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Abstract

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ON THE NATURE OF THE OPTICAL INHOMOGENEITY OF QUARTZ

(Presented by Academician G. V. Kurdyumov, June 13, 1966)

As is known, optical methods [1,2] reveal various inhomogeneities in quartz crystals (schlieren, sectoriality, banding, etc., Fig. 1a). The nature of these defects and the mechanism of their origin during crystal growth have not yet been fully clarified; however, it may be considered firmly established that they are associated with the capture of impurities from the nutrient solution and with fluctuations of thermodynamic parameters during the process of growing the crystals [3]. Also unclear remain the questions of what types of microdisturbances of the crystalline structure are associated with the inhomogeneities detected by optical methods (Figs. 1–3, see insert facing p. 555).

The task of the present communication is to present the results of a study of the inhomogeneity of quartz crystals by X-ray diffraction topographic methods and to compare the data obtained with optical data. Natural and synthetic quartz crystals were investigated using a specially made Lang camera [4,5].

Schlieren and their relation to dislocations. Figure 1b shows a diffraction pattern from a crystal of synthetic quartz in which intense schlieren are detected optically. As can be seen from a comparison of Figs. 1a and 1b, the topographic methods reveal a pattern of inhomogeneities in the quartz crystal very similar to the optical one; however, these patterns also have differences.

The sharp thin lines in Fig. 1b are due to contrast from dislocations. This is also confirmed by comparison with data on the etching of quartz crystals with hydrofluoric acid. In [6] it was shown that dislocations emerging on the basal plane appear in the form of etch pits and channels extending deep into the crystal. Figure 1b gives an etching pattern of the quartz crystal from which the diffraction pattern shown in Fig. 1b was obtained, convincingly confirming the conclusion stated above.

Proceeding from ideas about the dislocation mechanism of growth of a quartz crystal, one might expect these dislocations to be screw dislocations with a Burgers vector directed along the optical axis. But then, by virtue of the condition for revealing dislocations by the topographic method [7], they would not be observed in Fig. 1b. Thus, the Burgers vector of these dislocations has a component perpendicular to the optical axis of the crystal. Let us also note that these dislocations are not purely screw dislocations, since under certain exposure conditions the rosettes caused by them are detected (Fig. 2).

We propose to make a more complete analysis of dislocations in quartz crystals the subject of a subsequent communication. In keeping with the aim of the present communication, we shall confine ourselves only to the conclusion that the optical inhomogeneity of synthetic quartz crystals known as schlieren is caused by dislocations.

Concerning the reason for the connection between the dislocations under consideration and this optical inhomogeneity, the following considerations may be put forward: during the growth of the crystal, the dislocations themselves capture a large amount of impurity and, moreover, create favorable conditions for the formation of Suzuki atmospheres around them. Owing to this enrichment by impurity atoms (or

To the article by G. V. Kleshchev, I. V. Kabanovich, and L. N. Cherny, p. 585

Fig. 1. Inhomogeneities of synthetic quartz revealed by different methods: optical (*a*), etching method (*b*), and the method of X-ray diffraction topography (*c*).

Fig. 2. Rosettes revealed by the method of X-ray diffraction topography. Crystal of cut (0001), recorded in the (1020) reflection.

Fig. 3. Diffraction pattern of a natural quartz crystal. Cut (0001), recorded in the (1020) reflection.

complexes) regions with a high density of dislocations and are revealed as optical inhomogeneity (striae).

Let us note that the increased ability of the dislocations under consideration to capture impurity atoms (or whole complexes) indicates their special nature. Evidently, they differ from the dislocations due to which crystal growth occurs. It seems to us that these dislocations belong to the hollow type ([3,8]).

Figure 1 makes it possible to draw a conclusion about the origin of the indicated dislocations. These dislocations either are ([6]) a continuation, in the growing crystal, of dislocations from the seed, or arise on microscopic inclusions.

Banding in quartz crystals. In Figs. 1a and 1b one can also see another type of inhomogeneity of synthetic quartz crystals, called banding. In the crystal, bands are observed that differ from one another in the concentration of captured impurity and, consequently, also in refractive index (this explains the banding in Fig. 1a), and also in lattice parameters, which accounts for the banding visible in Fig. 1b.

It seems to us that the banding of crystals is connected with the fact that, during their growth, owing to fluctuations in the technological regime of crystal growth, the chemical nature of the complexes deposited on the crystal changes ([9]). For example, during normal crystal growth, SiO_2 molecules are deposited, whereas during fluctuations of the growth regime more complex polymeric SiO_2 complexes, containing different amounts of impurity, are deposited.

A banded structure is also detected by the topographic method in crystals of natural quartz (Fig. 3). Our attempts to reveal this type of banding by optical methods were unsuccessful. The banding of natural quartz crystals evidently has the same origin as in synthetic crystals, and is due to differences in the crystalline structure of the layers as a result of changes in the physicochemical growth conditions.

As can be seen from Fig. 3, the method of X-ray topography distinctly reveals the sectorial and zonal structure of quartz crystals, which makes it possible to reconstruct the conditions of their growth.

In conclusion, we note that the present work was begun on the initiative of A. M. Elistratov. The authors consider it their pleasant duty to express their gratitude to A. M. Elistratov' s students I. L. Shulpina and O. N. Efimov for help in mastering the technique and for useful discussions.

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