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Abstract

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CRYSTALLOGRAPHY

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MEASUREMENT OF THE BENDING OF CRYSTALLINE RIBBONS CAUSED BY AXIAL DISLOCATIONS BY METHODS OF DIFFRACTION ELECTRON MICROSCOPY

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The presence of dislocations in thin ribbon-like crystals causes a change in their shape ([1,2]). An edge dislocation lying in the plane of the ribbon causes a roof-like kink of it, while a screw dislocation causes twisting. The magnitude of the kink α or of the twisting β is directly related to the magnitude, direction, and sign of the Burgers vector **b**, and therefore a study of the shape of crystalline ribbons can completely characterize the dislocations contained in them.

According to the calculations of Eshelby ([1]) and Crouch ([2]), the value of the screw component b and the edge component b of the Burgers vector of axial dislocations in thin plates can be determined from the formulas

$$b = \frac{4\beta S}{3}, \qquad b = \frac{4\alpha t}{3}, \tag{1}$$

where S is the cross-sectional area and t is the thickness of the crystalline ribbon.

The twisting and kink of the ribbon along axial dislocations can be measured by analyzing the distortions of extinction contours at these dislocations. In plane-parallel plates, the extinction contours observed in electron-microscopic images of crystalline objects correspond to regions of the crystal in which a definite system of crystallographic planes is in the reflecting position. Dark-field analysis of extinction contours makes it possible to establish the arrangement of the normals to the surface of the ribbon.

At the point of intersection of two contours with known indices hkl and $h'k'l'$, the angles of deviation of the normal from the vertical position are determined from the relations

$$\varphi_x = \frac{\theta_{hk0}\cos\gamma_{h'k'l'} - \theta_{h'k'l'}\cos\gamma_{hkl}}{\sin(\gamma_{hkl} - \gamma_{h'k'l'})},$$

Figure 1

Figure 1: Figure 1

$$\varphi_y = \frac{\theta_{hkl} \sin \gamma_{h'k'l'} - \theta_{h'k'l'} \sin \gamma_{hkl}}{\sin(\gamma_{hkl} - \gamma_{h'k'l'})}, \tag{2}$$

where φ_x and φ_y are, respectively, the angles of rotation about the longitudinal axis of the plate x and about the transverse axis y; θ are the Bragg angles; γ are the angles between the x axis and the normal to the reflecting planes.

For extinction contours corresponding to double reflection, along the contour:

$$\varphi_x = \frac{\theta' \cos \gamma_2 - \theta'' \cos \gamma_1 + 2\theta' \cos(\gamma_1 - \gamma_2) \cos \gamma_1}{\sin(\gamma_1 - \gamma_2)},$$

$$\varphi_y = \frac{\theta' \sin \gamma_1 - \theta'' \sin \gamma_1 + 2\theta' \cos(\gamma_1 - \gamma_2) \sin \gamma_1}{\sin(\gamma_1 - \gamma_2)}, \tag{3}$$

where θ' and θ'' are the Bragg angles of the primary and secondary reflections, and γ_1 and γ_2 are the angles between the x axis and the normals to the reflecting planes for the primary and secondary reflections. To increase the number of points,

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Fig. 1. Distortions of extinction contours in basal ribbons of corundum: *a* —at an edge dislocation, *b* —at a screw dislocation.

in which, using relations (2) and (3), it is possible to determine the orientation of the normals to the surface, the object must be rotated through specified small angles, and the accelerating voltage must also be varied.

The study of the shape of ribbons containing dislocations was carried out on corundum filamentary basal ribbons grown from the gas phase. In such ribbons the extinction contours undergo either displacement along axial dislocations or a V-shaped kink (Fig. 1).

The magnitude of the Burgers vector of an edge dislocation, for an overall longitudinal bending of a ribbon with radius of curvature R, can be determined from the relation

$$b_{\text{edge}} = \frac{4}{3} \frac{t\,\Delta x}{R} \operatorname{ctg} \gamma, \tag{4}$$

where Δx is the displacement of the extinction contour along the dislocation; t is the ribbon thickness, determined from the intensity distribution in the dark-field image of the extinction contour.

Fig. 2

Figure 2: Fig. 2

Fig. 2. Results of an analysis of the shape of a basal ribbon containing one screw dislocation: a —axial twisting of the ribbon, b —shape of the transverse cross section

For intensity maxima far from the central position, the relation

$$t = \frac{1}{\Delta s}, \tag{5}$$

is valid; it makes it possible to determine the ribbon thickness t from the distance between maxima Δs, where s is the deviation vector from a reciprocal-lattice node.

The magnitude of the Burgers vector of edge axial dislocations in thin ribbons in most cases corresponds to the unit Burgers vector in corundum, 4.75 Å ([3]). The magnitude of the Burgers vector of axial screw dislocations, determined from relation (1), is 24–65 Å and is usually a multiple of the value of the unit Burgers vector.

The study of the shape of ribbons makes it possible to test the conclusions of the theory concerning the character of bending caused by the dislocations contained in them. For this purpose, a complete analysis of the shape of such ribbons was carried out. In ribbons with a V-shaped kink of the extinction contours, two kinds of deformation are observed: longitudinal twisting and bending of the transverse cross section (Fig. 2). It should be noted that bending of the transverse cross section does not follow from the linear theory of elasticity and, apparently, is a consequence of nonlinear effects.

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Note: Figure translations are in progress. See original paper for figures.