ON THE QUESTION OF THE GROWTH OF THE FACES OF A HEXAGONAL PRISM IN QUARTZ CRYSTALS

Crystallography

1970

SovietRxiv

Abstract

Full Text

UDC 548.5+549.514.51

Crystallography

V. T. USHAKOVSKII, L. N. CHERNYI, P. I. NIKITICHEV

ON THE QUESTION OF THE GROWTH OF THE FACES OF A HEXAGONAL PRISM IN QUARTZ CRYSTALS

(Presented by Academician N. V. Belov on 9 December 1969)

The morphology of natural quartz crystals, as is known, is very diverse. In all, more than 500 simple forms have been recorded for quartz ([2]). However, the principal forms on which the habit of quartz crystals depends are the hexagonal prism $\{10\bar{1}0\}$, as well as the positive $\{10\bar{1}1\}$ and negative $\{01\bar{1}1\}$ rhombohedra.

According to ideas concerning the sectorial structure of quartz crystals ([5]), the faces of the hexagonal prism, during growth, form their own growth pyramids. This is confirmed either by the presence of zonal coloration or by the presence of mineral inclusions (chlorite, carbonate, etc.), which form so-called phantom crystals.

In addition to prismatic quartz crystals, obelisk-like crystals are often encountered under natural conditions, i.e., crystals narrowing from the base toward the head. On such crystals the faces of the hexagonal prism are essentially absent. Instead, the faces of sharper rhombohedra are developed. It is believed that the growth of such crystals proceeds only along the optical axis, while the prism practically does not grow ([6]).

Among natural quartz crystals, defect-free crystals are often encountered in which the faces of the hexagonal prism did not grow, although morphologically they are clearly expressed. Such crystals are composed mainly of growth pyramids of the rhombohedral faces $\{10\bar{1}1\}$ and $\{01\bar{1}1\}$, which has been established by the method of X-ray diffraction topography ([4]).

Thus, among natural quartz crystals two groups of crystals are clearly distinguished: 1) crystals in which growth of the faces of the hexagonal prism occurs, and 2) crystals in which the prism faces practically did not grow.

Studies of synthetic quartz crystals have made it possible to establish that, over a wide range of temperatures, pressures, and supersaturation, the faces of the hexagonal prism practically do not grow ([1]).

Subsequent practice in growing synthetic quartz crystals on an industrial scale has shown that, regardless of growth conditions, the presence or absence of impurities, and the nature of the working solutions, it has not been possible to obtain substantial growth of the faces of the hexagonal prism. In this connection there arose the problem of obtaining crystals of large size, the need for which in industry is constantly increasing.

To clarify the conditions for growth of the faces of the hexagonal prism of natural quartz crystals, the method of X-ray diffraction topography ([3]) was applied. By this method, quartz crystals in which the growth of the prism was established macroscopically were studied.

A quartz crystal from a rock-crystal deposit in Kazakhstan belongs to crystals of flattened form: two opposite faces of the hexagonal prism are wider than the others and are close together. The faces of the rhombohedra are developed unevenly, from which it may be concluded that the crystal grew in a position close to horizontal. This is also indicated by the one-sided presence of flaky carbonate, forming phantom crystals. We note that the "inner crystal" has an obelisk-like–

habitus, although in its lower part the faces of the hexagonal prism have already formed. The length of the crystal described along the L_3 axis is 80 mm, and along the larger L_2 axis 25 mm.

Figure 1* shows an X-ray topogram of a section (0001) of this crystal. The topogram reveals interesting features in the growth of the crystal. First, attention is drawn to the fact that, after carbonate was deposited on the upper faces of the crystal, twinned growth of these faces began: Brazil twins appeared; whereas the faces directed downward and free of impurities grew without any defects. Second, a distinct change in the shape of the crystal is observed during growth: the initially obelisk-like crystal was transformed into a prismatic one.

Figure 2 shows an X-ray topogram of another crystal, more precisely of a fragment of it, in which a "crystal within a crystal" was observed. The fragment is colorless, without visible defects, with partially preserved faces of the hexagonal prism. In the topogram of the $(11\bar{2}0)$ section it is evident that the "inner crystal" was formed at the expense of the rhombohedron faces, and its habitus is obelisk-like. Although on the whole it has a fairly perfect structure, this crystal has defective regions along its edges as well. Defects in the structure of the "inner crystal" initiated the growth of Brazil twins. It is interesting that above the defects a lamination is observed, parallel to the steepest rhombohedra, and the transformation, during growth, of the obelisk-like crystal into a prismatic one again appears clearly.

Figure 3 presents a photograph of a plate of a quartz crystal of section (0001) from a deposit in the Southern Urals, in which a "crystal within a crystal" is also visible. The crystal is smoky, of slightly flattened habitus, weakly narrowing toward the head; its length along the L_3 axis is 125 mm, and along the larger L_2 axis 65 mm. The "inner crystal" is revealed by a zonal impurity of chlorite and carbonate; its shape is obelisk-like. On the surface of one face of the hexagonal prism a step is observed, inherited from the "inner crystal." Figure 3 clearly shows that the growth of the faces of the hexagonal prism is connected with the formation of Brazil polysynthetic twins.

The growth of the faces of the hexagonal prism, as is known, is characteristic of amethyst crystals of scepter-like appearance. Here too their growth is connected with the formation of Brazil twins, since these twins are present in all amethyst crystals without exception ([2]).

Thus, a direct connection is established between the growth of the faces of the hexagonal prism and the formation of Brazil twins. Most often this occurs after an interruption in mineral formation, when impurities are deposited on the crystal and conditions are created for the formation of twins.

The connection between the growth of the faces of the hexagonal prism and the formation of Brazil twins is not accidental.

According to the views of V. T. Ushakov ([7]), the growth of quartz crystals occurs only in the direction of the positive end of the polar axes X (L_2). In this connection, growth in the direction of the electrically neutral Y axes in quartz crystals should, in the ideal case, be absent. And since the faces of the hexagonal prism are arranged perpendicular to the Y axes, their growth does not occur. The formation of polysynthetic Brazil twins leads, as is known, to neutralization of the polar X axes; in connection with this, changes in the mechanism of crystal growth, still unknown to us, appear, leading to the growth of the faces of the hexagonal prism. The conditions for the formation of Brazil twins have not been studied in detail; it is known only that they are growth twins. Experiments aimed at obtaining polysynthetic Brazil twins during the growth of artificial quartz crystals have not yielded positive results.

* Figs. 1, 2, 3 see on the insert to p. 1027.

During the formation of Dauphiné twins, neutralization of the polar axes in quartz crystals also occurs; however, these twins have no effect on the growth of the faces of the hexagonal prism, since the individuals in them are arranged in rather large blocks, and each of them grows as a single crystal.

A stimulating factor for the growth of the faces of the hexagonal prism is the deposition on their surface of various impurities, owing to which reentrant angles are formed, leading to a disturbance of the equilibrium form.

As can be seen from the topogram (Fig. 1), along with twinned growth there also occurs, although at a lower rate, defect-free growth of individual faces of the hexagonal prism. This is evidently due to the formation of a reentrant angle as a result of the more intense growth of those faces on which Brazil twins are present.

The defect-free growth of individual faces of the hexagonal prism, associated with twinned growth of neighboring faces, can be used to obtain artificial quartz crystals with a large cross section.

Thus, artificial quartz crystals, as well as those among natural crystals that grow under stable conditions and are free of defects, are formed mainly by growth of the rhombohedron faces. Growth of the faces of the hexagonal prism does not occur under such conditions.

CITED LITERATURE

[1] V. P. Butuzov, N. Yu. Ikornikova, *Zap. Vsesoyuzn. Mineralog. Obshch.*, pt. 85, issue 3 (1956).

[2] J. Dana, E. S. Dana, V. Frondel, *The System of Mineralogy, Silica Minerals*, Moscow, 1966.

[3] I. V. Kabanovich, V. T. Ushakovsky et al., *Mineralog. Sborn. L' vovsk. Univ.*, issue 4, No. 20 (1966).

[4] K. F. Kapkurov, V. T. Ushakovsky et al., *Zap. Vsesoyuzn. Mineralog. Obshch.*, pt. 96, issue 4 (1966).

[5] G. G. Lemmlein, *Sectorial Structure of Crystals*, Acad. Sci. USSR Press, 1948.

[6] V. A. Mokievsky, *Zap. Vsesoyuzn. Mineralog. Obshch.*, pt. 82, issue 3 (1953).

[7] V. T. Ushakovsky, ibid., pt. 97, No. 5 (1968).

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