The Recrystallization of Aluminium

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By

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Abstract

The orientations of the single crystals formed by recrystallization in the extended wires and plates of single crystals of aluminium were examined by means of X-rays, and the orientations were observed to be rather at random in both cases, irrespective of the grade of extension and the orientations of the initial crystals.

When a deformed metal is subjected to suitable heat-treatment, there grow crystals of new orientation in a specimen of a deformed single crystal as well as in one composed of an assemblage of micro-crystals. In a previous experiment,[1] the writer examined the orientations of single crystals of aluminium formed in specimens composed of micro-crystals.

In the present research, the writer has determined the orientations of 192 crystals of aluminium obtained by recrystallization from deformed single crystals, to see whether there is some relation between the orientations of crystals before and after the recrystallization or not. The orientation of the crystals was determind by treating the distribution of Laue-spots with the globe and the spherical scale devised by U. Yoshida.[2]

The specimens were taken from commercial aluminium wires of 3 mm. in diameter and plates of 1.5 mm. in thickness. To let the crystal grow, the wires were drawn through circular dies and the plates were

1 K. Tanaka, Jap. J. Phys., **4**, 137 (1927)
2 U. Yoshida, Jap. J. Phys., **4**, 133 (1927)

extended by 1 or 2 per cent before annealing. The orientations of the large crystals thus formed were determind before recrystallization. The distribution of the orientations of the crystals thus obtained showed the same feature as noted in the previous paper, and it was observed that, in the case of the wire, the [210] axis of the crystal was more favoured by the direction of the axis of the wire than any other crystallographic axis.

These specimens were then extended by various percentages by pulling, and annealed at about 600°C. for 5 hours to let them recrystallize. Fig. 1, Plate I shows the Laue-photograph of an undeformed aluminium single crystal wire taken by the method of using a long slit[1]. Figs. 2 and 3 Plate I and Fig. 4 Plate II were taken by the same method and show the changes in the orientation of the crystal and the internal deformation of the same specimen when it was extended by 2, 10 and 42 (break) per cent respectively by pulling. As can be seen in these figures, the diffraction lines change their positions and become diffuse and irregular as the degree of extension increases. This shows that the single crystal is broken, by the process of pulling, into a large number of smaller pieces with the orientations scattered to some extent; and that, at the same time, the average orientation of these smaller crystals is altered gradually.

It has already been observed by Karnop and Sachs[2], and Arkel and Bruggen[3], that when the extension is too small, recrystallization does not take place in the case of an aluminium single crystal. In the case of Al wires of from 1 to 3 mm. in diameter, this critical per cent of elongation for the recrystallization to be effective was observed by the writer to be about 3 per cent from the identity of the distorted Laue-spots before and after the annealing. On the other hand, when the extension was larger than about 20 per cent the recrystallized grains were too small for Laue-photographs of them to be taken separately. Therefore, the range of the extension investigated here was from 4 to 20 per cent, and the corresponding linear sizes of the recrystallized grains varied mostly from about 0.4 to 8 cm.

The orientations of the crystals obtained by recrystallization were rather random, and no particular relation was detected between the initial crystals and those obtained by recrystallization, irrespective of the

1 U. Yoshida and K. Tanaka, Nature, **118**, 912 (1926)

2 R. Karnop and G. Sachs, ZS. f. Physik, **42**, 283 (1927)

3 A. E. V. Arkel and M. G. v. Bruggen, ZS. f. Physik, **42**, 795 (1927)

grade of extension applied to the specimens before recrystallization. This seems to be of no little interest; and it is especially worth noting that the crystals of new orientation come out and grow in a specimen of small extension, the orientation of small crystals formed by extension in this specimen being nearly the same as that of the original single crystal.

It has been stated that the orientations of the new crystals formed by recrystallization in the extended wires of single crystals are rather random. But this is only a general statement, and it would be more exact to say that the vicinity of the [111] axis of the crystal seems to be a little favoured by the direction of the axis of the wire, so far as the present experiment is concerned. Two examples of the orientations of the axes of two wires before and after the recrystallization, in refer-

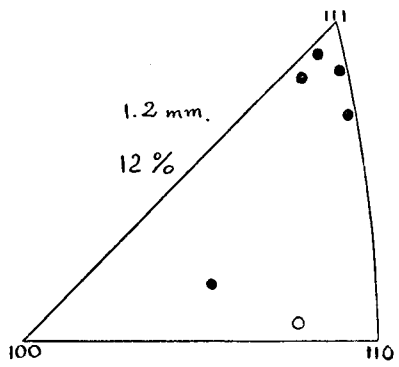

Fig. 1

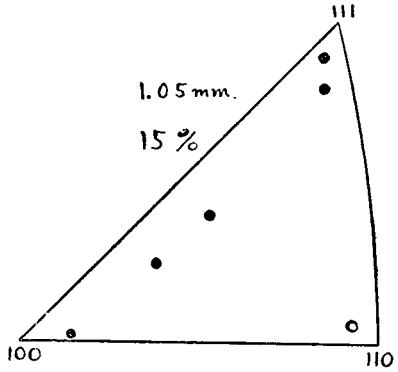

Fig. 2

ence to the crystallographic axes, are shown separately in Fig. 1 and 2, by the stereographic projection. Here 100, 110 and 111 represent the directions of the normals to the atomic planes (100), (110) and (111) respectively, and the small circle represents the direction of the axis of the wire before the recrystallization and the dots in the same figure those in separate pieces of single crystals obtained by recrystallization. The diameter of the wires and the percentage of the extension are written separately in each figure.

For the specimens in the form of plate, the lengthwise directions and the surface normals of them were represented in reference to the crystallographic axes, and it was observed that the orientation of the crystals formed by the recrystallization was rather at random, and no particular relation between the orientation of the crystals formed by recrystallization and that of the initial ones could be detected.

Four photographs in Fig. 5, Plate. II show the appearances of the crystal grains before and after the recrystallization when the specimens of single crystals were subjected to extensions of 4, 6, 8 and 10 per cent respectively before the annealing process. The boundaries of initial crystals are shown by the lines marked on the surfaces of the plates and those of the recrystallized grains will be easily detected from the difference in the shades of the photographic images at various parts of the surfaces of the specimens.

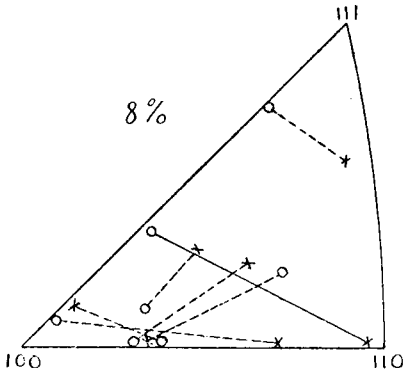

Fig. 3

In Fig. 3, for example, the direction of the surface normal and the lengthwise direction of a plate are shown, in reference to the crystallographic axes, by the stereographic projection as in the case of the wire. Here the direction of the surface normal and the lengthwise direction of the plate are indicated by a circle and a cross respectively, and the line connecting a circle and a cross indicates that they belong to the same crystal. Of the lines thus joining a circle and a cross, the full line means that the circle and the cross connected by this line belong to the crystal examined before recrystallization, and the remaining broken lines relate to the crystals obtained by the recrystallization at the place formerly occupied by the crystal signified by the full line.

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

Plate I

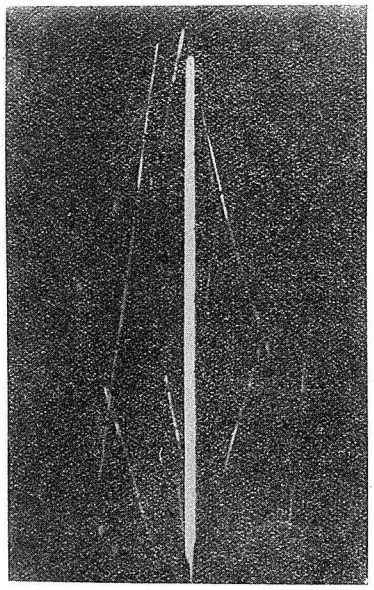

Fig. 1

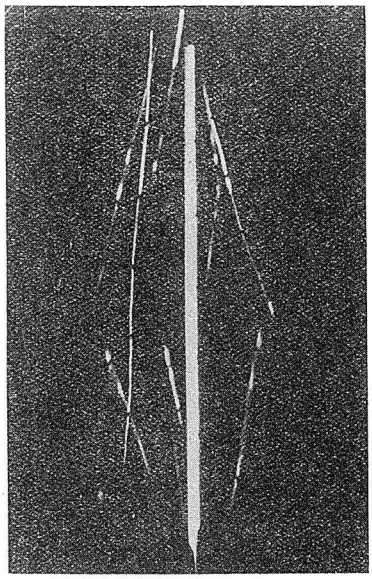

Fig. 2

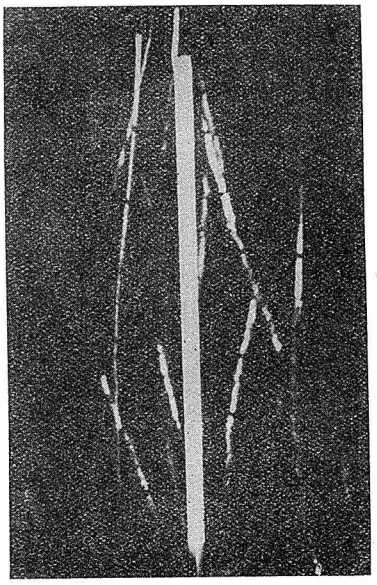

Fig. 3

Plate II

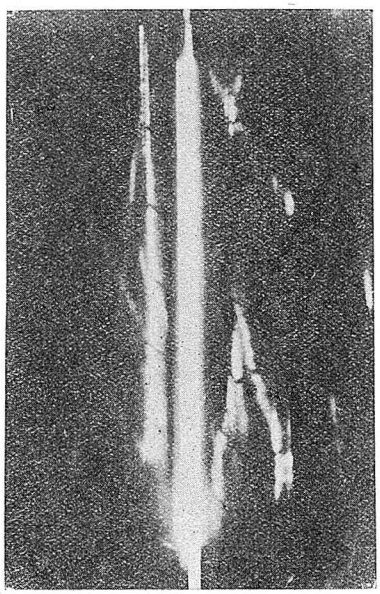

Fig. 4

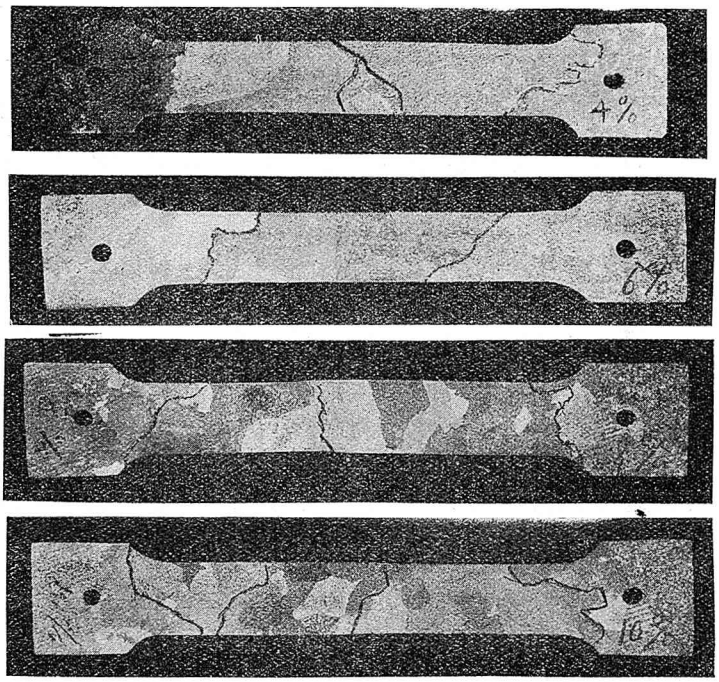

Fig. 5