more important than indentation creep at low homologous temperatures, whilst the converse should hold at higher homologous temperatures. These results indicate that the critical transition temperature is in the region of 0.25 to 0.3 T_m for the standard (12 sec) indentation measurement on rocksalt type crystals.

It is clear that, whatever more detailed analyses are subsequently developed, the apparently anomalous results reported for anisotropy in the hardness of rocksalt crystal structure are due to indentation creep phenomena. Moreover, this work emphasizes the need to control both the indentation time and homologous temperature for accurate comparisons of hardness data in crystalline solids.

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C. A. BROOKES
R. P. BURNAND*
J. E. MORGAN
Department of Engineering Science,
University of Exeter,
Exeter, Devon, UK

*Present address: De Beers Diamond Research Laboratory, P.O. Box No. 916, Johannesburg, South Africa.

Complex faults in sodium beta alumina

Sodium beta alumina is a ceramic oxide that is currently under intense investigation for its application as a solid electrolyte membrane in the sodium-sulphur battery [1]. At Cornell we are investigating the relation between microstructure, impurity content, and ionic conductivity in this material. Characterization of the microstructure is necessarily an important part of such a project. In this letter we report on the nature of some planar faults we observed in sodium beta alumina.

Polycrystalline solium beta alumina samples were prepared from commercial powder* by sintering in an argon atmosphere at temperatures between 1700 and 1750° C. The samples were packed in β-alumina to minimize soda loss during sintering. Sintering times were typically 45 min. Transmission electron microscope samples were prepared by ion-milling. The thin foils were observed in a Siemens 101B electron microscope.

Frequently, networks of planar faults can be observed, as shown in Fig. 1. These faults are probably similar to those reported by LeCars *et al.* [2], but these authors did not perform an analysis. The trace analysis showed that the planar faults were contained in the $\{2\bar{1}\bar{1}0\}$ type planes of the hexagonal beta alumina. This corresponds to the $\{1\,1\,0\}$ type planes in the "spinel block" [3] of the crystals. It was found that the faults were never observed when the $[0\,0\,0\,1]$ direction was perpendicular to the electron beam, indicating that the fault displacement vectors have to be contained in the basal plane. Since the faults extend over large distances, they must be of low energy, ruling out displacements that would produce oxygen stacking faults in the "spinel blocks". This is a reasonable observation, since to our knowledge no widely dissociated $\frac{1}{4}\langle 1\,1\,0\rangle$ dislocations have been observed in spinel type crystals, indicating indeed that anion stacking faults with $R = (1/12)\langle 1\,1\,2\rangle$ in spinel type

* Alcoa XB2 "superground".

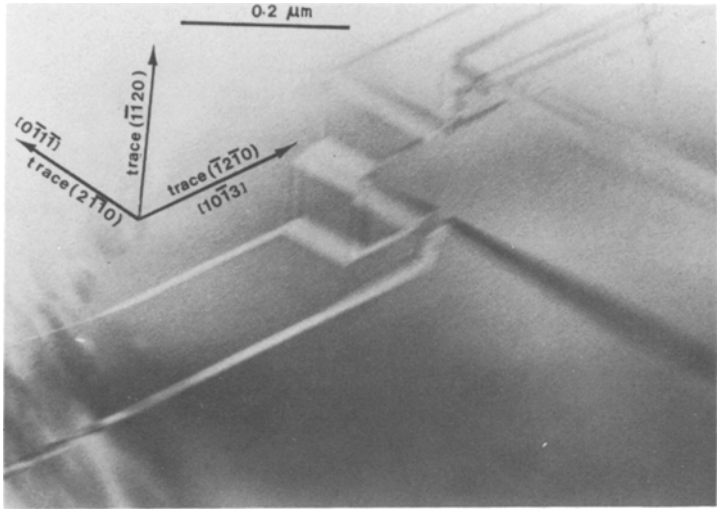

Figure 1 Network of planar faults in sodium beta alumina. The trace analysis shows that the faults are on $\{2\,\bar{1}\,\bar{1}\,0\}$ type planes.

structures have a high energy [4]. For the faults in sodium beta alumina, this leaves as possibilities $R_1 = \frac{1}{6}a\langle 2\,\bar{1}\,\bar{1}\,0\rangle$ (magnitude $= a/2$) or $R_2 = \frac{1}{2}\langle 1\,0\,\bar{1}\,0\rangle$ (magnitude $= a\sqrt{3}/2$). The electron microscope observations confirm that the observed faults are indeed of this type. Fig. 2 shows a bright-field and a $1\,0\,\bar{1}\,2$ dark-field image for which the fault labelled A is out of contrast. This fault is in the $(\bar{1}\,2\,\bar{1}\,0)$ plane, as the trace indicates. The displacement vector of this fault is thus either $R_1 = \frac{1}{6}a\,[\bar{1}\,2\,\bar{1}\,0]$, perpendicular to the fault plane, or $R_2 = \frac{1}{2}a\,[1\,0\,\bar{1}\,0]$ parallel to the fault plane. The magnitude and direction of these faults are confirmed by the observation that the faults are in contrast with $\mathbf{g} = 2\,\bar{1}\,\bar{1}\,0$ ($|\mathbf{g}| = 2/a$), and out of contrast with $\mathbf{g} = 4\,\bar{2}\,\bar{2}\,0$ ($|\mathbf{g}| = 4/a$). An examination of the spinel structure shows that the two possible faults vectors R_1 and R_2 in this geometry produce identical cation faults in the "spinel blocks". This is demonstrated in the 1 1 1 projection of the spinel lattice Fig. 3a (after Hornstra [5]). The two displacement vectors also produce identical faults in the conduction planes of sodium beta alumina, as shown in Fig. 3b. Since the faults produce only cation faults in the spinal blocks, and anion faults in the conduction plane, they are of a complex nature. Distinction between R_1 and R_2 fault vectors only arises in the way the faults are actually produced: by climb of $\frac{1}{6}a\langle\bar{1}\,2\,\bar{1}\,0\rangle$ type dislocations, or by glide of $\frac{1}{2}a\langle 1\,0\,\bar{1}\,0\rangle$ type dislocations in the $\{\bar{1}\,2\,\bar{1}\,0\}$ type planes. At present the mechanism of fault formation is not known; we do favour the $\frac{1}{6}a\langle\bar{1}\,2\,\bar{1}\,0\rangle$ type description of the faults, since dislocations that would be involved have a considerably lower energy than the $\frac{1}{2}a\langle 1\,0\,\bar{1}\,0\rangle$ type dislocations. This would imply that the faults are produced at high temperature, i.e. during the sintering of the sodium beta alumina powder, when diffusion can allow the fault formation.

We also note that the sodium ion conduction plane is altered at intersection with the faults (Fig. 3b), and one may expect that the sodium ion conductivity would be affected. It is, therefore, likely that some of the ionic blocking effects, deduced from the measurement of impedance as a function of frequency (see Powers and Mitoff [6])

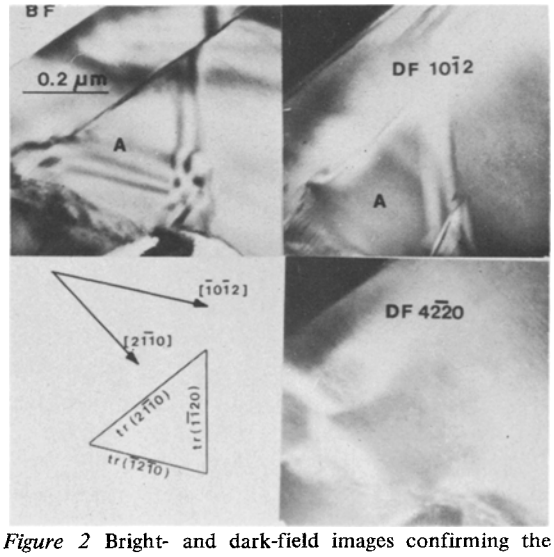

Figure 2 Bright- and dark-field images confirming the fault displacement vectors.

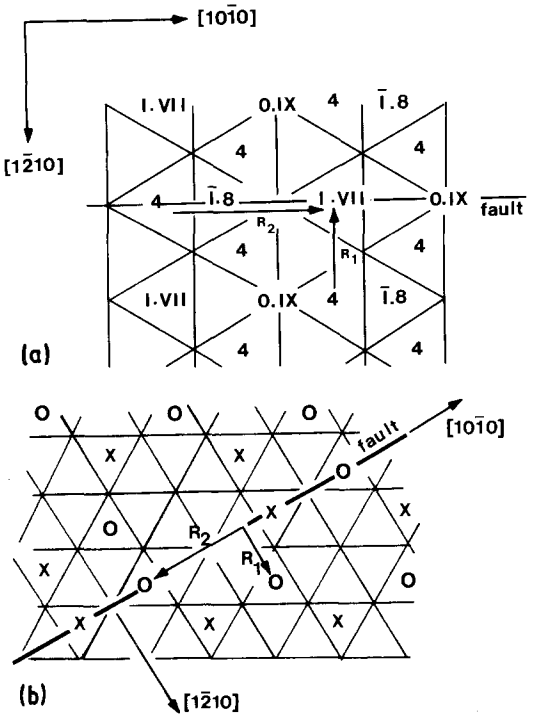

Figure 3 (a) Part of the perfect spinel unit cell projected onto the (1 1 1) plane [(0 0 0 1) plane of sodium beta alumina] (after Hornstra [5]). The oxygen ions are not shown. The roman numerals give the relative heights of the tetrahedral interstices in multiples of $1/24 a_s \sqrt{3}$ (a_s is the lattice parameter of "spinel block" in sodium beta alumina). The Arabic numerals refer to the position of the octahedral interstices. The equivalence of R_1 and R_2 is shown. (b) Fault produced in the sodium conduction planes at the intersection of the fault boundaries. Note again the equivalence of R_1 and R_2. O = position of oxygen ions in the conduction plane; x = possible position of sodium ions. The oxygen ions in the adjacent planes are on the grid intersections.

would be partially attributable to the presence of these faults.

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L. C. DE JONGHE
Department of Materials Science and Engineering, Cornell University, Ithaca, New York, USA

Fracture processes in polymethylmethacrylate

A recent paper [1] raises a number of points on the topic of fracture in PMMA that have been of considerable interest recently. Marshall *et al.*, (e.g. [2]) and the group at G.E. Schenectady, (e.g. [3–5]), have studied the phenomenon in considerable detail, and have emphasized the significance of the interrelation between crazing and fracture in glassy thermoplastics, (e.g. PMMA), albeit mostly at relatively slow crack speeds.

In particular, the effect of the molecular weight of PMMA on its fracture behaviour, as studied in [1], was considered in [6]. These data include measurements of the increase of fracture surface energy (γ) with molecular weight in PMMA. A value of strain energy release rate derived from these measurements gives $G = 0.266\,\text{kJ m}^{-2}$ for a PMMA with a viscosity average molecular weight of approximately 190 000 at slow crack speeds. This is not inconsistent, at first sight, with the values of $G = 0.83 \pm 0.1$ and $1.43 \pm 0.79\,\text{kJ m}^{-2}$ quoted in [1] for a crack moving in a PMMA of molecular weight 163 000 at several hundred metres per second, since it has been demonstrated [7] that G increases significantly with crack speed in PMMA. However, if the data from [7] are compared with the previously published [8,9] data by the author