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The Compression Textures of Polycrystalline Materials of Caesium Chloride Structure Type

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Specimens prepared by compressing, in a steel die, powders of CsCl, TlCl and NH_4Cl, at up to 75 tons/in.^{2}, are investigated by electron diffraction. The compression textures under these conditions are found to be ⟨111⟩. This texture is shown to be expected on the basis of slip on the usual systems, i.e. {011}, ⟨100⟩.

1. Introduction

For comparison with our results in experiments on the surface deformation and re-orientation of non-metallic salts during unidirectional abrasion, we have studied also the textures developed by pure compression in these materials. We have recently described (Dobson & Wilman, 1961) the results for various alkali halides of rocksalt type. The compression textures found for some salts of CsCl structure type (CsCl, TlCl and NH_4Cl) are now described below.

2. Experimental

The initial materials used were in the form of powders. The purity quoted by the suppliers was:—CsCl (from B.D.H.) >99%; TlCl (B.D.H.) ?%; NH_4Cl ('Analar', Hopkin & Williams Ltd.) >99%. These materials were ground further by hand with a pestle and mortar, and the mean particle diameter was then of the order of 150μ for the CsCl and NH_4Cl, and 60μ for TlCl.

The powders were compressed in a steel die of 0·5 in. diameter, using pressures up to 75 tons/in.^{2}. On removal from the die, the specimens were seen to be well-compacted and had very smooth shining surfaces. They were about 8 mm. thick and had densities approximately 0·95, 0·98 and 0·99 of the true densities of CsCl, TlCl and NH_4Cl respectively.

The plane ends of the cylindrical specimens, normal to the compression axis, were examined at grazing incidence by electron diffraction, using a camera length of 47 cm., and electrons accelerated through 60–70 kV. Electron-diffraction patterns showing more clearly the nature of the preferred orientation were obtained from the TlCl and CsCl surfaces exposed by etching a few sec. in 10% HCl-water solution for the TlCl and 10% H_2O in propyl alcohol for the CsCl, respectively.

3. Results

Figs. 1 to 3 are typical of the results obtained, and in all cases show relatively strong orientation with a ⟨111⟩ axis parallel to the compression axis. This is seen not only from the presence of the arc on the 111 ring position centred on the plane of incidence but also because the positions of the intensified arcs which can be recognized on other ring positions agree with the diffraction positions which would be expected from the ⟨111⟩-oriented crystals, shown in Fig. 4.

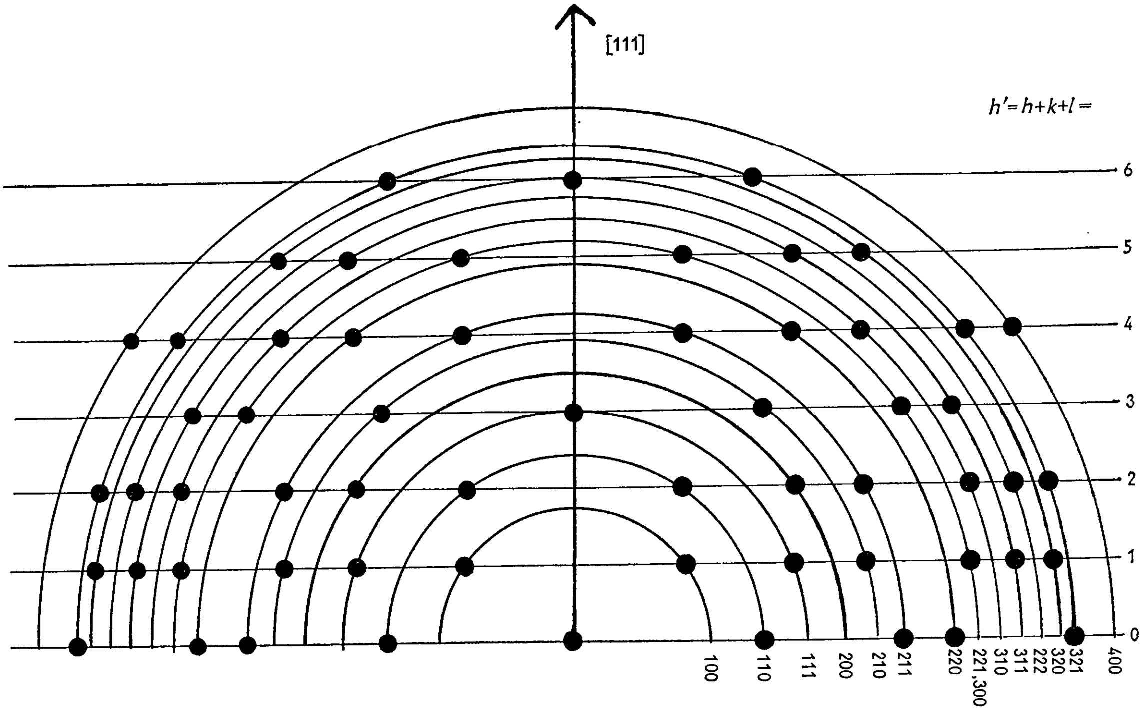

Fig. 4. Theoretical positions of diffractions from one-degree ⟨111⟩-oriented simple-cubic crystals.

4. Discussion

The results from the compressed CsCl, TlCl and NH_4Cl powders, show that plastic flow has occurred, resulting in a one-degree orientation being developed with its axis parallel to the compression axis. In all cases a well-defined ⟨111⟩ compression texture was observed.

It is easily shown, by a similar method to that used in the case of NaCl (Dobson & Wilman, 1961), that this ⟨111⟩ compression texture would be expected theoretically on the basis of plastic flow by slip, taking place on the normal type of slip system for these materials.

NH_4Cl and NH_4Br crystals are known to slip on planes of {011} type along a ⟨100⟩ direction (Johnsen, 1902; Seifert, 1927), and thus there are six different slip systems available in this lattice. The ones which are the most favourable to operate in any one crystal, when the polycrystalline specimen is subjected to a unidirectional compressive stress, are the ones for which the resolved shear stress along the slip plane, in the slip direction, is highest. Representing the operative direction of the compressive stress on any particular crystal under consideration, by a point in the unit triangle of the stereographic projection, with vertices defined by the [100], [110] and [111] directions (cf. Fig. 5), then the most favourable slip systems for various types of stress direction in this triangle are as shown in Table 1.

Table 1. *The most favourable slip systems (having highest resolved shear stress) in* CsCl-*type crystals, as a function of stress direction, for slip on* {110} *along* ⟨100⟩

Stereographic projection of stress direction	Most favourable slip systems	No. of favourable systems
Within unit triangle	(011) [100]	1
Boundary [100]/[110]	(101) [010]; (10$\bar{1}$) [010]; (011) [100]; (01$\bar{1}$) [100]	4
Boundary [100]/[111]	(011) [100]	1
Boundary [110]/[111]	(101) [010]; (011) [100]	2
[110]	(101) [010]; (10$\bar{1}$) [010]; (011) [100]; (01$\bar{1}$) [100]	4
[111]	(110) [001]; (101) [010]; (011) [100]	3
[100]	(110) [001]; (1$\bar{1}$0) [001]; (101) [010]; (10$\bar{1}$) [010]; (011) [100]; (01$\bar{1}$) [100]	6

The resolved shear stress is equal to the applied stress multiplied by $\cos\lambda \cos\psi$, where λ is the angle which the direction of the compression stress on the crystal under consideration, makes with the slip-plane normal; and ψ is the angle between this compressive stress direction and the slip direction. The contours of the resolved shear stress for the most favourable slip system (011) [100] are shown in Fig. 5, where the numerical values represent $\cos\lambda \cos\psi$. In order to

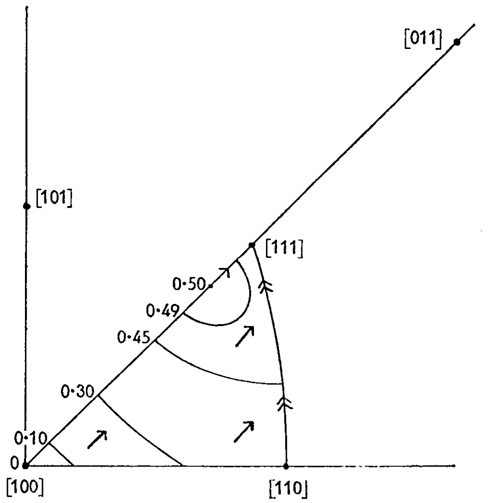

Fig. 5. Unit triangle of stereographic projection, showing contours of resolved shear-stress values for (011) slip planes, with slip along [100]. Typical directions of movement of the effective axis of compression are shown by the arrows, for slip on this system alone, and (double arrows) for the resultant in the special case of points on the boundary [110]–[111], where slip can occur both on (011) [100] and (101) [010].

retain cohesion at the grain boundaries, much of the slip must take place when the effective stress is along a direction such that a number of slip systems are equally favourable (Taylor, 1938). The direction of the effective stress exerted on any one crystal grain will therefore tend to move down the contour gradient in Fig. 5 towards directions such that multiple slip can occur simultaneously (see Calnan & Clews, 1950, 1951). When such multiple slip occurs, however, it is associated with little or no lattice rotation.

However, for all directions of the effective compressive stress within the unit stereographic triangle, there is only one most favourable slip system in the present case, and in order to account for the lattice rotation observed, some single slip must occur on this system. Slip on a single plane, caused by a compressive stress, results in a lattice rotation such that the slip-plane normal tends to rotate towards the axis of compression. The general directions of this lattice rotation for typical directions of the effective compressive stress, i.e. corresponding to typical points in the unit triangle, are indicated by arrows in Fig. 5. If the effective compressive stress direction lies on the [110]–[111] boundary, then duplex slip occurs and the resultant lattice rotation is the vector sum of the two single rotations.

It is seen clearly from Fig. 5 that for all compressive stress directions represented by points in the unit triangle, slip on the most favourable slip plane, (011), results in a lattice rotation towards a final orientation such that a ⟨111⟩ axis is parallel to the compression axis. In the final stable orientation the effective stress direction on the crystal approximates to the direction of the applied compressive stress. This orientation is therefore in agreement with the compression texture observed.

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