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DYNAMICS OF STRESS FIELDS NEAR A CRACK TIP IN ALCALI-HALIDE CRYSTALS UNDER THE INFLUENCE OF ELECTROMAGNETIC RADIATION

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Abstract. This paper investigates the change in stress fields at crack tips in alkali-halide crystals under the influence of electromagnetic radiation in visible, ultraviolet and X-ray wavelength ranges. It is shown that electromagnetic radiation causes the relaxation of mechanical stress in crack tips. The relaxation is caused by reversible motion of dislocations into a crack cavity. It is established that the largest stress relaxation is observed under the influence of X-ray radiation.

1. INTRODUCTION

The polarized-optical research method for mechanical stress distribution in transparent models allows taking quantitative measurements to a sufficiently high degree of accuracy. In simplicity and presentation, this method surpasses other methods for experimental research in stress distribution.

This work is meant to investigate stress fields' dynamics near a crack tip under the influence of electromagnetic radiation with various wavelengths.

2. DESCRIPTION OF EXPERIMENT

The changes of stress fields near a crack tip were investigated on KCl crystal samples. With this purpose, in the sample of size 15x30x3 mm the plane crack (100) of length 10-11 mm was created. Fields of elastic stress in the crack tip were registered in polarized light. The crystal was positioned so that the crack plane was parallel to the polaruzation plane of the polarizor. The analyzer was in a crossed position.

In the first series of experiments, crystals were subjected to the influence of light radiation with wavelength λ = 760 nm. The stress field of the cracked crystal was photographed before and after the influence of radiation on the crystal. The duration of irradiation was 48 hours. The light exposure for the surface of samples was made $7 \cdot 10^3$ lux.

In the second series of experiments, the crystal was subjected to the influence of light radiation with wavelength λ = 400 nm. The duration of irradiation was 24 hours. The light exposure for the surface of the sample was made $11 \cdot 10^3$ lux.

In the third series of experiments, the crystal was exposed to the influence of ultraviolet radiation with wavelength λ = 250 nm. The field of the cracked crystal was photographed before and after one-hour radial influence on the crystal. The irradiation doze was made 229 J/kg.

In the fourth series of experiments, the crystal was exposed for 5 minutes to the influence of X-ray radiation with wavelength λ = 0.154 nm. The irradiation doze was $0.18\text{-}1.8 \cdot 10^{-5}$ J/kg.

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The received photographs were processed with a special program written in language Delphi. The program reads out two pictures, before and after irradiation, one pixel after another.

The relation between the light intensity and mechanical stress is given by [1]:

$$J = J_0 \sin^2 2\alpha \cdot \sin^2 \frac{\pi R}{\lambda}.$$

Here $R=CT\sigma$ is the linear difference of a course, C is the optical factor of stress, t is a sample thickness, σ is the main stress; J_0 is the biggest possible enlightenment, J is the intensity of enlightenment, α is the angle between the polarization plane and the direction of one of the main stresses, in our case $\alpha = 45°$, λ is the irradiation wavelength.

From this relation we find that

$$\sigma = \frac{\lambda}{\pi Ct} \arcsin \sqrt{\frac{J}{J_0}}.$$

It allows to evaluate the difference between stresses of the two pictures in corresponding points:

$$\Delta\sigma = \frac{\lambda}{\pi Ct} \left(\arcsin \sqrt{\frac{J_2}{J_0}} - \arcsin \sqrt{\frac{J_1}{J_0}} \right).$$

The program allows also investigating the fields in any direction from any point of the picture. This enables to estimate and compare the influence of electromagnetic radiation with various wavelengths on stress fields' dynamics in a crack tip.

3. RESULTS AND DISCUSSION

It is established that under the influence of electromagnetic radiation, in polarized light, there are noticeable changes in stress fields near the crack tips. There exist quantitative changes in the intensity of the photoelastic enlightenments which reflect value of elastic stress fields in a crack tip before and after the influence of electromagnetic radiation. It is observed that the largest stress relaxation is reached under the influence of X-ray radiation.

It is experimentally established that, under the influence of electromagnetic radiation of various wavelengths, there exist noticeable changes in the dislocation structure at crack tips: the integrated density of dislocations decreases, the length of plasticity zones shortens (dislocation rays) in the crack tip, a sector of discontinuity cures. By the method of double etching, it was shown that, under the influence of radiation, the noticeable changes in dislocation pictures are connected with reversible movement of dislocations in the rays of dislocation socket, formed in the crack tip at its stop. The change in the etching picture is observed not only in the rays of dislocation socket but also in the entire area that is adjacent to the crack tip [2].

Therefore, the influence of electromagnetic radiation of visible, ultraviolet and X-ray wavelength ranges causes mechanical stress relaxation in crack tips. The relaxation is caused by reversible movement of dislocations in the crack cavity and is capable to cause its partial curing [3]. The reversible movement of dislocations under the influence of X-ray radiation is observed only with small dozes of irradiation, $0.18\text{-}1.8 \cdot 10^{-5}$ J/kg. The doze increase does not contribute to the continuing movement of dislocations.

The intensity of stress relaxations and curing depends on irradiation wavelength. When the wavelength is reduced, the effect of stress fields relaxation and curing increases [3].

In the experiments, the luminescence of crystals and the crystals' coloring are observed under UV and X-ray irradiation. The mechanism of interaction between dislocation in ionic crystals and low-energy excitons may provide a foundation for the observed results. The excitons are formed under irradiation of ionic crystals with UV and X-rays. The interaction between an exciton and a charged step on a dislocation is accompanied by its displacement onto the single inter-nuclear distance. This interaction causes the increase in the screw elements of the dislocation, which was stopped by a stopper. Annihilation of screw pieces is accompanied by the separation of the dislocation from the stopper. Therefore, dislocation–exciton interaction can promote overcoming the stopper with the dislocation and provide the easier movement for the dislocation.

The dislocation-exciton mechanism is described in [4].

4. CONCLUSIONS

1. It is shown that the influence of visible, ultraviolet, X-ray radiation causes decrease in the general level of stress in a crack tip that was determined on photoelastic pictures.
2. It is established that the largest relaxation of stress fields is observed under the influence of X-ray radiation.

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