OBSERVATION OF STABILITY LOSS OF THE SURFACE LAYER OF A BENT CRYSTAL BY REFLECTION X-RAY MICROSCOPY TECHNIQUES

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Stability loss of a single-crystal surface layer in the form of coarse "folds" roughly normal to the preferred directions of slip was observed, for instance, in [1, 2]. In the following, a method is proposed for the two-dimensional determination of the size of the folds with the aid of oblique photography and the method of reflection X-ray microscopy of bent crystals [3].

Investigations were performed with aluminum crystal-analyzers of the Kapitsa-Johann X-ray spectrograph, which were bent in the crystal holder between two cylindrical surfaces. When a rectangular plate bends under an applied force, its concave surface experiences compressive strains which, under certain conditions, may lead to stability loss [4]. It is known that a thin single-crystal plate bent in the crystal holder of an X-ray spectrograph experiences mechanical polygonization of its crystalline structure [5].

In the experiment described, polygonization was accompanied by simultaneous stability loss of the surface layer: neighboring polygonal blocks became oriented to each other in such a way that the imaginary surface enveloping all of them had the shape of a wave.

The profile of this surface can be revealed by reflected rays only with the aid of oblique photography, namely, from the shape of the corresponding boundary of the image (Fig. 1).

A cross-sectional view of the experimental scheme is shown in Fig. 2. Here, an element of the wave-shaped surface, in the form of a convexity adjacent to a concavity, is examined. AD is the generatrix of the cylindrical surface of the crystal at the top of the convexity; BC is the generatrix at the bottom of the concavity. The projections of the normals to these generatrices at the points A, B, C, and D are indicated by dashed lines. The projection of the ray PB, incident at the point B, and the normal to BN form the angle α. The projection of the ray BB_1, reflected from the point B, touches at point S a rectangular window in the crystal holder, the cross section of which is hatched. Through point S must pass the projection of any ray at the boundary of a pencil of rays, including the ray AA_1 reflected from the point A that is situated at a distance BE with respect to the generatrix BS in the cross section.

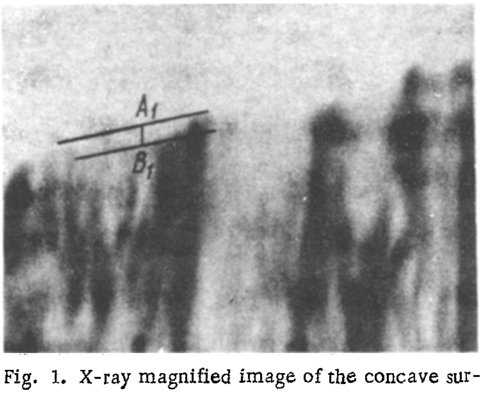

Fig. 1. X-ray magnified image of the concave surface of an aluminum single crystal. Due to oblique photography, the upper boundary of the image corresponds to the contour of the crystal block surface. (See below for information on conversion from A_1B_1 to the depth of a fold.)

The intersection at point S of the projections of rays reflected from the points A and B results in the appearance on the X-ray film A_1D_1 of a magnified image of the intercept AB, in the form of the intercept A_1B_1. The pencil of X-rays is bounded by the edge Q of the window in such a way that the projections of rays incident on the points D and C coincide, while the rays reflected from these points are parallel in the projection. Hence, it may be assumed that the projection of the intercept CD is not magnified on the film. That this is so may be seen from the configuration of the lower boundary of the image in Fig. 1, the distortion of which does not exceed the blurring of the image boundary.

By varying the position of the crystal relative to the window in the crystal holder or by designing the window in the form of several parallel slots, it is possible to obtain information on the shape of the envelope of the system of blocks at various parts of the reflecting surface of the crystal. In the case of parallel slots, when stability loss sets in, a photograph exhibits several reflections, the upper boundaries of which are wave-shaped. Due to the absorption of X-rays at the window edges S and Q, the boundary of an image appears blurred for a given curve.

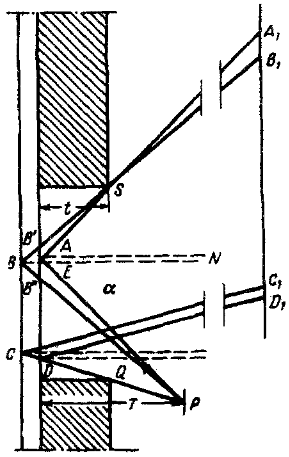

Fig. 2. Projection of the X-ray optical system onto the cross-sectional plane through the center of the focal circle and the bending axis of the crystal analyzer of a Kapitsa-Johann spectrograph.

It should be noted that the length of a half-wave of the fold, measured on an X-ray photograph, is in rigorous agreement with the theory [4]. Etching of the aluminum surface also confirmed the conclusions of this theory concerning a layer after stability loss. The height h of a fold was determined from the size of A_1B_1 as measured on the photograph, and also by making use of experimental data obtained for SB_1, SB, T, and t (it may be seen from Fig. 2 that these quantities are given a priori in the experiment). Taking into account that $\Delta B''BE = \Delta B'BE$ and $\Delta PB''A \sim \Delta SB'A$, we may express the height h, equal to the intercept BE, by the formula

$$h = \frac{b}{2\,\mathrm{tg}\,\alpha}\left(1 + \frac{T}{t}\right) \qquad \left(b = A_1B_1\frac{SB'}{SB_1} = AB'\right).$$

The value of h calculated from this formula in the experiment did not exceed 0.2 mm.

The specific features of cylindrical optics employed by the X-ray optical system appreciably increase the sensitivity of oblique photography in the recognition of a contour formed by crystalline blocks.

The magnified image of a concave crystalline surface obtained by the method of reflection X-ray microscopy of bent crystals is a transformed one. The anamorphosis coefficient of such an image is less than unity, so that the magnification obtained along the boundary line of the image is less than in the transverse direction to this line. Oblique photography for a bent crystal is, therefore, more sensitive to distortions of a contour that are determined along the boundary of an image than oblique photography in microroentgenography of flat crystals.

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