investigated.

Figure 2 shows the amplitude dependences of  $\delta$  and  $\Delta\mu/\mu$  obtained at various temperatures for the same sample before exposure (curves 1–5 in Fig. 2) and after exposure to the  $F$ -active light for 1 min (curves 6–10 in Fig. 2). Clearly, cooling shifted significantly the amplitude dependences of both quantities in the direction of higher strain amplitudes, which was characteristic of the thermally activated process of the detachment of dislocations from their pinning centers.

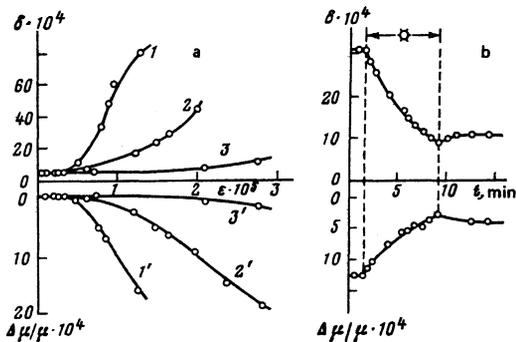


FIG. 1. a) Changes in the amplitude dependences of the damping decrement of ultrasound  $\delta$  and of the defect modulus  $\Delta\mu/\mu$  after exposure to the  $F$ -active light: 1), 1') before exposure; 2), 2') after exposure for 1 min; 3) 3') after exposure for 9 min;  $\epsilon$  is the strain amplitude;  $T = 297$  °K. b) Changes in the amplitude-dependent decrement and in the modulus defect under the action of the  $F$ -active light;  $\epsilon = 1 \times 10^{-5}$ .

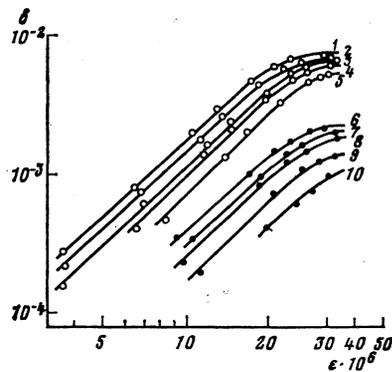


FIG. 2. Amplitude dependences of the damping decrement of ultrasound  $\delta$  before exposure (curves 1–5) and after exposure (curves 6–10) obtained at the following temperatures (°K): 1) 297; 2) 287; 3) 270; 4) 259; 5) 228; 6) 298; 7) 279; 8) 264; 9) 239; 10) 217;  $\epsilon$  is the strain amplitude.

We shall analyze the results obtained using the model that Indebom and Chermov<sup>13</sup> developed to give a quantitative description of the amplitude-dependent internal friction due to the thermally activated unpinning of dislocations from obstacles. According to the theory of Ref. 13, in the case of usual dislocation segments of length  $L > 50b$  the expression for  $\delta$  has the following form if the "binding energy" approximation is used<sup>13</sup>:

$$\delta = \pi L_n^2 \int_{L_n}^{\infty} LN(L) dL, \quad (1)$$

where  $N(L)$  is the distribution function of dislocation segments lengths  $L_n = F(T)/\mu b \varepsilon$ . Here,  $\mu$  is the shear modulus,  $\varepsilon$  is the strain amplitude,  $F(T)$  is the solution of the equation  $H(F) = kT \ln(\xi \nu_0/\nu)$ , where  $H(F) = H(L, \varepsilon)$  is the activation energy of the process of detachment of a dislocation from a pinning point,  $\nu_0$  is the natural frequency of vibrations of a dislocation segment,  $\nu$  is the measurement frequency, and  $\xi = \text{const} \sim 1$ . If  $L = 3 \times 10^5$  cm, then  $\nu_0 = 10^9$  Hz. Inversion of (1) allows us to find the distribution function of the lengths of dislocation segments:

$$N(L) \sim e^{\int \frac{\partial}{\partial \varepsilon} [\varepsilon^2 \delta(\varepsilon)] d\varepsilon}, \text{ where } \varepsilon = \frac{F(T)}{\mu b L}. \quad (2)$$

It is clear from Eq. (2) that the amplitude dependence  $\delta(\varepsilon)$  can be used to determine the function  $N(L)$ .

We shall first consider an unexposed sample. The graphs of  $\delta(\varepsilon)$  plotted on a logarithmic scale for various temperatures (curves 1–5 in Fig. 2) can be described largely by straight lines practically parallel to one another. The slopes of these lines are  $k = 1.8$ . Thus, large parts of the dependences  $\delta(\varepsilon)$  can be described by the power function  $\delta \propto \varepsilon^k$ , where  $k = 1.8$ . Substituting this dependence  $\delta(\varepsilon)$  in Eq. (2), we find that for large values of  $L$  the distribution function is also described by a power law  $N(L) \propto L^{-(k+2)}$ .

We can thus approximate  $N(L)$  as follows:

$$N(L) = 0 \text{ for } L < L_0; \quad N(L) = NL_0^{k+2}/L^{k+2} \text{ for } L > L_0. \quad (3)$$

Here,  $N$  is the dislocation density and  $L_0$  is the characteristic length of a loop. The average length of a loop for this distribution function is

$$L_{av} = (k+3)L_0/(k+2),$$

so that the concentration of the pinning centers on a dislocation is

$$c = N/L_{av} = (k+2)N/L_0(k+3).$$

Substituting the distribution function (3) in Eq. (1) and expressing  $L_n$  in terms of  $\varepsilon$  and  $L_0$  in terms of  $c$ , we obtain the dependence of  $\delta$  on the concentration of pinning centers in the form  $\delta \propto \varepsilon^k c^{-(k+2)}$ . If the experiments are carried out under  $\delta \varepsilon = \text{const}$  conditions, we can easily show that  $\delta \propto c^{-(k+2)/(k+1)}$  and measurements of  $\delta$  can be used to estimate  $c$ .

Since in the temperature range 240–300 °K the dependence  $\delta(\varepsilon)$  remains practically unchanged as a power law with the exponent  $k = 1.8$  (Fig. 2), it follows that there is no change in the function  $N(L)$  described by Eq. (3). This allows us, in accordance with Ref. 13, to

use the graphs of  $\delta(\varepsilon)$  at various temperatures and the dependences  $\varepsilon(T)$  for  $\delta = \text{const}$  to find the power law and the energy of the interaction of a dislocation with a pinning center. The activation energy of the process of detachment from old obstacles governing the amplitude dependence of the internal friction before exposure was found in this way and its value was  $\sim 0.35$  eV.

Illumination alters the nature of the amplitude dependence of the internal friction (curves 6–10 in Fig. 2) but in this case the nature of the dependence  $\delta(\varepsilon)$  varies slowly with temperature and is still described by a power law with the exponent  $k = 1.8$  (curves 6–10 in Fig. 2), which is exactly the same as before exposure. It follows that the nature of the distribution function of the loop lengths is in this case almost independent of temperature in the range 220–300 °K and exposure affects only the value of  $L_0$ , i. e., the concentration of pinning centers. It was found that prolonged exposure could increase the number of photoobstacles so that their number is several times greater than that of the old obstacles. For example, an exposure for 1 min produced twice as many photoobstacles as the old obstacles.

The law describing the force interaction of a dislocation with obstacles, governing the amplitude dependence of  $\delta$  after exposure, is not very different from the same law for obstacles present on dislocations before exposure and the activation energy of the process of detachment is again  $\sim 0.35$  eV.

Measurements of the amplitude dependence of the internal friction at various temperatures make it possible to estimate the energy of coupling of a dislocation to its pinning centers, whereas comparison of the data on the influence of light on the mechanical properties  $\delta$  and  $\Delta\mu/\mu$  and on the dislocation charge  $q$  allows us to draw certain conclusions also about the nature of photoobstacles. In this case it is convenient to carry out exposure experiments under  $\delta \varepsilon = \text{const}$  conditions. As shown above, we then find that  $U \propto q$  and  $\delta \propto c^{-(k+2)/(k+1)}$ . In our case, the power exponent is  $k = 1.8$  and, there-

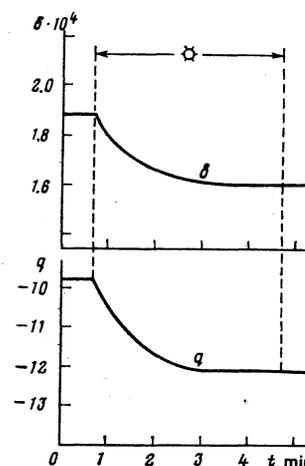


FIG. 3. Changes in the amplitude-dependent damping decrement of ultrasound  $\delta$  and in the dislocation charge  $q$  under the influence of light;  $T = 236$  °K.

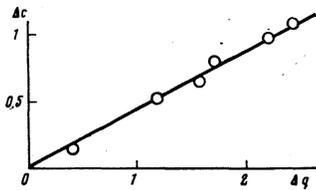


FIG. 4. Correlation between the changes in the dislocation charge  $\Delta q$  and in the number of photoobstacles  $\Delta c$  during exposure at  $T = 236^\circ\text{K}$ .

fore,  $\delta \propto c^{-1.4}$ .

It is known<sup>10</sup> that a change in the dislocation charge due to illumination with the  $F$ -active light occurs in three stages, the rate of the changes as well as their occurrence depend on temperature. We shall consider the case of low temperatures in the range  $T \leq 240^\circ\text{K}$  (Fig. 3), where only the first stage is observed: photoelectrons are captured by dislocation traps and this increases the negative charge on a dislocation. We can see that dependences of both  $q$  and  $\delta$  on the exposure time are described by curves which reach saturation, and the saturation of  $q$  associated with the filling of dislocation traps<sup>10</sup> occurs at the same time as the saturation of  $\delta$ . Thus, 1–2 min after the beginning of exposure, both  $q$  and  $\delta$  cease to vary, although the sample still contains a large number of the  $F$  centers.

As described above, the measured values of  $\delta$  can be used to calculate the change in the concentration of photoobstacles with the duration of illumination. It is found that  $\Delta q \propto \Delta c$  (Fig. 4). There is thus full correlation between the changes in the number of photoobstacles and the changes in the dislocation charge caused by the capture of electrons at dislocation traps. However, we can easily show that the changes in the dislocation charge due to other processes such as the arrival of anion vacancies (second stage) at dislocations do not alter the number of photoobstacles.

In fact, at temperatures  $T \leq 240^\circ\text{K}$ , when the second stage is realized, illumination causes  $q$  and  $\delta$  to reach saturation at the same time (Fig. 5) and  $\Delta q \propto \Delta c$ . The mobility of anion vacancies is now sufficiently high and their arrival at dislocations after the end of illumination increases the positive charge of dislocations (Fig. 5). Although the change in  $q$  due to this arrival of anion vacancies after the end of illumination is comparable with the change in the dislocation charge during illumination, there is practically no change in the number of obstacles after the end of illumination.

When illumination is started for the second time, the dislocation charge reaches the same saturation level as in the first exposure because of the capture of photoelectrons at newly formed traps and the number of photoobstacles rises additionally by an amount proportional to the number of trapped electrons (Fig. 5). It follows from this experiment that the formation of photoobstacles requires the presence of electrons, which is ensured by the photoionization of the  $F$  centers, and the presence of electron traps at dislocations, which may be anion vacancies; moreover, these vacancies do not act as obstacles (Fig. 5).

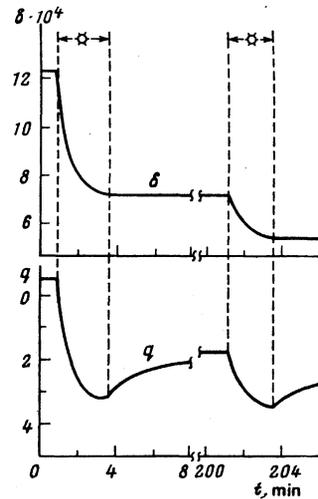


FIG. 5. Changes in the amplitude-dependent damping decrement  $\delta$  and in the dislocation charge  $q$  under the influence of illumination at  $T = 264^\circ\text{K}$ .

This can be demonstrated also in a different way. It is known that ultrasonic excitation of sufficiently large amplitude can detach dislocations from the pinning clouds of point defects, and that after such excitation a recovery process involves diffusion of pinning centers to the new position of a dislocation. Thus, ultrasonic excitation alters the number of obstacles on a dislocation. We investigated the process of recovery of the internal friction and dislocation charge after ultrasonic excitation of the samples exposed to light. It was found that although the number of obstacles changed considerably (Fig. 6b) the dislocation charge was practically unaffected by these operations (Fig. 6a). Hence, we conclude that the absolute value of the dislocation charge could have only a very slight effect on the pinning of dislocations. Thus, the formation of photoobstacles requires that photoelectrons reach a dislocation and that such a dislocation has empty traps, which are mainly anion vacancies. Electron filling of these anion vacancies on a dislocation produces a higher concentration of the  $F$  centers and of complex aggregate color centers in its vicinity, and this may include precipitation of tiny colloids of metallic Na ( $X$  centers). We may assume that these colloid centers act as foreign photoobstacles. The question is now how such metallic colloids form near dislocations.

A thermodynamic equilibrium exists between color and colloid centers and the latter can be regarded as a condensate whereas the  $F$  centers as a vapor,<sup>15</sup> to that the formation of the colloid centers can occur only when the concentration of the  $F$  centers exceeds the equilibrium value at a given temperature. Studies of thermal and radiation formation of colloids in NaCl crystals<sup>15</sup> indicate that the minimum concentration of the  $F$  centers needed for this process is  $\sim 10^{18} \text{ cm}^{-3}$  at  $300^\circ\text{K}$ .

Since our crystals were characterized by  $N_F \sim 10^{16} \text{ cm}^{-3}$ , which was less than the necessary value, illumination should not result in precipitation of colloids in the bulk of a crystal. The concentration of anion vacancies near dislocations is much higher because dislocations act as the main sinks of anion vacancies formed by illumination. Illumination fills anion vacan-

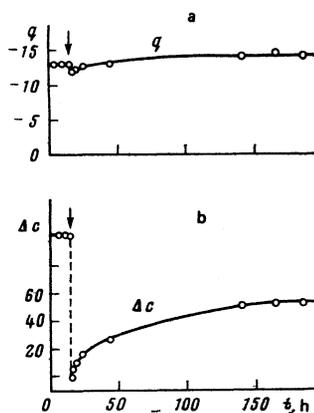


FIG. 6. Kinetics of changes in the dislocation charge (a) and in the number of photoobstacles (b) during recovery after ultrasonic excitation for 20 min. The beginning and end of excitation are identified by the same arrow;  $T = 297^\circ\text{K}$ .

cies with electrons and this produces the  $F$  centers so that the concentration of the  $F$  centers near dislocations is much higher than elsewhere. It follows from a study of the photostimulated changes in the dislocation charge<sup>10</sup> that even a brief exposure (10 sec) supplies  $N_a \sim 10^5$  anion vacancies per unit length of a dislocation. During subsequent exposure these vacancies are filled with electrons producing the  $F$  centers, so that the concentration of the  $F$  centers at a dislocation becomes  $N_F \sim N_a/\pi d^2$ , where  $d$  is the radius of a dislocation core. If we assume that  $d = 4b$ , we find that  $N_F = 10^{18} \text{ cm}^{-3}$ , so that even after the first exposure near a dislocation we have a supersaturation with the  $F$  centers sufficient to begin formation of colloids, which act as permanent obstacles. It is very likely that the aggregate color centers formed near dislocations together with colloids can also act as pinning centers because they introduce tetragonal distortions. On the other hand, such complex color centers are unstable at  $300^\circ\text{K}$  and suffer photodissociation. Hence, we may conclude that these complex color centers are the temporary obstacles. On the other hand, the colloidal centers are stable at  $300^\circ\text{K}$  and are not photodecomposed by light of 700–2000 nm wavelengths<sup>15</sup> and these are the conditions satisfied (as shown above) by the permanent pinning centers.

We shall now consider in greater detail the possibility of estimating some characteristics of these colloids which pin dislocations. The process of formation of a colloid near a dislocation in NaCl can be represented as follows. Let us consider the NaCl lattice. The  $\text{Na}^+$  ions in the lattice form an fcc sublattice which can be regarded as a distorted bcc lattice of Na, where the  $\text{Cl}^-$  ions are located on the bases and at the centers of the faces. The increase in the concentration of the  $F$  centers is then equivalent to the replacement of  $\text{Cl}^-$  with electrons and a local part of the NaCl lattice then transforms into a distorted region of the bcc lattice of metallic Na. We shall now estimate the size of a colloid, acting as a permanent pinning center. If we assume that each electron arriving at a dislocation corresponds to one metal atom in a colloid and that the number of metal atoms in all the pinning centers is the same, it follows that the number  $\eta = \Delta q_e / \Delta c$  represent-

ing the electrons arriving at a dislocation per one pinning point is a measure of the number of atoms at a pinning center. Here,  $\Delta q_e$  is the change in the dislocation charge due to the arrival of electrons. If we assume that the loop length is  $L \sim 10^{-5} \text{ cm}$ , we find from our experiments (Figs. 3 and 4) that  $\eta \sim 50$ . This number represents the upper limit of the colloid size.

It is known that inclusions of this type produce strong bulk and tetragonal distortions and can therefore act as strong obstacles to dislocation motion. If we estimate the magnitude of such distortions following Friedel,<sup>16</sup> we can show that bulk distortions play the dominant role in our case. Then,  $W$  is the energy of the interaction of an edge dislocation with a coherent Na inclusion, which can be calculated according to Friedel<sup>16</sup> as

$$W = \frac{1}{3\pi} \frac{1+\nu_p}{1-\nu_p} \mu b \beta \int \frac{dv_{\text{incl}}}{r},$$

where  $\nu_p$  is the Poisson ratio,  $r$  is the distance from a dislocation, and  $\beta$  is the bulk mismatch factor. In our case, we have

$$\beta = \frac{v_{\text{NaCl}} - v_{\text{Na}}}{v_{\text{NaCl}}} = 0.12.$$

Here,  $v_{\text{Na}}$  and  $v_{\text{NaCl}}$  are the molecular volumes of Na and NaCl. If the inclusion in question is planar, contains  $\sim 50$  atoms, and is located at a distance  $r \sim 3b$  from a dislocation, we find that  $W \sim 0.5 \text{ eV}$ , which is in satisfactory agreement with the values of the activation energy of the process of the detachment of dislocations from permanent photoobstacles found in our experiments.

The hypothesis that the photodrag of dislocations is due to precipitation of metal colloids under the influence of light is quite reasonable and is confirmed by our experiments. Since the concentration of the  $F$  centers and the density of dislocations in our samples are relatively low, such colloids are small and their total concentration is low. In samples with a higher concentration of the  $F$  centers the exposure produces larger colloids on dislocations and there can be observed directly. In fact, bleaching of alkali halide crystals with high concentrations of the  $F$  centers frequently reveals decoration of slip bands with metallic colloids. It has been found<sup>15</sup> that small colloids precipitate at single dislocations. Heating of additively colored alkali halid crystals also results in decoration of dislocations with metal particles.<sup>17</sup>

The above hypothesis on the processes producing permanent pinning centers can be used to explain some of the features of the formation of colloids in alkali halide crystals. We can assume that colloids are formed heterogeneously and that their points of nucleation are mainly edge dislocations. In fact, dislocations are the main sinks for anion vacancies, and illumination fills them with electrons producing the  $F$  centers. Thus, the high concentration of the  $F$  centers needed for the onset of precipitation of the second phase is indeed created near dislocations. Therefore, colloids form mainly at dislocations and decorate them. According to Amelinckx,<sup>17</sup> edge and not screw dislocations are decorated in this way. This is in good agreement with the fact that screw

dislocations, which produce no dilatation distortions and have zero characteristic charge,<sup>18</sup> are not effective sinks for anion vacancies and, therefore, supersaturation in respect of the  $F$  centers does not appear near them. Thus, we shall explain the photodrag of dislocations by assuming that permanent photoobstacles are colloidal precipitates of metallic Na. Formation of these precipitates is the final product of the process of coagulation of the  $F$  centers. The temporary obstacles are intermediate products of the coagulation process. The proposed model provides the basis for explaining the photoplastic effect in alkali halide crystals containing the  $F$  centers.

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