The Arrangement of the Micro-Crystals in Compressed Single-Crystal-Plates of Aluminium (Part III)

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By

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Abstract

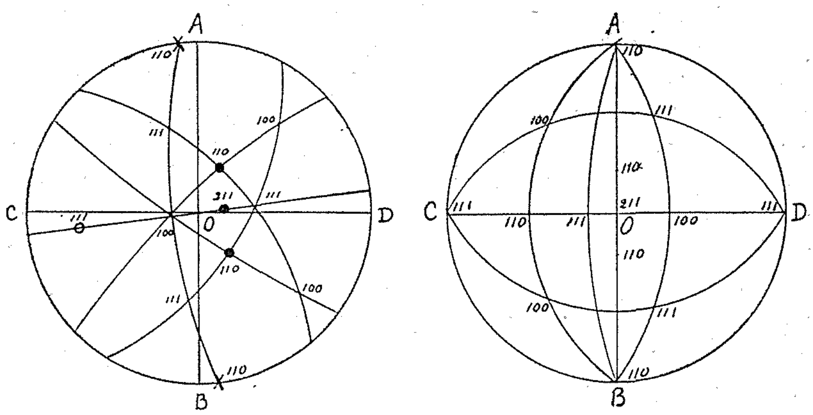
When a rectangular single crystal plate of aluminium was compressed to a thickness of 3 %–10 % of the initial thickness, the axis of the imperfect fibrous arrangement of the micro-crystals, owing to the destruction of the single crystal by compression, was always parallel to the direction of the flow of the metal by compression. It was found that according to the initial orientation of the crystallographic axes with reference to the specimen and the direction of the flow of the metal by compression, such fibrous arrangement could be classified into four types :— (1) The [110] axis was nearly parallel to the longer side of the specimen, the fibrous axis [111] was parallel to the direction of the flow of the metal by compression, and thus the (211) plane was nearly parallel to the flat surface of the specimen. (2) The [111] axis was nearly parallel to the longer side, the fibrous axis [211] was parallel to the direction of the flow of the metal, and thus the (110) plane was nearly parallel to the flat surface. (3) The [110] axis was parallel to the longer side, the fibrous axis [100] was parallel to the direction of the flow of the metal, and thus the [110] plane was nearly parallel to the flat surface. (4) The [100] axis was parallel to the longer side, the fibrous axis [110] was parallel to the direction of the flow of the metal, and thus the (110) plane was parallel to the flat surface. Of the four types of the fibrous arrangement mentioned above, the first two occured more frequently than the last two. The relation between the fibrous arrangement of the micro-crystals in a rectangular plate which is caused by compression of such high degree and of the micro-crystals in rolled aluminium foils was also examined both for single- and polycrystalline specimens, and it became clear that the fibrous arrangement of the micro-crystal was almost the same in both cases, if we regard the direction of the flow of metal on compression as the direction of rolling.

In the two previous investigations[1], the writer examined the arrangement of the micro-crystals in compressed circular and rectangular single crystal plates of aluminium. The micro-crystals in a circular

1. These Memoirs, **12**, 261 (1929) ;— **13**, 299 (1930)

plate rotated themselves, on compression, in such a manner that the (110) plane which made the slightest inclination to the flat surface of the plate became nearly parallel to the flat surface of the specimen on making the [111] or [110] axis which was almost parallel to the flat surface the axis of rotation of the micro-crystals by compression; and when the specimen was compressed to a thickness of less than 30% of the initial thickness, the [110] axis which was nearly perpendicular to the flat surface became the axis of rotation of the micro-crystals. The micro-crystals in a rectangular plate rotated themselves in such a manner that the (110) plane, which made the slightest inclination to the flat surface, became nearly parallel to the flat surface of the specimen, the [111], [110] or [211] axis which was almost parallel to the longer side of the specimen being taken as the axis of rotation of the micro-crystals. It was also stated in the former papers that in the case of circular plates, the (110) plane which was nearly parallel to the flat surface of the specimen was able to become completely parallel to the flat surface on compression, but in rectangular plates it happened sometimes that the (110) plane which was nearly parallel to the flat surface of the specimen was not able to become completely parallel to the flat surface according to the initial crystallographic orientation, being restricted by the condition that the direction of the fibrous axis [111], [110] or [211] axis remained unchanged by compression. In the previous experiments with rectangular plates the specimen were compressed to the thickness of 25%–95% of the initial thickness. In the present investigation, the single crystal specimens of aluminium in the form of rectangular plates were still compressed to the thickness of 3%–10% of the initial thickness. The machine which was used to compress the specimen was a hydraulic press with a maximum pressure of 30,000$^{\mathrm{kgms}}$. With this hydraulic press it was difficult to compress the specimen to a thickness of less than 3% of the initial thickness. The size of the single crystal plate which was obtained by the stress-annealing method was generally 3 cms. × 1 cm. × 1 mm. A rectangular plate whose longer side was about five times longer than the shorter side was obtained from the specimen above mentioned by etching off slowly its outer portion with some dilute acid. When the single crystal specimens thus prepared were compressed to less than 10% of the initial thickness, the axis of the fibrous arrangement of the micro-crystals of aluminium became always parallel at last to the direction of the flow of the metal caused by the compression; and it was found that such a final state of the fibrous arrangement might be classified into the following four types :— (1) The fibrous axis [111] axis was parallel to the direction of the flow of the metal, the [110] axis was nearly parallel to the longer side of the specimen and consequently the (211) plane was nearly parallel to the flat surface of the specimen. (2) The [211] axis was parallel to the direction of the flow of the metal, the [111] axis was nearly parallel to the longer side, and consequently the (110) plane was nearly parallel to the flat surface. (3) The [100] axis was parallel to the direction of the flow of the metal, the [110] axis was nearly parallel to the direction of the longer side, and consequently the (110) plane was nearly parallel to the flat surface. (4) The [110] axis was parallel to the direction of the flow of the metal, the [100] axis was nearly parallel to the longer side, and consequently the (110) plane was nearly parallel to the flat surface. In the following four sections the details of the results obtained in the experiments are described.

Fig. 1



(I) The [111] axis is parallel to the direction of the flow of the metal on compression, the [110] axis is nearly parallel to the longer side of the specimen, and consequently the (211) plane is parallel to the flat surface of the specimen.

(a) of Fig. 1 represents the initial crystallographic orientation of a single crystal specimen whose thickness was 0.85 mm. The line AB is the direction of the longer side of the specimen and the line CD is the direction of the flow of the metal on compression. As stated in the description of the previous experiment, when such a specimen was compressed little by little, the [110] axis shown by a cross became the axis of rotation of the micro-crystals produced by the compression, and the two [110] axes shown by the dots approached gradually to the line AB. Consequently the [111] axis shown by a small circle became gradually parallel to the direction of the flow of the metal on compression. As the direction of the [110] axis shown by a cross remained almost unchanged during the whole process of compression, the [110] axes shown by the dots were not able to come completely to the centre O. In other words the (110) plane which made the slightest inclination to the flat surface of the specimen was not able to become completely parallel to the flat surface. Fig. 1 of Plate I is a Laue-photograph taken with the specimen which was compressed to a thickness of 3% of the initial thickness, by sending the X-ray beam from a molybdenum target normally to the flat surface of the specimen. It is found from this photograph that the [110] axis is nearly parallel to the longer side of the specimen and the [111] axis is nearly parallel to the direction of the flow of the mental on compression, and consequently that the (211) plane is nearly parallel to the flat surface of the specimen. The ideal orientation of the micro-crystals in the specimen is thus just as shown by (b) in Fig. 1, when the specimen is compressed to a thickness of 3% of the initial thickness. Next the writer examined the angle of deviation of the crystallographic axes of the micro-crystals in the specimen from those of the ideal orientation. The amount of the angle of such deviation of the crystallographic axes of the micro-crystals was estimated from the elongation of the Laue-spots which were caused by a small scattering of the crystallographic orientation of the micro-crystals, near their ideal orientation. From the photograph reproduced in Fig. 1 of Plate I, the maximum deviation of the [111] axis, which is nearly in the direction of the flow of the metal, from the flat surface of the specimen is thus found to be about $\pm 14^\circ$; and the maximum deviation of the [110] axis, which is nearly in the direction parallel to the longer side, from the flat surface is found to be about $\pm 21^\circ$. Consequently the maximum deviation of the (211) plane which is nearly parallel to the flat surface is $\pm 14^\circ$ in the direction of the flow of the metal, and $\pm 21^\circ$ in the direction parallel to the longer side of the specimen. That is to say, the deviation of the crystallographic orientation of the micro-crystals is less in the direction of the flow of the metal than in the direction parallel to the longer side of the specimen for compression of such high degree. Judging from this, it seems natural to say that the fibrous axis of the micro-crystals for slight compression is parallel to the direction of the longer side of the specimen and remains almost unchanged till the specimen is compressed to about 25% of the initial thickness, as reported in the former reports; but the fibrous axis changes for compression less than 10% of the initial thickness and finally becomes parallel to the direction of the flow of the metal. The above stated facts were also ascertained diagrammatically. The writer assumed that the [111] axis is the axis of the fibrous arrangement, in the direction of the flow of the metal on compression, the [110] axis is nearly in the direction of the longer side of the specimen, that the maximum deviation of the [111] axis from the flat surface is $\pm 14^\circ$ and the maximum deviation of the [110] axis from the flat surface, $\pm 21^\circ$. On these assumptions, the diffraction diagram of the X-rays that might be expected to be impressed on the photographic plates by the K_α-line of molybdenum impinging normally to the flat surface of the specimen was drawn. Fig. 2 shows the diagram thus calculated and a fair agreement between this diagram and the photograph

Fig. 2

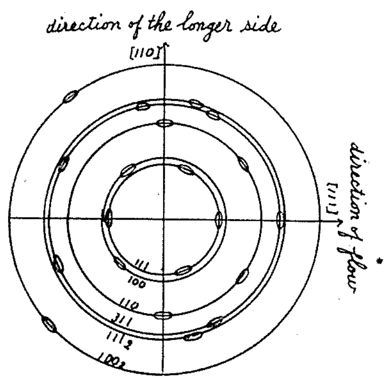
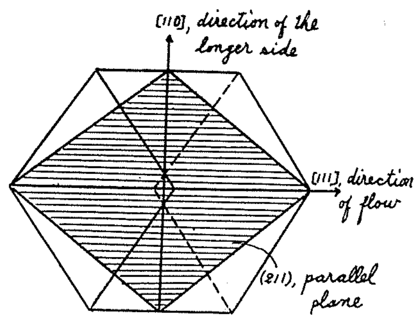


Fig. 3

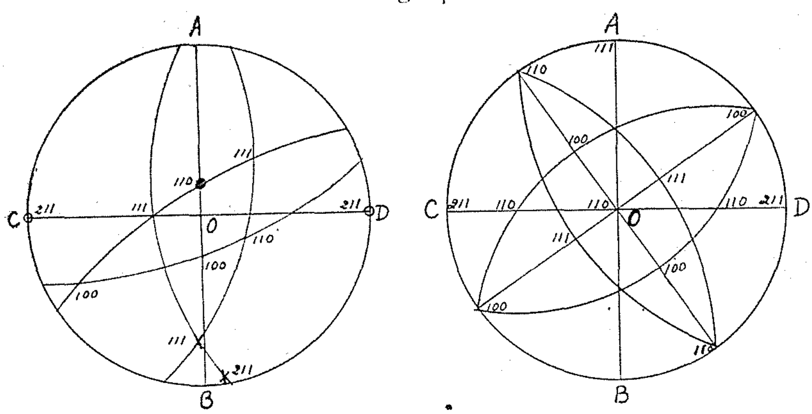


shown in Fig. 1 of Plate I was confirmed. Fig. 2 of Plate I is the Lauephotograph taken with the same specimen, by sending the X-ray beam in the direction parallel to the flat surface of the specimen and perpendicular to the direction of the flow of the metal. From this photograph, it became also clearer that the (211) plane is nearly parallel to the flat surface of the specimen and the [111] axis is parallel to the direction of the flow of the metal, and that the degrees of the deviation of the crystallographic orientations of the micro-crystals from the ideal orientation are just as already stated. Fig. 3 shows the ideal orientation of the micro-crystals in a specimen compressed to such a high degree.

(II) The $[21\bar{1}]$ axis is parallel to the direction of the flow of the metal, the [1 1 1] axis is nearly parallel to the direction of the longer side of the specimen, and consequently the (1 1 0) plane is nearly parallel to the flat surface of the specimen.

(a) of Fig. 4 represents the initial crystallographic orientation of a single crystal specimen whose thickness is 1.10 mm. in stereographic projection. AB is the direction of the longer side of the specimen and CD is the direction of the flow of the metal on compression. For slight compression in this case, the [2 1 1] axis, shown by a cross, becomes the axis of rotation of the micro-crystals, as stated in the report on the former investigation. But, as the compression was

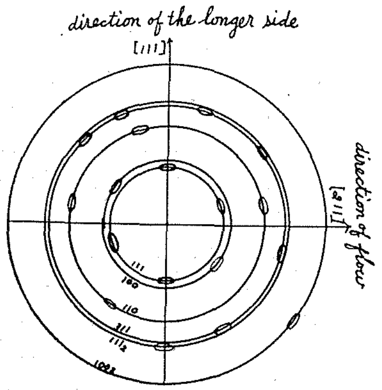
Fig. 4



(a) (b)

increased more and more, it was impossible for the [2 1 1] axis to continue to be the axis of rotation of the micro-crystals. Instead of the [2 1 1] axis, the [1 1 1] axis, shown also by a cross, gradually became nearly parallel to the direction of the longer side of the specimen and this axis became the axis of rotation of the micro-crystals for the compression to less than 20% of the initial thickness. Consequently the [1 1 0] axis, shown by a dot, approached gradually to the centre O, and the [2 1 1] axis, shown by a small circle, became nearly parallel to the direction of the flow of the metal. Fig. 3 of Plate I is a Laue-photograph taken with a specimen which was compressed to a thickness of 3% of the initial thickness, by sending the X-ray beam normally to its flat surface. This photograph shows that the [111] axis is nearly parallel to the direction of the longer side of the specimen and the [211] axis is nearly parallel to the direction of the flow of the metal on compression. Thus the ideal orientation of the micro-crystals in a specimen which is compressed to such a high degree is just as shown by (b) of Fig. 4. Next, as in case (I), the writer calculated the deviation of the crystallographic orientation of the micro-crystals in the specimen from the ideal orientation by means of Fig. 3 of Plate I, and ascertained that the maximum deviation of the [211] axis, which was nearly in the direction of the flow of the metal, from the flat surface of the specimen was about $\pm 13^\circ$ and that the maximum deviation of the [111] axis, which was nearly in the direction parallel to the longer side of the specimen from the flat surface was $+21^\circ$ and -15°. This inequality of the deviation on the two sides of the flat surface seems to be due to the initial great inclination of the [111] axis to the flat surface of the specimen. Thus the (110) plane, which is nearly parallel to the flat surface, deviated by $\pm 13^\circ$ in the direction of the flow of the metal on compression, and by $+21^\circ$ and -15° in the direction parallel to the longer side of the specimen. As the deviation of the [211] axis is less than the deviation of the [111] axis, it seems to be natural to consider that the axis of the fibrous arrangement of the micro-crystals is the [211] axis which is nearly parallel to the direction of the flow of the metal for compression of such a high degree. The above-stated facts were also ascertained by the following consideration as was done in the case (I). The writer assumed the [211] axis to be the fibrous axis which is in the direction of the flow of the metal on compression, and the [111] axis the longer side of the specimen. Then, by taking into consideration the above-stated deviation of the crystallographic orientation of the micro-crystals from the ideal orientation, the diffraction diagram of the X-ray that might be expected to be impressed on a photographic plate by the K_α-line of molybdenum was calculated. Fig. 5 shows the diagram thus calculated and a fair agreement between this diagram and the photograph reproduced in Fig. 3 of Plate I was observed. Fig. 4 of Plate I is the Laue-photograph taken with the same specimen, by sending the X-ray beam parallel to the flat surface of the specimen and perpendicular to the direction of the flow of the metal. From this photograph, it became also clearer that the above stated consideration was correct. Fig. 6 shows the ideal orientation of the micro-crystals in such a compressed specimen.

Fig. 5



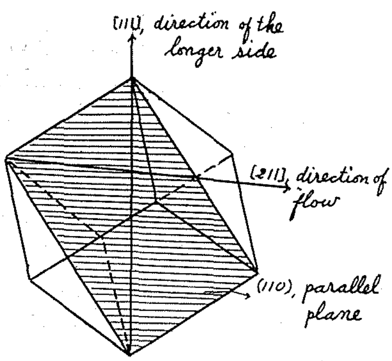
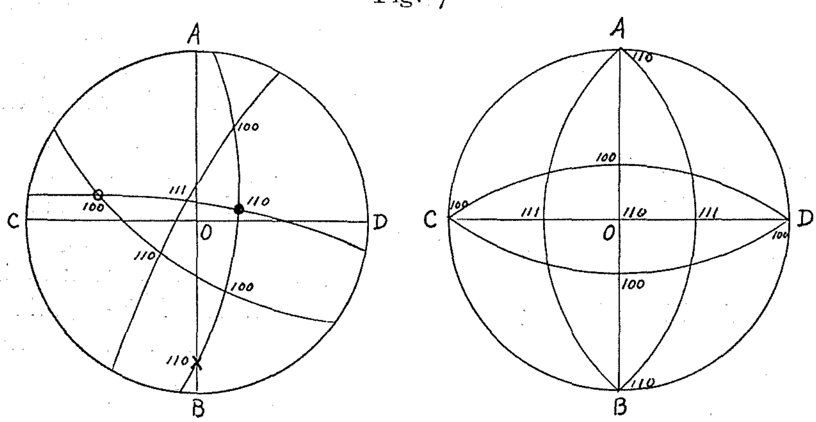


Fig. 6

(III) The [100] axis is parallel to the direction of the flow of the metal on compression, the [110] axis is nearly parallel to the direction of the longer side of the specimen, and consequently the (110) plane is nearly parallel to the flat surface of the specimen.

(a) of Fig. 7 shows the initial crystallographic orientation of a single crystal specimen whose thickness was 0.80mm. Here AB is the direction of the longer side of the specimen and CD is the direction of the flow of the metal on compression. As the process of compression proceeded the [110] axis shown by a cross, which was almost parallel to the direction of the longer side of the specimen, became the axis of the rotation of the micro-crystals; and the [110] axis shown by a dot approached to the centre O. Conse-

Fig. 7



(a) (b)

quently the [100] axis, shown by a small circle, became nearly parallel to the direction of the flow of the metal. Fig. 5 of Plate I shows the Laue-photograph taken with a specimen which was compressed to 8% of the initial thickness, by sending the X-ray beam normally to the flat surface. This photograph shows that the [110] axis is nearly parallel to the direction of the longer side of the specimen, and the [100] axis is nearly parallel to the direction of the flow of the metal on compression. Thus, the (110) plane must be nearly parallel to the flat surface of the specimen. The ideal crystallographic orientation of the micro-crystals of the specimen compressed to such a high degree is represented by (b) of Fig. 7. The deviation of the crystallographic orientation of the micro-crystals from the ideal orientation was estimated in the same way as in the former cases by means of Fig. 5 of Plate I. The maximum deviation of the [100] axis, which is nearly in the direction of the flow of the metal on compression, is about $\pm 13^\circ$ from the flat surface; and the maximum deviation of the [110] axis, which is nearly in the direction of the longer side of the specimen, is about $\pm 20^\circ$ from the flat surface. Thus the (110) plane, which is nearly parallel to the flat surface, deviates from the flat surface by $\pm 13^\circ$ in the direction of the flows of the metal on compression and by $\pm 20^\circ$ in the direction of the longer side of the specimen. As the deviation of the orientation of the micro-crystals in the direction of the [100] axis, which is nearly in the direction of the flow of the metal, is less than that in the direction of the longer side of the specimen, it seems to be natural to consider that the axis of the fibrous arrangement of the micro-crystals is the [100] axis which is parallel to the direction of the flow of the metal for a specimen compressed to such a high degree. Fig. 6 of Plate I is the Laue-photograph taken with the same specimen, by sending the X-ray beam parallel to the flat surface of the specimen and perpendicular to the direction of the flow of the metal. As the ideal orientation of the micro-crystals is just as shown by (b) of Fig. 7, the orientation of the micro-crystals in the following two cases is entirely the same with respect to the X-ray beam :—(1) when the X-ray beam is sent normally to the flat surface of the specimen, (2) when the X-ray beam is sent in the direction parallel to the flat surface and perpendicular to the direction of the flow of the metal. Consequently the photographs of Figs. 5 and 6 of Plate I which are impressed by the K_α-line of molybdenum must be similar to each other; and both of them must also be similar to the calculated diagram shown by Fig. 8 which is drawn by taking into consideration the deviation of the micro-crystals from the ideal orientation. A fair agreement among these three figures supports the consideration mentioned before. Fig. 9 shows the ideal orientation of the micro-crystals in such a compressed specimen.

Fig. 8

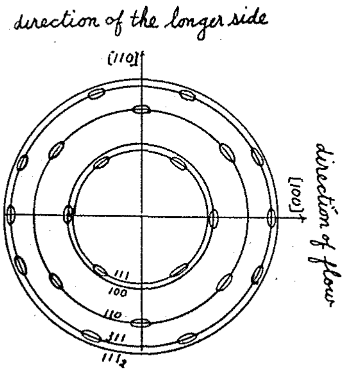
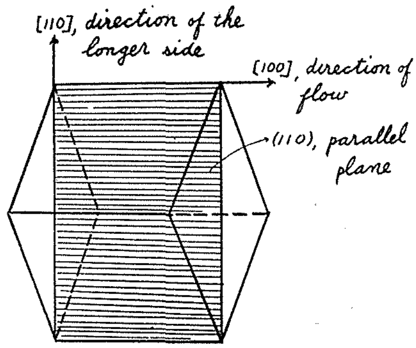


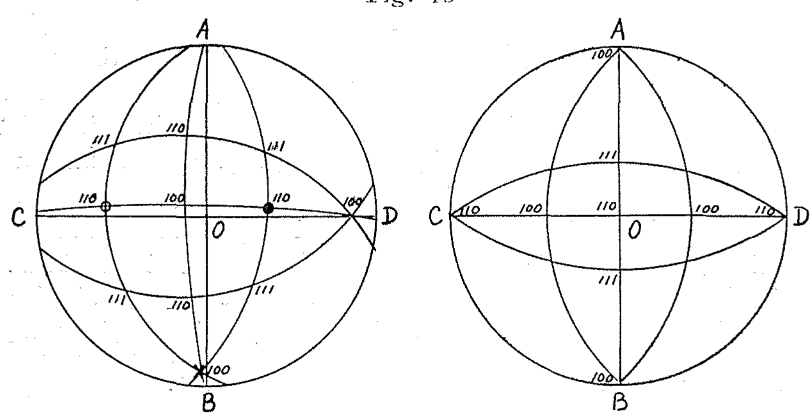
Fig. 9



(IV) The [110] axis is parallel to the direction of the flow of the metal on compression, the [100] axis is nearly parallel to the direction of the longer side of the specimen, and consequently the (110) planes are nearly parallel to the flat surface of the specimen.

(a) of Fig. 10 shows the initial crystallographic orientation of a single crystal specimen whose thickness is 0.80 mm. The directions represented by AB and CD are respectively the same as stated in the

Fig. 10



(a) (b)

preceding sections. As the process of compression proceeded, the [100] axis shown by a cross became the axis of rotation of the micro-crystals and the [110] axis shown by a dot approached to the centre O, therefore the [110] axis shown by a small circle became nearly parallel to the direction of the flow of the metal gradually. Fig. 7 of Plate I is a Laue-photograph taken by sending the X-ray beam normally to the flat surface, with a specimen compressed to 10% of the initial thickness. From this photograph it is clear that the [100] axis is nearly parallel to the direction of the longer side, the [110] axis is nearly parallel to the direction of the flow of the metal, and consequently that the (110) plane is nearly parallel to the flat surface. Calculating from Fig. 7 of Plate I the direction of the crystallographic orientation of the micro-crystals from the ideal orientation, the writer found that the deviation of the [110] axis, which is nearly in the direction of the flow of the metal on compression was about $\pm 16^\circ$ from the flat surface, and the deviation of the [100] axis, which was nearly in the direction of the longer side of the specimen, was about $\pm 20^\circ$ from the flat surface. Thus it may be considered that the axis of the fibrous arrangement is the [110] axis which is parallel to the flow of the metal on compression. It follows, from the facts above stated, that the (110) plane which is parallel to the flat surface deviates from the flat surface by about $\pm 16^\circ$ in the direction of the flow of the metal and by about $\pm 20^\circ$ in the direction of the longer side of the specimen. As the ideal orientation of the micro-crystals is just as shown by (b) of Fig. 10 in this case, the crystallographic orientation of the micro-crystals in the specimen with respect to the X-ray beam is entirely similar in the following two cases:—(1) when the X-ray beam is sent normally to the flat surface, (2) when the X-ray beam is sent in the direction parallel to the flat surface and perpendicular to the longer side of the specimen. Fig. 8 of Plate I is a Laue-photograph taken by sending the X-ray beam parallel to the flat surface and perpendicular to the longer side of the specimen. By comparing Figs. 7 and 8 of Plate I we can detect a close resemblance between them. These two figures are also in fair agreement with Fig. 11 which is the diagram calculated from the consideration mentioned before. Fig. 12 shows the ideal orientation of the micro-crystals in this case.

The writer has mentioned in the preceding four sections that there are four different types in the manner of the fibrous arrangement of the micro-crystals when the rectangular single crystal plates of

Fig. 11

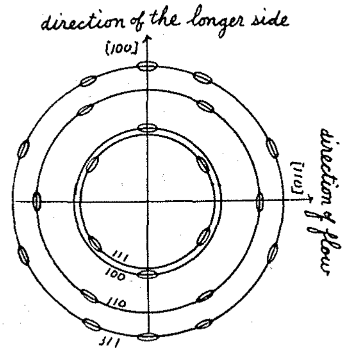
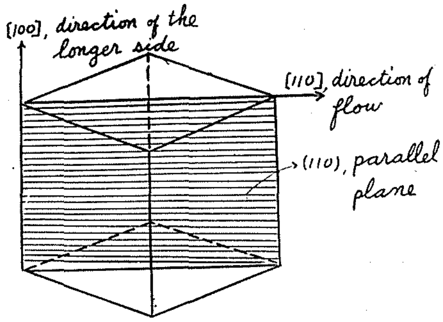


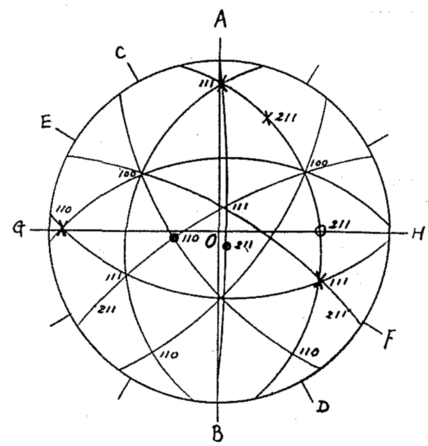
Fig. 12



aluminium are compressed to less than 10% of the initial thickness. So far as the present experiment is concerned, whatever the initial crystallographic orientation may be, the final arrangement of the micro-crystals belongs to any one of the four types mentioned above, and the writer was not able to find out any other manner of arrangement of the micro-crystals. Of the four different types, the first two were observed to occur very much oftener than the last two. The final fibrous arrangements depend, of course, upon the initial crystallographic orientation of the single crystal specimen and the direction of the flow of the metal on compression. Thus, even though the rectangular specimens are prepared from the same single crystal plate, the manner of the fibrous arrangement ought not to be always the same, if the specimens are so prepared that the direction of the flow of the metal on compression is not the same from one specimen to the other. For example, let us mention the results which were obtained with specimens which were so prepared from the same single crystal plate that the direction of the flow of the metal on compression was different in different specimen. Fig. 13 shows the initial crystallographic orientation of a single crystal plate whose size was 4 cms. × 1.5 cms. × 0.8 mm. Four rectangular specimens were so prepared from the mother crystal that the directions of the longer side were parallel to the lines AB, CD, EF, and GH respectively, the angle between any two successive lines being 30°.

(a) When the specimen whose longer side was parallel to the direction AB was compressed to 10% of the initial thickness, the fibrous arrangement of the micro-crystals was as follows:— the [111] axis shown by a cross on the line AB becomes nearly parallel to the

Fig. 13



direction of the longer side, the [110] axis shown by a dot approaches to the centre O, and consequently the [211] axis shown by a small circle on the line GH becomes parallel to the direction of the flow of the metal on compression. This fibrous arrangement is the same as case (II) mentioned before. Fig. 1 of Plate II is a Laue-photograph taken by the normal incidence of the X-ray beam to the flat surface of the compressed specimen, and Fig. 2 of Plate II is one taken by sending the X-ray beam parallel to the flat surface and normal to the longer side of the specimen. These photographs show that the above stated facts are correct.

(b) As the writer has already given in case (III) details about the same specimen whose longer side is parallel to CD, the description of it is omitted here.

(c) When the specimen whose longer side was parallel to EF was compressed to the same high degree as before, the fibrous arrangement of the micro-crystals was as follows:— the [111] axis shown by a cross on EF becomes nearly parallel to the direction of the longer side, the [110] axis shown by a dot approaches to the centre O, and consequently the [211] axis shown by a cross becomes nearly parallel to the direction of flow of the metal. Such arrangement of the micro-crystal is the same as in case (II). Figs. 3 and 4 of Plate II are the Laue-photographs taken by the normal and the parallel incidence of the X-ray beam to the flat surface of the specimen respectively, and show that the above stated facts are correct.

(d) When the specimen whose longer side was parallel to GH was compressed to the same high degree as before, the fibrous arrangement of the micro-crystals became as follows:— the [110] axis shown by a cross on GH becomes nearly parallel to the direction of the longer side, the [211] axis shown by a dot approaches to the centre O, and consequently [111] axis shown by a cross on the line AB becomes parallel to the direction of the flow of the metal. This fibrous arrangement is just as in case (I). Figs. 5 and 6 of Plate II are the Laue-photographs taken by the normal and the parallel incidence of the X-ray beam to the flat surface of the specimen respectively and show that the above stated facts are correct.

As reported in the former investigations, in the compressed circular plates, the manner of the fibrous arrangement of the micro-crystals was rather simple. In compressed rectangular plates it was seen to be different and not so simple as in the circular plates. But there seems not to exist any fundamental difference between the two cases and some complexity in the latter case seems to be due merely to the shape of the specimen. If the initial crystallographic orientation in a rectangular specimen is known, we can now easily find out the fibrous arrangement of the micro-crystals in a specimen compressed to such a high degree, by the aid of the crystallographic globe.

Let us suppose that the equatorial plane of the crystallographic globe is the flat surface of the specimen and a diameter which lies in this plane is the direction of the longer side of the specimen. Then the pole of the globe is the direction of the normal to the flat surface of the specimen. If a [111] axis on the hemispherical celluloid cap of the globe is made to coincide with the direction of the diameter, the number of the [110] axes which lie on the great circle, passing through the pole perpendicularly to the diameter, is six. The angle, which any two adjacent ones of these [110] axes subtends at the centre, is 60°. Consequently the angle between the pole and the [110] axis which is the nearest to the pole is less than 30°. Thus, for full compression, the direction of the [111] axis which is parallel to the longer side remains unchanged and the [110] axis which lies on the great circle and is the nearest to the pole approaches completely to the pole and the [211] axis becomes the direction of the flow of the metal. Therefore the ideal orientation of the micro-crystals becomes just as shown in Fig. 6. Next let us suppose that the [110] axis is parallel to the longer side of the specimen and this axis is made to coincide with the direction of a diameter lying on the equatorial plane of the crystallographic globe. The number of the [110] axes which lie on the great circle passing through the pole and perpendicularly to the diameter is only two in this case; and the angle which these two [110] axes subtend at the centre, is 180°. Moreover there are four [211] axes on the great circle. When the micro-crystals rotate around the [110] axis parallel to the longer side of the specimen, the one of the [110] and [211] axes which lies on the great circle and is nearest to the pole approaches to the pole on compression.

When one [211] axis approaches to the pole, the direction of the flow of the metal becomes the [111] axis, and the ideal orientation of the micro-crystals is just as shown in Fig. 3. If one [110] axis approaches to the pole, the [100] axis becomes parallel to the direction of the flow of the metal on compression, and the ideal orientation of the micro-crystals is just as shown in Fig. 9. Thus if the [110] axis is parallel to the longer side of the specimen, there may happen two different types of the fibrous arrangement caused by full compression. Even if the [111] or the [110] axis deviates initially more or less from the direction of the longer side, the final fibrous arrangement of the micro-crystals becomes any one of the above stated three types of the fibrous arrangement on full compression. When the [100] axis is parallel to the direction of the longer side, this axis becomes the axis of rotation of the micro-crystals and its direction remains unchanged during the whole process of compression. Now make one [100] axis on the hemispherical celluloid cap of the crystallographic globe coincide with a diameter in the equatorial plane of the crystallographic globe. Then the number of the [110] axes which lie on the great circle passing through the pole perpendicularly to the diameter, which is parallel to the longer side of the specimen, is four; and the angle which any two adjoining ones of these [110] axes subtend at the centre is 90. Thus, of these four [110] axes, the one which is nearest to the pole makes the angles less than 45° with the pole. Consequently, on compression, the [110] axis which is nearest to the pole as above stated approaches to the pole, making another [110] axis parallel to the direction of flow of the metal on compression. The ideal orientation of the micro-crystals in this case is as shown in Fig. 12.

It has already been stated that, of the four different types of arrangement of the micro-crystals, the first two are more frequent than the others. This seems to be easily explained, at least to some extent, by the possible number of the crystallographic axes present in the cubic crystal of aluminium as shown in Table I. Let us suppose that the frequency of occurrence of the four types is primarily influenced by the possible number of the crystallographic axes which are to be arranged parallel to the longer side of the specimen. Such numbers for respective types is given in the third column of Table I. This number is three in the fourth type, and it is the smallest compared with that of the other types. This is in agreement with the

Table I

Type	The axis parallel to the longer side of the specimen		The axis parallel to the direction of the flow of metal		The axis normal to the flat surface of the specimen	
	Axis	possible number	Axis	possible number	Axis	possible number
(1)	[110]	6	[111]	2	[211]	2
(2)	[111]	4	[211]	3	[110]	3
(3)	[110]	6	[100]	1	[110]	1
(4)	[100]	3	[110]	2	[110]	2

fact that the fourth type is not so frequent as the first two types. Next if we assume, as was considered above, that the crystallographic axes which are to be arranged parallel to the longer side of the specimen are primarily selected, then the crystallographic axes which are to be arranged parallel to the direction of the flow of metal by compression and those which are to be arranged parallel to the normal to the flat surface of the specimen must be those which are perpendicular to the crystallographic axes selected primarily as to be arranged parallel to the longer side of the specimen. The numbers given in the fifth and seventh column of the table are obtained in this way. In types (1) and (3), the crystallographic axes which are to be arranged in the direction parallel to the longer side of the specimen are the same; and consequently their possible numbers are equal too. However, the possible numbers of the axes which are to be arranged in the direction parallel to the surface normal of the flat surface of the specimen are not the same; they are 2 and 1 respectively. This is in good agreement with the fact that type (1) is more frequent than type (3).

Lastly let us consider the relation between the fibrous arrangements of the micro-crystals produced by compression and by rolling the aluminium plates. Prof. U. Yoshida was of opinion that the mechanism of compression and of rolling of metal might be essentially the same, if we regard the direction of the flow of the metal on com-

1. These Memoirs, **10**, 303 (1927)
2. Zs. f. Physik, **14**, 328 (1923)
3. Zs. f. Physik, **28**, 69 (1924)

pression as the direction of rolling. Investigations of the fibrous arrangement of the micro-crystals of aluminium caused by rolling have been carried out by S. Tanaka[1], Mark and Weissenberg[2], Weber[3] and others. S. Tanaka found three types of fibrous arrangement of the micro-crystals in rolled single-crystal plates. The first two types which occurred very often in the present investigation are similar to two of the three types found by S. Tanaka. Two Laue-photographs were taken by sending the X-ray beam normally to the flat surface of compressed and rolled polycrystalline aluminium foils respectively, which were reduced to 4% of the initial thickness in both cases. Figs. 7 and 8 of Plate II show respectively the photographs taken with the compressed and the rolled foils of polycrystalline aluminium foils. From these figures it was observed that the [211] axis was nearly parallel to the direction of the flow of the metal on compression or to the direcrion of rolling, the [110] axis was nearly parallel to the surface normal of the flat surface and the [111] was nearly perpendicular to the former two axes. Thus we see that, in polycrystalline plates, the fibrous arrangement of the micro-crystals produced by compression is similar to that of the micro-crystals produced by rolling, and that this arrangement belongs to the second type mentioned before. These facts seem to support the view that the mechanism of compression is essentially the same as that of rolling, as was suggested by Prof. U. Yoshida.

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

Plate I

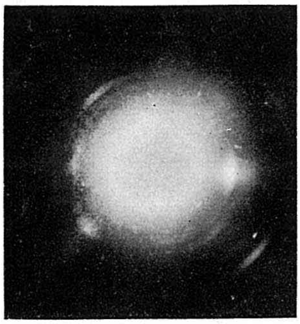


Fig. 1

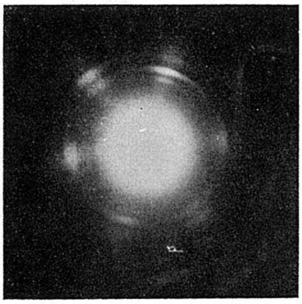


Fig. 2

Fig. 3

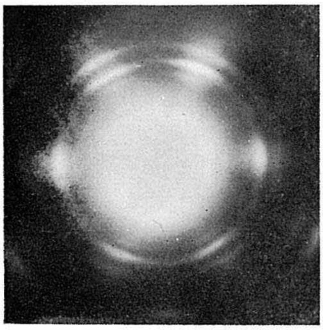


Fig. 4

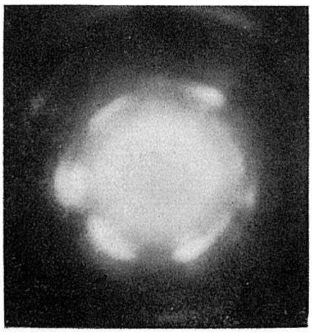


Fig. 5

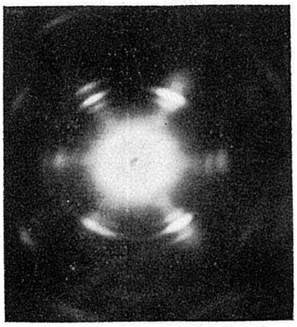


Fig. 6

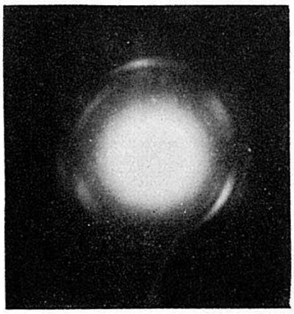


Fig. 7

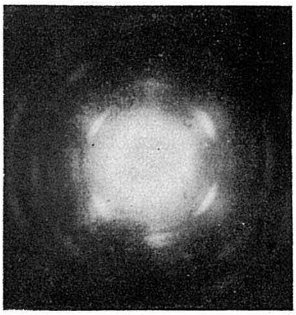


Fig. 8

Plate II

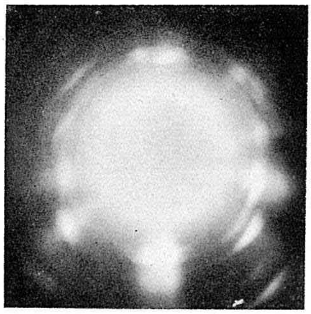


Fig. 1

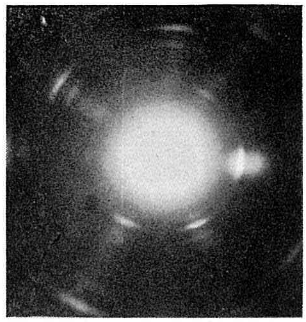


Fig. 2

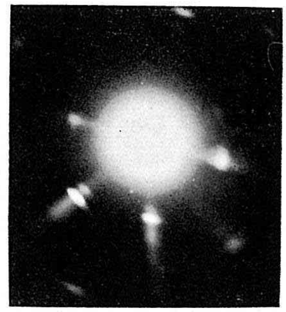


Fig. 3

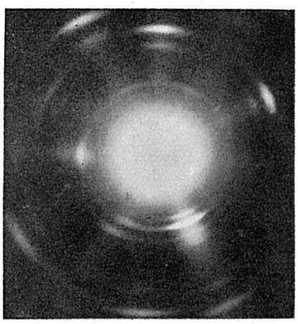


Fig. 4

Fig. 5

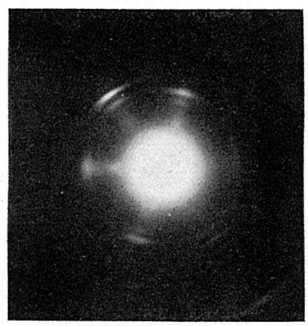


Fig. 6

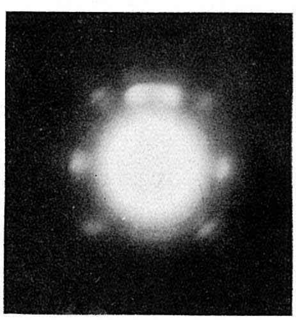


Fig. 7

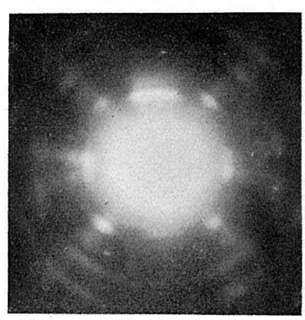


Fig. 8