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The projection topograph: a new method in X-ray diffraction microradiography.

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Some time ago the author described a method for the examination of crystal sections using penetrating characteristic radiation (Lang, 1957*a*). The 'section topographs' so obtained show imperfections in the interior of the crystal. With this technique it was discovered that individual dislocations can be detected by X-ray diffraction (Lang, 1957*b*, 1958). However, a large number of section topographs must be compared in order to build up a picture of the spatial distribution of imperfections in the crystal. To obtain this information more readily a new method of diffraction microradiography has been developed which shows directly the imperfection distribution in the specimen volume under investigation. Fig. 1 is a plan of the experimental arrangement. The X-ray beam from a relatively distant X-ray tube passes through the specimen crystal after appropriate horizontal and vertical limitation at the slit. The crystal is set so that Bragg reflection occurs from a lattice plane making a high angle with the face of the crystal slab. A fixed screen intercepts the directly transmitted beam but allows the Bragg-reflected beam to reach the film. Crystal and film are both mounted on an accurate linear traversing mechanism. During the exposure they move back and forth together as indicated by arrows. The two-dimensional pattern appearing on the film is a projection of the crystal slab and its imperfection content, hence the name 'projection topograph'. It will be seen that the projection topograph is equivalent to a superimposition of many section topographs. Consequently the maximum imperfection density at which individual imperfections can be resolved is much lower in projection topographs than in section topographs. However, the projection topograph presents a useful survey of the over-all distribution of imperfections. Additional information on the imperfection distribution may be obtained by stereo-diffraction microradiographs composed from a pair of projection topographs, of the *hkl* and $\overline{hkl}$ reflections, respectively. Such stereos give a vivid three-dimensional picture of the course of sub-grain boundaries or individual dislocations within the volume of the crystal slab. In the author's apparatus the maximum height of X-ray beam is about $2\frac{1}{2}$ cm. and the maximum length of traverse is also $2\frac{1}{2}$ cm. These dimensions define the maximum area of crystal slab that can be examined in one exposure. In practice, penetrating radiations such as Mo $K\alpha$, Ag $K\alpha$ and W $K\alpha$ have been used so that very thin specimens are not required.

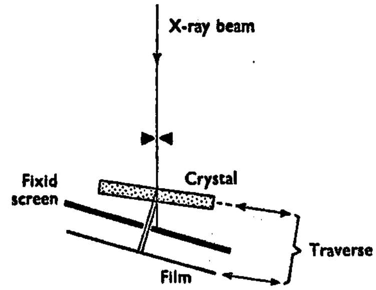

Fig. 1. Plan of the experimental arrangement.

The chief instrumental factor affecting the topographic resolution in the vertical plane is the angular size of the X-ray source. Resolution in the horizontal plane may be affected by the presence of both the $K\alpha_1$ and $K\alpha_2$ images. A typical value for their separation at the film is 10 microns. With good crystals such as silicon it was found convenient to eliminate the $K\alpha_2$ image by reducing the horizontal divergence of the primary beam to about half the difference in Bragg angle of the $K\alpha_1$ and $K\alpha_2$ reflections. The vertical magnification of the image is close to unity. The horizontal magnification is unity if the film is placed parallel to the specimen slab. With thick-emulsion films, however, the film must be kept normal to the diffracted beam. The horizontal magnification is then cos $(\theta+\alpha)$, in the case when the reflecting plane makes an angle α with the normal to the specimen slab, measured in the same sense as the deviation of the diffracted beam. The horizontal magnification is independent of the direction of crystal traverse, but it is desirable to traverse the specimen slice parallel to its own plane so that the aperture in the fixed screen may be as narrow as possible.

The method has been applied to the study of (i), individual dislocations in nearly perfect crystals, in particular the variation of the strength of the dislocation image with the angle between Buerger's vector and reflecting-plane normal. (A. R. Lang, in preparation); (ii) Pendellösung (N. Kato & A. R. Lang, in preparation); (iii) diffraction effects at sub-grain boundaries (N. Kato & A. R. Lang, in preparation); (iv) precipitates and inclusions in single crystals; (v) new diffraction effects in quartz and calcite; (vi) oxygen bands in silicon;

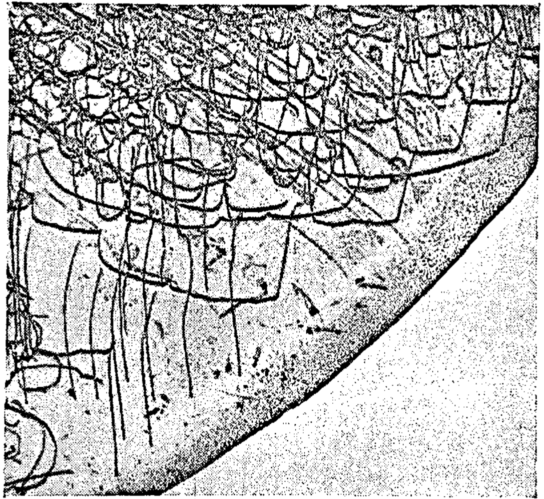

Fig. 2. A projection topograph of dislocations in a {111} slice of silicon, taken with a 220 reflection from planes normal to the slice.

(vii) radiation damage in single crystals; and (viii) influence of the Borrmann effect on diffraction images of dislocations (A. R. Lang, in preparation).

Fig. 2 shows a projection topograph of dislocations in a {111} slice of silicon, taken with a 220 reflection from planes normal to the slice. The area covered is about 5 mm. × 4½ mm. Pendellösung fringes may be seen in the bevelled edge of the slice. Noteworthy is the strong visibility of dislocations whose Buerger's vector is normal to the reflecting planes.

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