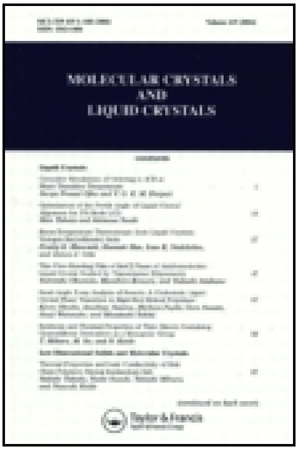

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The Investigation of Heat, Release in Slip Bands Consisting of Edge or Screw Dislocations

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The Investigation of Heat, Release in Slip Bands Consisting of Edge or Screw Dislocations

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The temperature rise in screw and edge dislocation slip bands of the NaCl crystals by deformation by compression has been studied with the help of cholesteric liquid crystals CLC.

INTRODUCTION

It is known that over 90% of the work, spent on the plastic deformation of a crystal solid dissipates in specimen transforming to heat which leads to an increase of the specimen temperature.

The amount of local heat in slip bands has not yet been determined because of lack of reliable methods of registration. The theoretical estimates of heat release in slip bands are contradictory.

The aim of the present work is to evaluate a temperature rise in slip bands consisting of edge or screw dislocations during the deformation of NaCl crystals by compression.

DISCUSSION

a) The method of experiment

The temperature rise was estimated with the help of thermosensitive layers of cholesteric liquid crystals (CLC).[3] Two specially prepared thermosensitive compositions of CLC were used (CLC–I and CLC–II) with selective

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reflection at 30°C. They provided a good colour contrast in the temperature intervals

(1.5–2°) – CLC–I and
(3–5°) (CLC–II)

In addition, a sample of CLC–III consisting of 26% of cholesteryl chloride and 74% of cholesteryl oleate was studied.

The CLC–III exhibits a green colour in the temperature range from 0° to 18°C, an orange colour from 18 to 20°C and a red colour from 26° to 30°C. At 30.3°C it transforms to the isotropic liquid. This CLC mixture is characterized by rather high sensitivity to deformation.

The NaCl crystals were prepared for experimentation as follows:

1) Preparation of preliminary specimens 12 × 12 × 12 mm in size.

2) Mechanical grinding and polishing the ends of the specimen.

3) Annealing at 600°C for 5 hours in air.

4) Irradiating the ends of the specimen to dose about 10^4r to prevent the deformation of the ends.

5) Cleaving test specimens 3 × 3 × 12 mm in size.

6) Scratching one of the lateral faces of the specimen.

7) Chemical polishing the specimen in a solution of the following composition: 500 ml CH_3OH + 100 ml H_2O + 40 g $CaCl_2$.

The experiments on deformation by compression were carried out at room temperature in a testing machine of Instron type and specimen where slip bands were expected to appear: the thermal capacity of the film and the time taken to respond to changes of temperature were both small enough to be neglected. The change of CLC colour during specimen deformation was registered on colour film.

b) The selective etching experiments

If the sample prepared as indicated above is deformed and etched after the deformation one can observe the following picture: two slip bands inclined at 90° to each other and at 45° to the edge of the crystal appear[4] (Figure 1). These slip bands consist of edge dislocations.

At first narrow slip bands seem to arise but in the course of deformation they eventually widen. The transition from a state arising from the widening slip bands corresponds with the beginning of the yield stress on a stress strain curve. The rate of slip band expansion is a very sensitive function of the applied stress. The slip bands consisting of screw dislocations are revealed by selective etching on the surface B (Figures 3 and 4).

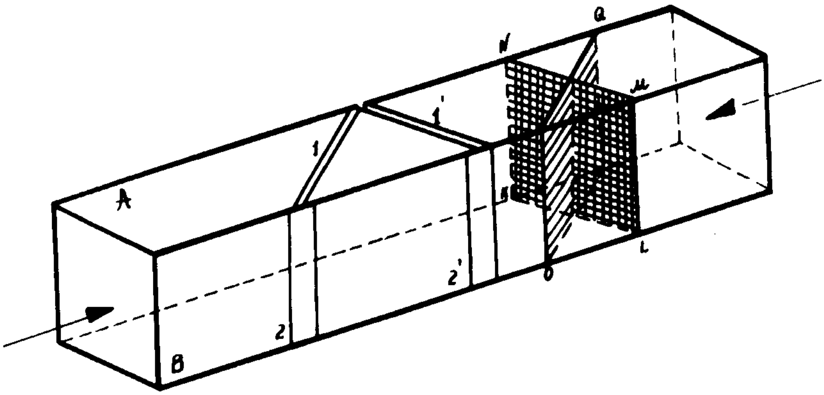

FIGURE 1 A schematic drawing of a NaCl specimen (the arrows indicate the direction of loading). LMNK and OPQR are the operating slip planes, 1-1' are slip lines consisting of edge dislocations, 2-2' are slip lines consisting of screw dislocations.

These slip bands are wider than those consisting of edge dislocations. The dependence of the width of screw and edge slip bands on the degree of deformation is presented in Figure 4.

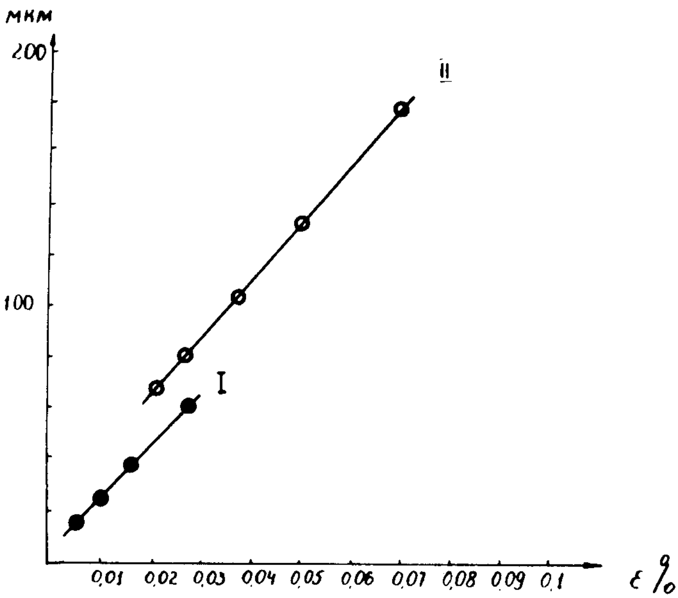

FIGURE 2 The dependence of the width of slip bands on the total deformation. 1—edge dislocations, 2—screw dislocations.

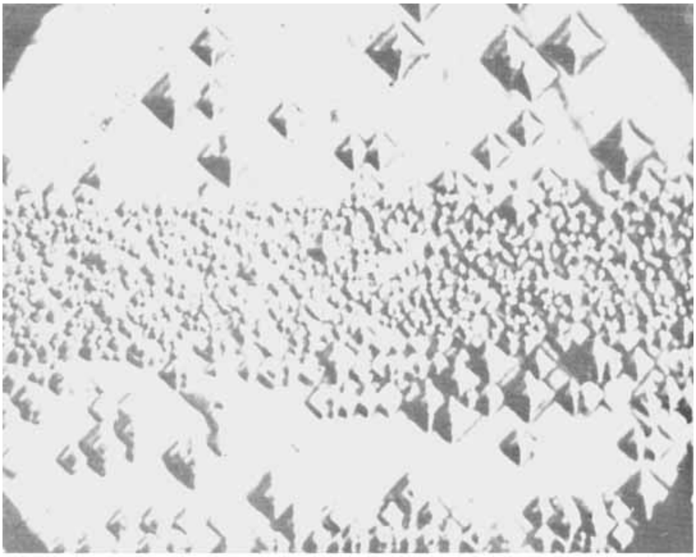

FIGURE 3 A picture of selective etching a slip band consisting of edge dislocations. × 500.

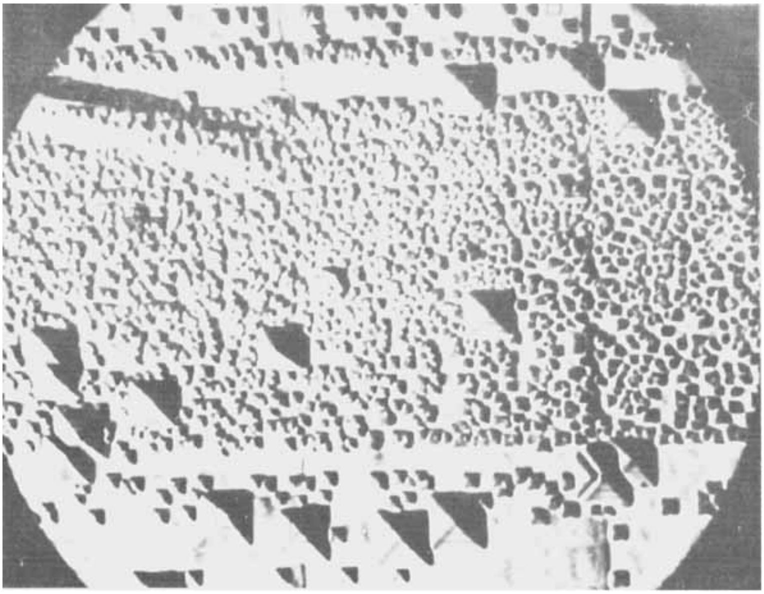

FIGURE 4 A picture of selective etching a slip band consisting of screw dislocations. × 500.

c) The experiments with the thermo-sensitive mixtures CLC–I and CLC–II

A thin layer of CLC–I was deposited on the surface A (Figure 1) to study heat release in slip bands consisting of edge dislocations. The remaining three lateral surfaces of the studied specimen were blackened to provide better conditions for observing colour changes of the CLC layer.

The observations show that the colour of the CLC–I rapidly changes at the moment of the appearance of slip bands which coincide with the beginning of the plastic deformation. It is as if the band "flashes" and becomes green-coloured at the rate of deformation equal to 0.0003 s^{-1} or blue-coloured (at the rate of deformation equal to 0.008 s^{-1}. This corresponds to a temperature rise in the slip bands from 0.5 to 1°. A sharp local rise of the temperature (operation time of separate slip bands is about 10^{-5} s)[5] leads to a sharp local change of surface tension in the CLC layer and to the onset of a convection (so-called Morangony convection).[6] A further observation of temperature changes becomes complicated by this CLC flow.

The attempt to reveal a temperature rise in slip bands consisting of screw dislocations with the help of CLC–I was unsuccessful because of the full flowing of CLC–I away from the slip band. We were able to fix colour changes in such slip bands with the help of CLC–II having a wider range of selective reflection. The temperature change revealed by CLC–II was up to 1.5° at the deformation rate of 0.0003 s^{-1} and 3° at the deformation rate of 0.008 s^{-1}. In the case of a slip band consisting of screw dislocations a wider region is coloured. This is in accordance with the data on selective etching.

Thus it has been established with the help of the CLC–I and CLC–II where the temperature in slip bands consisting of edge dislocations changes from 0.5° to 1° while in slip bands consisting of screw dislocations changes from 1.5 to 3° with the deformation rates 0.0003 and 0.008 s^{-1}, respectively.

The area of the heating field is in accordance with the etching picture observed. Impulse local heating in a slip band gives rise to a hydrodynamic flow of CLC which complicates the observation of the temperature rise in a dynamic regime.

d) The experiments with CLC–III

Having obtained the data on the local temperature rise in slip bands we carried out control experiments with the help of CLC–III. The experiments were made in a similar way as before with CLC–I and CLC–II at the deformation rate of 0.008 s^{-1}. The temperature at which the specimen is deformed was established at 0.5°C under the point of CLC–III transition to isotropic liquid, i.e. at 29.8°C when observing the temperature rise in slip bands con-

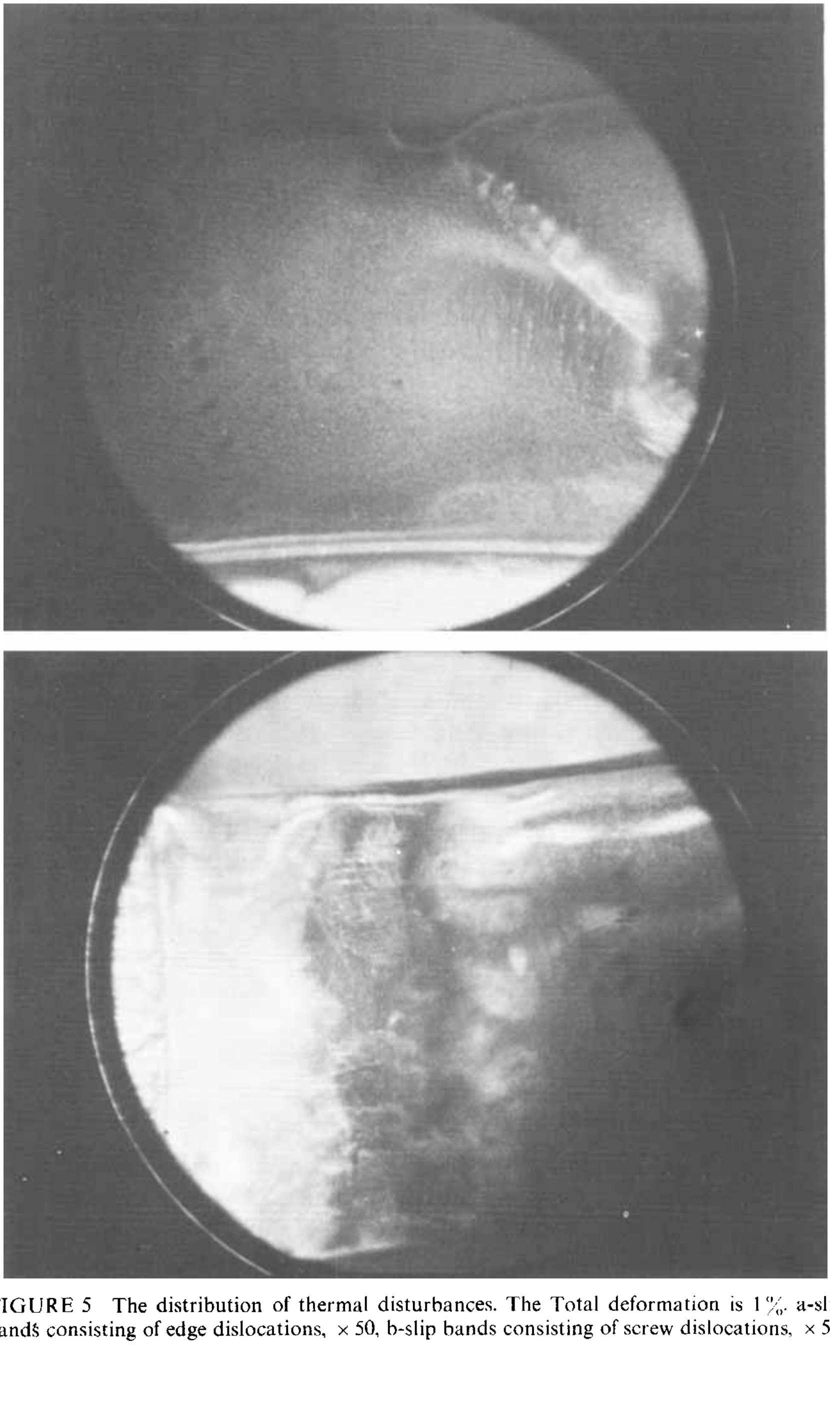

FIGURE 5 The distribution of thermal disturbances. The Total deformation is 1%. a-slip bands consisting of edge dislocations, × 50, b-slip bands consisting of screw dislocations, × 50.

sisting of edge dislocations and by 1° under the transition point, i.e. at 29.3°C when studying slip bands consisting of screw dislocations.

In both cases melting of the CLC–III was observed in the region over the slip band which was revealed by the change of the CLC–III texture from planar to confocal.[7] This means that the temperature in the slip bands exceeded 30.3°C (the temperature of the CLC–III transition to isotropic liquid), i.e. the temperature difference induced in edge dislocation slip bands exceeded 0.5°C and that induced in screw dislocation slip bands exceeded 1°C.

Thus, from the data obtained it may be concluded that first, the collective movement of both edge and screw dislocations is accompanied by heat rise at room temperature.

This confirms that the high local rate of the plastic deformation inside slip bands considerably exceeds the mean macroscopic deformation rate calculated for the specimen on the whole. Therefore, it is the local deformation rate rather than the rate averaged on the whole volume of the specimen will correctly determine the physical processes connected with the collective movement of dislocations in the process of deformation.

Secondly, the temperature rise in screw dislocation slip bands is approximately three times more than that in edge dislocation slip bands. This may be connected with dissipation of the screw dislocations due to the interaction with point defects.

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