EVIDENCE OF A DISLOCATION FEEDING MECHANISM FOR CRACK REINITIATION IN F-COLORED NaCl

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ABSTRACT

A description of dislocation pinning and of crack reinitiation in sodium chloride is developed on the basis of cleavage energy studies in single crystals. Cleavage energy is shown to increase with the square root of F-center concentration in darkness. Nadeau has shown an increase of yield stress with color center density. Increased cleavage energy accompanying bleaching is taken to indicate a significant electrostatic component in the dislocation F-center interaction.

INTRODUCTION

There is considerable evidence that the presence of F-centers leads to increased indentation hardness and yield strength in NaCl crystals. The mechanism for such hardness increases has been shown to be connected with the direct interaction of anion vacancies or with interstitials which, of course, are related to the F-centers in the crystals. In the present work, it has been found that the cleavage energy of NaCl also increases with F-coloring and that the amount of this increase is much greater when the cleavage energy is measured during radiation of the sample by a tungsten lamp. (This radiation included enough F-band light to cause bleaching.) The close relationship between cleavage energy and hardness effects due to F-centers along with the observed radiation effect implies a mechanism for dislocation pinning in NaCl, as well as a possible description of the crack initiation mechanism in this material.

EXPERIMENTAL TECHNIQUE

Single crystals of Harshaw optical quality NaCl were water polished to remove surface defects and then additively colored using standard techniques. The colored crystals were prepared for testing by starting a cleavage crack along a (100) crystalline plane in the center of the sample. (Fig. 1) Holes were drilled in the specimen for mounting purposes. All sample preparation was done in the dark. The F-center density was measured both before and after testing, using a Beckman DK-2 spectrophotometer. Some of the crystals were tested in vacuum (at -175°C) and darkness as a control for the optical radiation tests. Both dark and optical radiation tests were carried out in vacuum and submerged in liquid nitrogen. No effect is seen due to the change from liquid nitrogen to vacuum.

EXPERIMENTAL RESULTS

The cleavage energy of the crystals was determined from the critical force for crack propagation according to the method of Gillis and Gilman. The results of the various tests are shown in Fig. 2. From these results, one can observe that the crack energy increases linearly with the one-half power of concentration of F-centers in darkness. Nadeau has shown that the yield stress of NaCl increases with F-center concentrations.

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When measured during optical radiation the crack energy is the same as in the dark case until a concentration of about $10^{15}$ F-centers/cm$^3$ is reached. For greater F-center densities, the cleavage energy with radiation is greater than in darkness, the value in light being over twice the value in dark at $3 \times 10^{16}$ F-centers/cm$^3$. (Higher color center densities are prevented by colloid formation.) While it is to be admitted that the cleavage energy measured by this technique presents a reasonably wide scatter of experimental points, the general trend as indicated by the curve is quite clear.

It is interesting that radiatively* colored specimens show higher cleavage energies than do additively colored samples of the same color density. This is believed to result from the Cl interstitials which are formed in conjunction with radiation coloring. A more quantitative study of this result is now in progress.

DISCUSSION

In view of the increase in both hardness and cleavage energy with F-coloring one is led to seek an explanation of both effects in terms of dislocation-defect interaction.

First, one must relate the pinning of dislocations with the observed crack energy. This relation can be established if one assumes that the reinitiation of the crack involves a mechanism whereby dislocations are moved toward the crack tip by the applied stress field as has been suggested by Cottrell.\(^6\) Thus, any mechanism which hinders the movement of dislocations in the crystal would hinder crack initiation as well as increase the hardness of the crystal. If one decreased the pinning of the dislocations, crack initiation would be facilitated and lower values of crack energy would be observed. That such is the case here is suggested by the fact that both the cleavage energy and hardness increase with coloring.

Further evidence of this crack mechanism is shown by the higher measured crack energy in x-radiation colored samples than in additively colored

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* X-radiation 50 kv.