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Surface distortion features on indented CaF_2 cleavages

G C JAIN and P N RAWAT
Department of Applied Physics, Government Engineering College, Jabalpur 482011, India

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Abstract. Surface distortion features around static indents on the cleavages of CaF_2 single crystals have been investigated by multiple beam interference technique. At room temperature microcracks around such indents nucleate at the sinking in regions. Fizeau fringe patterns (around indents at 200° C) revealed a transition from a three-fold to a six-fold material flow.

Keywords. Calcium fluoride ; dislocation reaction ; multiple beam interferometry; surface distortion.

1. Introduction

Calcium fluoride crystals possess only limited ductility at room temperature and therefore, their bulk deformation behaviour has been studied in the past only after heating them to higher temperatures and subjecting them to shear in compression (Evans *et al* 1966 ; Feltham and Ghosh 1968 ; Phillips 1961). Temperature-dependent indentation deformation processes in calcium fluoride have been reported very recently (Jain and Rawat 1982). These studies have stimulated the present work of studying the influence of temperature on the surface distortion features on indented CaF_2 cleavages.

2. Experimental procedure

The CaF_2 samples were heated at different steady temperatures using a flat-bottomed heating device (Jain 1979) suitably mounted on the Reichert microscope stage ; the samples were then indented by the Vickers diamond pyramid. Surface distortion features around indents were studied by using multiple beam interference fringes as well as using the fringes of equal chromatic order (FECO).

3. Results and discussion

The Fizeau fringe patterns of figures 1 and 2 (a) show the shapes acquired by the surface distortion patterns around Vickers indents at room temperature and at 100° C respectively. In both cases there are three arms extending symmetrically around the indents. However, the symmetry remains incomplete (figure 1) due to microcracks between the two arms of the pattern. A study by FECO has revealed that the arms of these patterns are the regions where the piling-up of the displaced material has taken place, and the regions of sinking-in fall in between the arms of the pattern. Pattern in figure 2 (a) shows sharper distortions both above and below the surface than those in figure 1. The microcrack of figure 1 has nucleated in the sinking-in region.

By developing suitable etchants for the four {100}, {110}, {111} and {211} crystallographic surfaces of CaF_2 crystals the present authors (Jain 1979; Jain *et al* 1981a,b) had studied dislocation etch figures on them and concluded that CaF_2 slips primarily on the {100} planes. These results agree with those reported by Schmid and Boas (1950). The glide traces on the (111) cleavage surface of CaF_2 being parallel to $\langle 0\bar{1}1\rangle$ directions. The resultant flow of the material around indents causes piling-up along the $\langle \bar{1}\bar{1}2\rangle$ directions and the sinking-in along the $\langle 11\bar{2}\rangle$ directions.

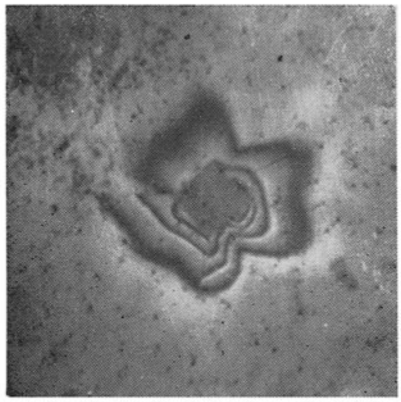
The slip system being {100} $\langle 01\bar{1}\rangle$, two dislocation vectors such as $[0\bar{1}1]$ and $[10\bar{1}]$ in {100} planes give rise to a resultant dislocation vector $[1\bar{1}0]$ in {110} planes. As this dislocation vector is accompanied by the release of energy it is favoured (Keh *et al* 1959). Piling-up of such dislocations generate cracks along {110} planes ; these cracks then appear along the $\langle 11\bar{2}\rangle$ directions on a (111) plane of CaF_2 crystals.

Fizeau fringe pattern around the Vickers indent at 200° C shown in figure 2 (b) reveals a tendency of its arms to split into two. A study by FECO reveals that there is a six fold weak piling-up and a six fold pronounced sinking-in around the indent. The weak piling-up is probably due to the large spread of the displaced material.

Evans *et al* (1966) have shown that in CaF_2 crystals at about 200° C a secondary slip system {110} $\langle 1\bar{1}0\rangle$ too gets activated in addition to the primary {100} $\langle 0\bar{1}1\rangle$ slip system. The glide traces due to the secondary slip system lie along the $\langle \bar{1}\bar{1}2\rangle$ and $\langle \bar{1}10\rangle$ directions on the (111) plane.

The three-fold distortion feature of figures 1 and 2 (a) is the result of glide along the $\langle 0\bar{1}1\rangle$ directions. Now with the activation of the secondary system, two more glide traces along $\langle \bar{1}\bar{1}2\rangle$ and $\langle \bar{1}10\rangle$ directions play their role in giving shape to the distortion feature around the indent on a (111) plane at 200° C. Considering the contribution of all the glide elements, in all, there are nine glide planes causing slip along $\langle \bar{1}10\rangle$ directions whereas there are only three planes which cause slip along $\langle \bar{1}\bar{1}2\rangle$ directions. Naturally the glide along $\langle \bar{1}10\rangle$ directions will now be more prominent than the one at lower temperature. It may be seen that the material flow along $\langle \bar{1}\bar{1}2\rangle$ directions in this case will act merely as a separator for the $\langle \bar{1}10\rangle$ glide traces causing the splitting-up of each of the three arms into two ; thus the distortion feature acquires a six-fold piling-up along $\langle 0\bar{1}1\rangle$ directions and a six-fold sinking-in along $\langle 11\bar{2}\rangle$ directions.

It may also be seen that although the indenting load is the same, the size of the deformation pattern is larger in figure 2 (b) than that of figure 2 (a). Such an increase in the extent of deformation has earlier been explained by the present



(1)

(2a)

(2b)

Figure 1. Fizeau fringe pattern around Vickers indent (due to 132 g load at room temperature) on a CaF_2 cleavage (× 100).

Figure 2. Fizeau fringe patterns around Vickers indents on CaF_2 cleavages at 124 g load (× 150) (a) at 100° C, (b) at 200° C.

authors (Jain and Rawat 1982) in terms of the easier glide of dislocations with the increase in temperature.

4. Conclusions

At room temperature indentation deformation on CaF_2 cleavages results in a three-fold piling-up and a three-fold sinking-in of material in the directions of easy and hard glide respectively ; microcracks, if any, are initiated preferentially at the sinking-in regions. At about 200° C the pattern of surface distortion changes to a six-fold piling-up and a six-fold sinking-in of material around indents due to the activation of secondary system of glide elements.

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