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USSR

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FOREWORD

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THE EFFECT OF VIBRATIONS ON THE FORM OF SINGLE CRYSTALS GROWN BY THE CHORKHRAL'SKIY METHOD

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The effect of vibrations on the formation of crystal faces was discovered. Without vibrations, KCl, NaCl, Ge, and other crystals of roughly cylindrical form were usually grown out of the melt. In the presence of vibrations, the cross sections of the crystals turned out to be roughly square or triangluar, depending upon the direction of extraction.

Single crystals of alkali halide salts (KCl, NaCl, LiF, and others) grown from melts by the Chokhral'skiy method held at a constant temperature and a constant rate of extraction usually turned out to be roughly cylindrical. The cross section of such crystals depends chiefly on the form of the meniscus of the melt which, in turn, is caused by the action of surface tension, and also depends on the distribution of temperatures in the crucible.

In order to achieve even heating of the melt, our experiments showed that inserting a hollow copper cylinder between the crucible and the heating furnace was a useful procedure. The developing crystals were withdrawn from the melt by placing a float in a vessel containing water, and the rate of withdrawal was determined by the rate at which the water flowed from the vessel.

Several single crystals were grown out of the same chemical compound by the Chokral'skiy method in an apparatus in which the developing crystals were rotated and withdrawn, by means of motion transmitted from an electric motor through a reduction gear, vibrations were usually set up in the melt and the crystal holder.

We discovered that single crystals grown with rotation and vibration turned out to be bounded with faces, not cylindrical. Their cross section was roughly square if the crystals were pulled in the (100) direction shown in Figure 1b, and trigonal or ditrigomal in the (111) direction--Figure 1d. In the first case, the shape of crystal was a tetragonal pseudo-prism whose smooth lateral faces correspond to (100) faces in KCl. In the second case, the shape of the crystal was a trigonal or ditrigonal prism (if the temperature of the melt and the rate of withdrawal were changed, necked-in sections were formed). The surfaces of their lateral faces were usually striated and consisted of steps formed by the faces of cubes.

The phenomenon described above was also observed in single crystals of germanium grown out of a melt by the Chokhral'skiy method in an apparatus designed and assembled in the Siberian Physico-Technical Institute [1]. Single crystals of germanium grown along the (111) direction with vibration and without rotation of the developing crystals had a roughly cylindrical shape (Figure 2a).

When the germanium crystals were pulled in the (100) direction, a roughly tetragonal pseudo-prism was obtained (Figure 2c). Even though its lateral surface did correspond generally with the crystallographic form (111), in reality, however, it was striated and consisted of steps formed by the faces of octahedrons (111).

When the crystals were pulled in the (111) direction, triagonal or ditrigonal pseudo-prisms were obtained (Figure 2b) whose lateral surfaces were also roughly striated and formed by steps composed of narrow faces corresponding to octahedra [2].

The tendency of single crystals of germanium to form surfaces with face formations corresponding to the crystallographic form (111) is wholly understandable if one takes into consideration that they form octahedrons when they are permitted free growth in the melt [3].

It may be considered that face formation of crystals in our case appears only in connection with rotation of the developing crystals and does not depend upon vibration. In order to clarify this point, we grew crystals with rotation, arranging that vibrations would be transmitted from a supplementary source to the body of the apparatus. We found at this time that intensifying the vibrations resulted in a markedly better face formation than simple rotation of the developing crystals.

Increasing the amplitude of the vibrations aided the formation of faces while decreasing the amplitude, on the contrary, diminished such face formation. It is probable that the frequency of vibrations also has an effect on the degree of rounding and face formation in single crystals. So far, however, we have studied only the effect of vibrations with a frequency of 2-20 cycles per second.

It is also noteworthy that crystals of smaller diameter generally show considerably better face formation (Figure 3).

With the same amplitude and frequency of vibrations, formation of crystal faces is less pronounced in germanium crystals than in crystals of alkali halide salts.

This observation is probably connected with the fact that the surface tension of molten germanium is greater than that of the above mentioned salts in molten form.

It seems to us that the role of vibrating the melt and the crystal holder in the appearance of crystal face formation, also the role of rotating the developing crystals consist in equalizing the conditions of crystallization for the entire interface of the solid and liquid phases. It is probable that this is what makes it possible for the crystals to become capable of spontaneous face formation. Therefore, in the presence of vibrations the difference in the forces of interaction of surface particles of the crystals with particles of the melt acting in different crystallographic directions becomes so perceptibee that the appearance of anisotropy in the growth of the crystals is possible.

So far as we know, the effect of low-frequency vibrations on the shape of a growing crystal has not been described in the literature. It is to be expected that vibrations affect not only the shape, but also the properties of crystals. We have, therefore, considered it necessary to continue work in this direction.

In conclusion, the authors express their gratitude to Academician V. D. Kuznetsov for his interest in the work and his participation in judging the results of the experiments.

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Siberian Physico-Technical Institute of the Tomsk University imeni V. V. Kuybyshev

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FIGURE APPENDIX

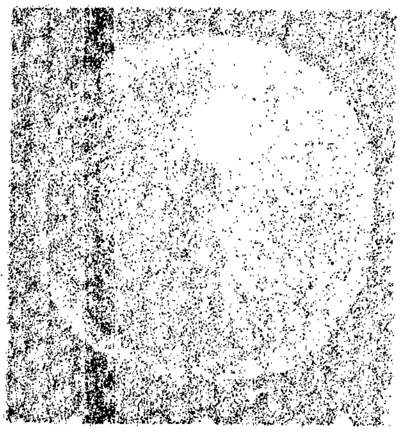

Figure 1a. Direction of growth (100); the nucleus and growing crystal were neither rotated nor vibrated (cross section of the crystal - circular).

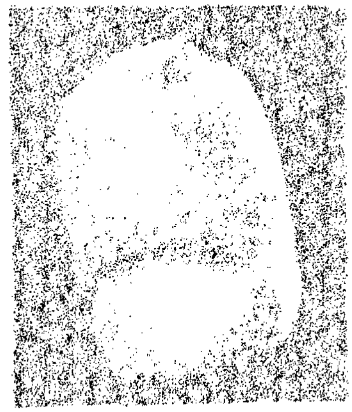

Figure 1b. Direction of growth (100); the nucleus was rotated and vibrated (cross section - square).

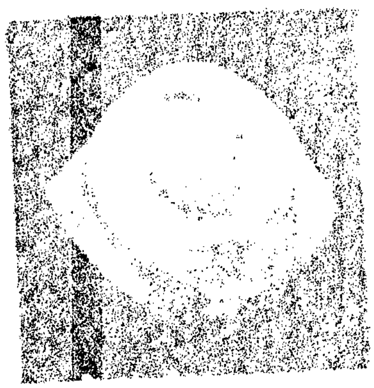

Figure 1c. Direction of growth (100); the crystal was not rotated or vibrated at the beginning of growth, but subsequently subjected to rotation and vibration. Face formation is apparent in the lower part of the crystal.

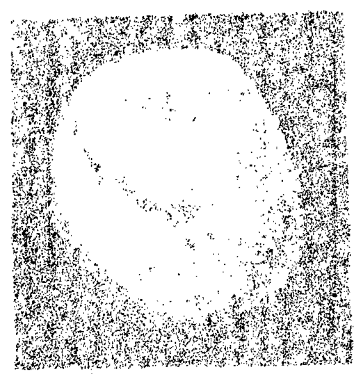

Figure 1d. Direction of growth (111); the crystal was rotated and vibrated.

Figure 1. Single crystals grown by the Chokhral'skiy method.

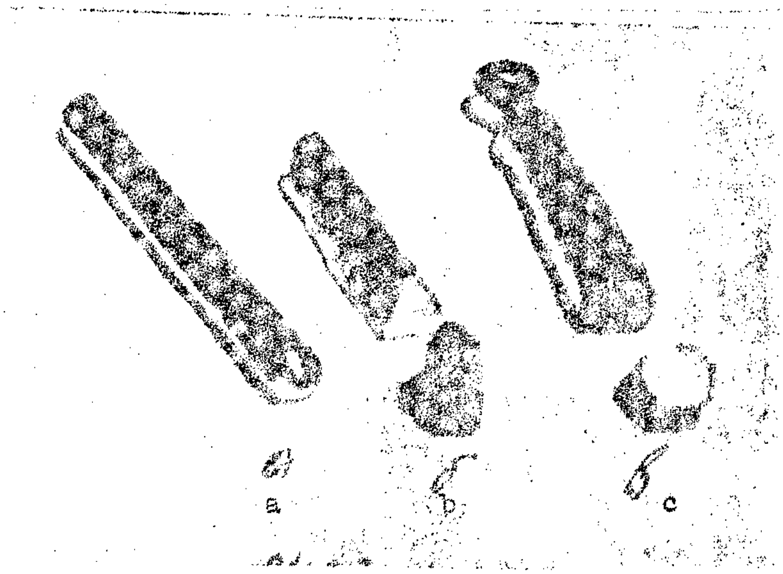

Figure 2. Single crystals of germanium: a - direction of growth (111), the nucleus and growing crystal were not rotated and there was no vibration (cross section of the crystal - circular); b - direction of growth (111), the nucleus was rotated and vibrated (cross section - triangular); c - Direction of growth (100), the nucleus was rotated and vibrated (cross section - square).

Figure 3. Single crystal. The direction of growth (100), the crystal was rotated and vibrated. The upper part of the crystal has a smaller diameter and face formation is more pronounced.

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