# A Simple Method of Obtaining a Single-Crystal of Zinc with Approximately any Desired Orientation of its Principal Axis

By

**Shuyo Ito**

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## Abstract

When a single-crystal of zinc of known orientation is welded at one end to a sheet of zinc plate, which is in the melting state, and when this melted zinc is cooled gradually from the welded portion to the other end, we can get a single-crystal with approximately the same orientation of the principal axis of the hexagonal zinc crystal as the former, which may be called the "mother crystal." We are, therefore, able to obtain a single-crystal with approximately any desired orientation of its principal axis by setting initially the mother crystal in a proper orientation. Often we obtain a specimen composed of several strips which have different lusters, and which are running parallel to the direction of the advance of the cooling process on the surface of the zinc plate as shown in Fig. 2, Plate I. By means of X-rays it is revealed that these strips are all composed of single-crystals of zinc with approximately the same orientation of their principal axes as the mother crystal.


When the surface of a melted metal is touched by a single-crystal of the same metal, and when the former is cooled gradually by being hung up slowly, we can get a fairly long single-crystal having the same orientation of the crystallographic axes as the mother crystal. This is the well known method of obtaining a single-crystal of a metal, devised by Mark, Polanyi and Schmid. In the present experiment, it is slightly modified. A flat parallelopiped box, made of thick asbestos plates, has an opening at its narrow side, through which zinc plates are inserted. The zinc plate in this asbestos box is heated by a Bunsen burner and is made to be in the condition of being just melted. Then a single crystal of zinc of known crystallographic orientation is inserted in the furnace, and is made to be in contact with the molten zinc plate in such an orientation that, when the two are solidified and crystallized as one body they will have the required orientation of their crystallographic axes. This is easy to accomplish when the crystallographic orientation of the mother crystal is known, by using only a protractor and a ruler. Next, they are fixed in their proper positions, and welded cautiously by a fine flame, and then the molten plate is cooled slowly from the joint to the other end by gradually moving the flame in the same direction and weakening the flame gradually and simultaneously. A single-crystal of zinc having approximately the same orientation of its principal axis as the mother crystal is thus obtained in the solidified part of the molten mass of zinc.

In this way we can get a fairly large single-crystal of zinc by making use of a large furnace and by uniform heating with a larger flame. For example a single-crystal of 7 cms. in breadth, 9 cms. in length and 0.15 cms. in thickness was obtained by using only one Bunsen burner.

As the present experiments are made in the air, the oxidization of the surface of the specimens has, of course, taken place during the process of heating and cooling. Moreover many impurities are to be expected to be contained in the specimens as they are taken from commercial zinc plate. If purer zinc plates were employd and special care were taken to prevent oxidization, we should be able to get a larger single crystal.

The growth of the single-crystals in the above mentioned process seems to depend, at least to some extent, upon the orientation of the crystallographic axes of the crystals. Generally when the basal plane of the hexagonal crystal of zinc is roughly parallel to the direction of the advance of cooling, it grows more easily up to a fairly large single-crystal; but when its basal plane is roughly perpendicular to the direction of the advance of cooling, it is rather hard for it to grow, and it is rather liable to be divided into several long and slender strips of single-crystals running parallel to the direction of the advance of cooling, the orientation of their crystallographic axes being all slightly different from each other in the vicinity of that of the mother crystal.

The details of the results of the experiments are summarized in the following four sections. In every cases the orientations of the crystallographic axes of the single crystals are determined by treating their Laue-photographs with the spherical scale and the globe deviced by Professor U. Yoshida.[1]

*I. The basal plane of the hexagonal crystal is nearly parallel to the*

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1 U. Yoshida: Japanese Jour. of Phys. **4**, 133 (1927)

*flat surfaces of the plates, and consequently it is nearly parallel to the direction of the advance of cooling.*

The mother crystal was obtaind by letting a molten zinc plate solidify slowly from one end to the other. The crystallographic orientation of the crystal thus obtained was determined by taking a Laue-photograph. Transferring this orientation of the crystallographic axes to three different zinc plates of 7 cms. × 3 cms. × 0.15 cms. in size, we got 9 strips of single-crystals, running parallel to the direction of cooling. The orientations of the principal axes in these 9 single-crystals are shown in Table I by means of their polar coordinates, the direction of the surface normal of the specimen being taken as the polar direction and the plane containing this direction and the principal axis of the mother crystal as the plane of zero declination.

Table I

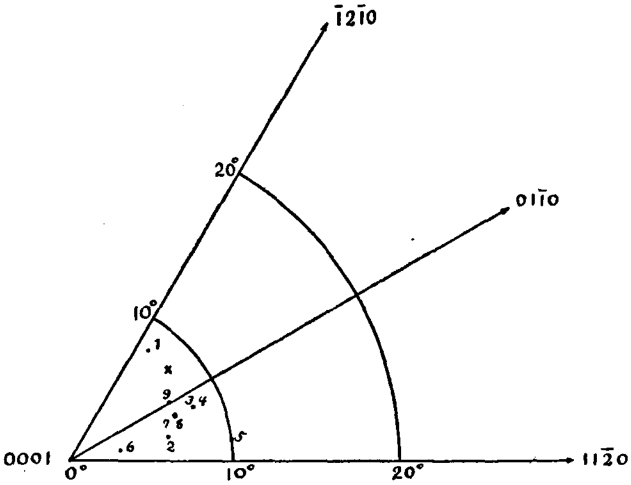
| No. of specimen | No. of strip | Declination | Polar angle |
|---|---|---|---|
| Mother crystal | — | 0° | 8° |
| No. 1 | No. 1 | +10° | 8° |
| | No. 2 | +23° | 6° |
| | No. 3 | −20° | 8° |
| No. 2 | No. 4 | −20° | 8° |
| | No. 5 | −15° | 10° |
| No. 3 | No. 6 | −38° | 3° |
| | No. 7 | +37° | 7° |
| | No. 8 | +38° | 6° |
| | No. 9 | +45° | 7° |

It will be seen from Table I that the basal planes and the principal axes which are perpendicular to the basal planes of the hexagonal crystals of zinc decline almost equally with that of the mother crystal against the flat surface of the specimens in the limit of experimental errors, but that the declinations of these principal axes are scattered rather evenly within a certain range.

The stereographic projections of the directions of the surface normals of the specimens in reference to the crystallographic axes of the hexagonal crystal, are shown in Fig. 1.

*II. The basal plane of the hexagonal crystal of the mother crystal is parallel to the direction of cooling and is perpendicular to the plane of the specimen.*

Fig. 1




× : *Direction of the surface normal of the mother crystal.*
• : Direction of the surface normal of the strips.

In this case the mother crystal was fixed in such a position that the basal plane of the hexagonal crystal was perpendicular to the flat surface of the zinc plate and was parallel to the direction of cooling, and then it was allowed to cool slowly from the joint to its other end. Experiments were made on 12 different strips contained in two sheets of zinc plates

Table II

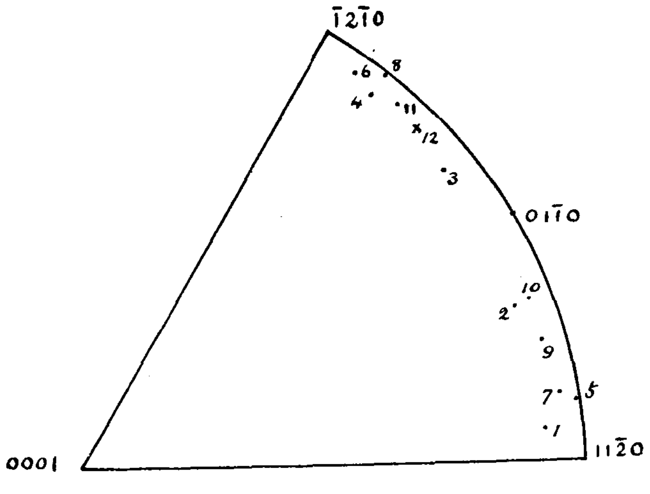
| No. of specimen | No. of strip | Declination | Polar angle |
|---|---|---|---|
| Mother crystal | — | 0° | 86° |
| No. 1 | No. 1 | −2° | 96° |
| | No. 2 | −1° | 96° |
| | No. 3 | +1° | 95° |
| | No. 4 | −3° | 86° |
| | No. 5 | +1° | 92° |
| | No. 6 | +7° | 87° |
| | No. 7 | +2° | 93° |
| | No. 8 | −5° | 88° |
| No. 2 | No. 9 | +4° | 86° |
| | No. 10 | +3° | 86° |
| | No. 11 | −4° | 86° |
| | No. 12 | 0 | 87° |

prepared in such a manner. The size of these plates was 9 cms. × 7 cms. × 0.15 cms.

Orientations of the principal axes of the single-crystals, of which the strips were composed, are given in Table II, in the same manner as in Table I. It will be seen, from this Table, that the orientations of the principal axes of the hexagonal crystals belonging to different strips are approximately the same, not only with respect to the polar angle but also with respect to the declination, as that of the mother crystal within the limit of experimental errors.

In the same way as in Fig. 1, the stereographic projections of the directions of the surface normals of the specimens, referring to the directions of the crystallographic axes of the single-crystals, are shown in Fig. 2.

Fig. 2




× : Direction of the surface normal of the mother crystal.
• : Direction of the surface normal of the strips.

*III. The basal plane of the mother crystal is parallel to the flat surfaces of the specimens, and consequently it is parallel to the direction of the advance of cooling.*

Three specimens were prepared in the same way as in the case of I, by setting the mother crystal in such a position that the basal plane of the hexagonal crystal was exactly parallel to the flat surface of the zinc plates. The size of the specimens was 6 cms. × 4 cms. × 0,15 cms. in this case.

Fig. 1, Plate I shows the appearance of the specimen examined in this case.

The orientations of the principal axes of the single-crystals belonging to different strips are shown in Table III, in the same manner as in Table I by taking roughly the direction of cooling as the direction of zero

Table III

| No. of specimen | No. of strip | Declination | Polar angle |
|---|---|---|---|
| Mother crystal | — | — | 0° |
| No. 1 | No. 1 | — | 0° |
| | No. 2 | −30° | 6° |
| | No. 3 | — | 0° |
| | No. 4 | +15° | 2° |
| No. 2 | No. 5 | +80° | 2° |
| | No. 6 | +30° | 1° |
| | No. 7 | 0° | 2° |
| | No. 8 | − 1° | 1° |
| | No. 9 | −90° | 1° |
| No. 3 | No. 10 | −170° | 5° |
| | No. 11 | +108° | 6° |
| | No. 12 | −95° | 5° |
| | No. 13 | +70° | 2° |
| | No. 14 | −80° | 7° |

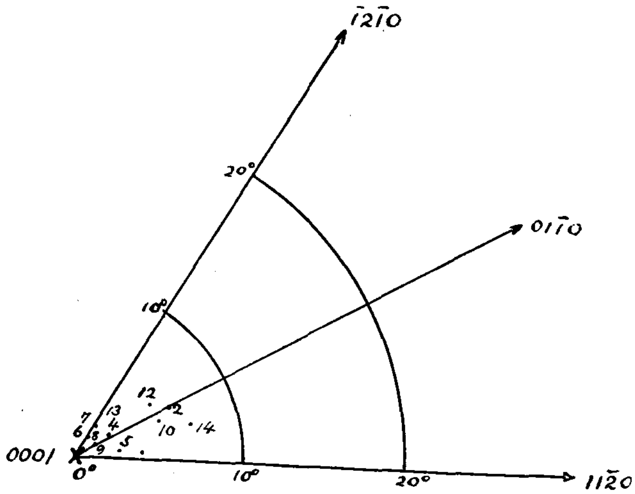
declination. The orientations of the surface normals of the specimens, referring to the directions of the crystallographic axes of the zinc crystal, are shown in Fig.3 by the stereographic projection.

It will be seen from Table III and Fig.3 that the polar angles of the principal axes of the crystals belonging to different strips are all the same as that of the mother crystal and is nearly 90°, but that their declinations are scattered rather evenly in a wide range, the same as in the case of I.

*IV. The basal plane of the hexagonal crystal of zinc is perpendicular both to the flat surface of the specimen and to the direction of advance of cooling.*

The specimens were prepared as in the previous cases by setting the basal plane of the hexagonal crystal perpendicularly both to the flat surface of the specimen and to the direction of the advance of cooling. The size of the zinc plate used was 6 cms. × 4 cms. × 0.15 cms. The appearance of one of the specimens, which was etched with dilute sulphuric acid, is

Fig. 3




× : Direction of the surface normal of the mother crystal.
• : Direction of the surface normal of the strips.

shown in Fig. 2, Plate I.

The orientations of the principal axes of the single-crystals belonging to different strips are given in Table IV, in the same way as the previous

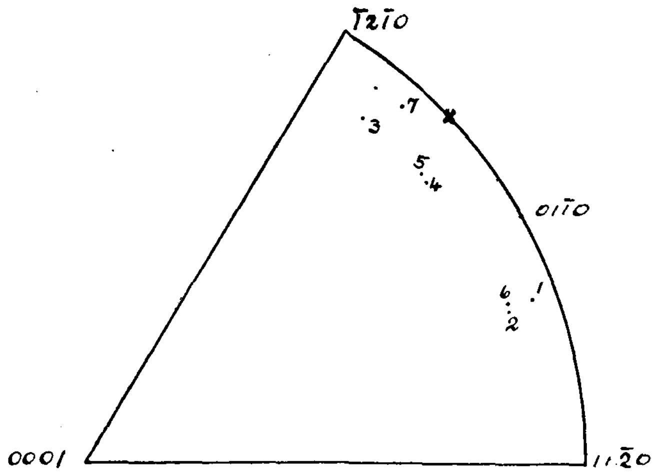
Table IV

| No. of specimen | No. of strip | Declination | Polar angle |
|---|---|---|---|
| Mother crystal | — | 0° | 89° |
| No. 1 | No. 1 | 0° | 86° |
| | No. 2 | −4° | 83° |
| | No. 3 | +16° | 81° |
| | No. 4 | −1° | 81° |
| | No. 5 | −5° | 81° |
| | No. 6 | +1° | 83° |
| | No. 7 | 0° | 86° |
| No. 2 | No. 8 | 0° | 84° |
| | No. 9 | +3° | 85° |
| | No. 10 | 0° | 87° |
| | No. 11 | −7° | 88° |

cases. The strips from No. 1 to No. 7 in Table IV correspond to fairly distinct strips shown in Fig. 2, Plate I, taken successively from left to right. It will be seen from Table IV that the orientations of the principal axes of the crystals belonging to different strips are all roughly the same as that of the mother crystal, excepting the case of strip No.3 where the declination of the principal axis is about 16°. In the present case, the strips seem to develop themselves comparatively longer and more slender than in other cases, as will be seen from Fig.3, plate I.

The stereographic projections of the directions of the surface normals of the specimens, referring to the directions of the crystallographic axes, are shown in Fig.4.

Fig.4




× : Direction of the surface normal of the mother crystal.
• : Direction of the surface normal of the strips.

The infuence of external shocks to the furnace during the solidification and the cooling of the specimen and of the rapidity of cooling on the development of the strips under various conditions was investigated, but they were found to have no influence. It seemed, however, to be easier to obtain larger single-crystals when the basal plane of the mother crystal was parallel to the direction of cooling, so far as the present experiment is concerned.

## Conclusions

From the experiments described before we may conclude that the direction of the principal axis of the hexagonal crystal of zinc obtained by letting the mother crystal solidify and cool slowly is roughly the same as that of the mother crystal, but that the orientation of the other crystallographic axes of the same metal is beyond the control of the experimental conditions examined in the present research.

In conclusion, the writer wishes to express his sincere thanks to Professor U. Yoshida for his kind guidance.

## Plate I

Fig. 1

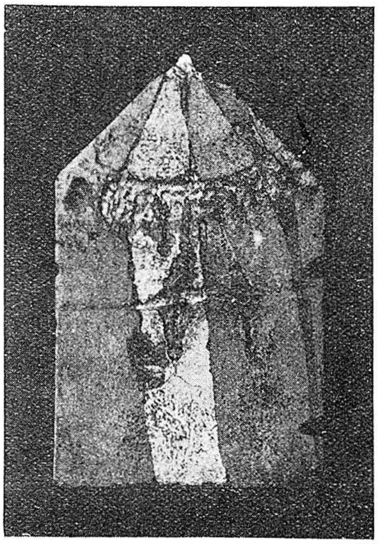


Fig. 2