Crystal-Faces developed by etching Metallic Crystals of Aluminium and Zinc

By

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(Received April 12, 1929)

Abstract

When the surface of a block of the single-crystal of a metal is etched by some reagent, its surface shines brightly in several directions. This seems to be caused by the reflection of light at many small and regularly arranged facets of the crystal, which are developed by etching. In the present experiment the writer has determined the crystallographic indices of the crystals of aluminium and zinc, by means of an optical goniometer and X-ray analysis. In the case of the aluminium crystal these facets are (100) and (110), the intensity of light reflected from the (110) facets being much fainter than that reflected from the (100) facets. In the case of the zinc crystalthese facets are (0001) and (10$\bar{1}$0).

The specimens of aluminium examined in the present experiment were taken from commercial wires of 3 mms. in diameter and commercial plates of 1–1.5 mms. in thickness, and the specimens of zinc were also taken from commercial plates of 1–1.5 mms. in thickness. To cause the crystal to grow, the method of straining followed by heat-treatment was applied.[1] When the surfaces of specimens thus prepared are etched by HCl, HF and NaOH etc., their surfaces shine brightly in several directions. This means that the etched surface is not a flat surface, but consists of many zig-zag facets of the crystal, which are arranged regularly.

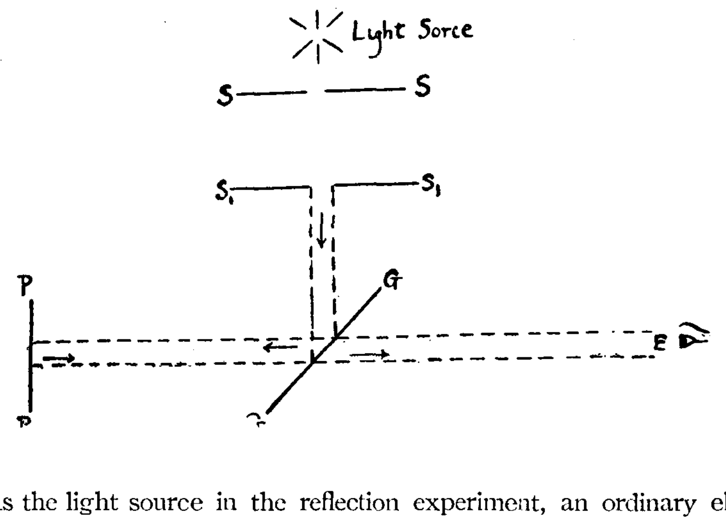
Experiments to determine the crystallographic indices of such facets of the crystal of aluminium have already been made by J. Weerts[2], Y. Shimizu,[3]

1 H. Carpenter and F. Elam, Proc. Roy. Soc., **100**, 329 (1922)
2 J. Weerts, Z. S. f. techn. Physik, **9**, 126 (1928)
3 Y. Shimizu, Sci. Rep. Tôhoku Imp. Univ., **16**, 621 (1927)

H. H. Potter and W. Sucksmith[1] and others, from the angular relation between the directions of the normals to such facets, which were obtained by measuring the reflected directions of the light falling on the etched surface at a certain direction. But the results obtained by these authors are not concordant. Shimizu obtained (221) faces as such facets, Weerts (100), and Potter and Sucksmith two kinds of faces, (100) and (110). As to the zinc crystal, no such experiment has yet been attempted, so far as the writer is aware.

Now, in the present experiment the indices of the crystal-facets developed by etching were obtained by comparing the orientation of the normals of such facets with that of the crystallographic axes of the single-crystal. The former was determined by using an optical goniometer as shown diagramatically in Fig. 1, and the latter by treating the Laue-photograph taken with the specimen with the globe and the spherical scale devised by Prof. U. Yoshida.[2] X-ray analysis is of course necessary, because it may sometimes be erroneous to determine the indices of the crystal facets only from the angular relation between the directions of the normals to such crystal facets.

Fig. 1



As the light source in the reflection experiment, an ordinary electric lamp is used. A bundle of parallel rays of about 1 cm.^{2} in cross-section limited by the two slits SS and S_1S_1 in Fig. 1, is first reflected by a glass

1 H.H. Potter and W. Sucksmith, Nature, **119**, 924 (1927)

2 U. Yoshida, Japanese, J. Phys., **4**, 133 (1927)

plate GG standing at 45° to the incident rays, and then it is sent to the surface of the specimen at PP. The position E of the observer is just opposite to the specimen in reference to the glass plate GG. If the specimen at PP is properly rotated about two axes, one horizontal and the other vertical, we can find several positions of the specimen at which the surface is most brilliant. In each one of such positions of the specimen the direction of both the incident and the reflected rays coincides with that of the normal to one of the crystal facets, and thus we can easily find the orientation of the normals to the crystal facets referring to the specimen; and consequently we can find the latitude Φ and the longitude Θ of the normals to the crystal facets referring to the surface of the specimen.

Practically the reflected light does not come suddenly to the observer brilliantly just at the position expected from the law of reflection, but it becomes brilliant gradually within a certain angular interval ($\pm 3°$) of the orientation of the specimen. These circumstances hinder the precise determination of the orientation of the crystal facets. This inaccuracy of the orientation of the crystal facets was made up for to some extent in the present experiment by taking the mean value of several different observations of the latitude and the longitude of the normal to the same crystal facet.

I. Aluminium Crystal

About thirty specimens were examined in the present experiment and in all cases the indices of the crystal faces developed by etching were (100) and (110), (for examples, see Table I). This means that the crystal faces developed by etching belong to one of the following two cases.

a. An assemblage of the cube-faces (100) and the dodecahedral faces (110). (Fig. 2a and Fig. 2b).

b. A combination of the dodecahedral faces and the cube-faces. (Fig. 3).

Table I

	Φ	Θ	Φ	Θ	Φ	Θ	Φ	Θ	Φ	Θ	Φ	Θ	Φ	Θ	Φ	Θ
By optical method	42°	26°	176°	57°	302°	20°	73°	62°	142°	19°	203°	18°	264°	55°	350°	30°
By X-ray analysis	40°	27°	180°	60°	300°	18°	72°	66°	142°	25°	207°	19°	268°	55°	348°	32°
Indices of the crystal faces	100		001		$0\bar{1}0$		101		011		$\bar{1}01$		$0\bar{1}1$		$1\bar{1}0$	

Fig. 2a

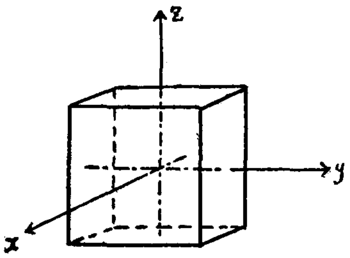


Fig. 2b

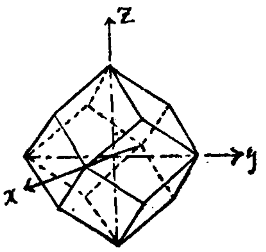
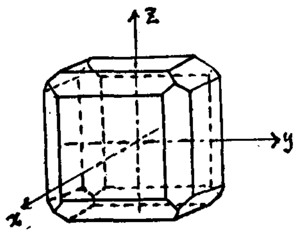
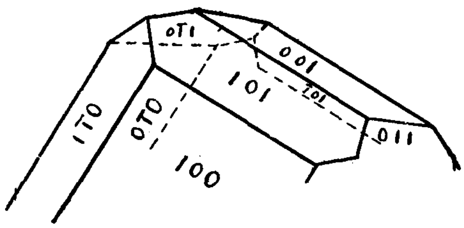


Fig. 3



Of these two cases, the latter seems to be more probable than the former; because the intensity of the light reflected from the (110) faces is alway fainter than that from the (100) faces in a certain ratio. Thus considering, the case of Table I seems to be such as shown graphically in Fig. 4, where the crystal faces developed by etching are a combination of cube and dodecahedron, the corners of the cube being truncated by the faces of the dodecahedron.

Fig. 4



The results described above are independent of the kind and the concentration of the etching solutions so far as the present experiment is concerned. By using HCl, HF, and NaOH as etching solutions, and by changing their concentrations from 5% to 50% the writer obtained the same results as those stated before.

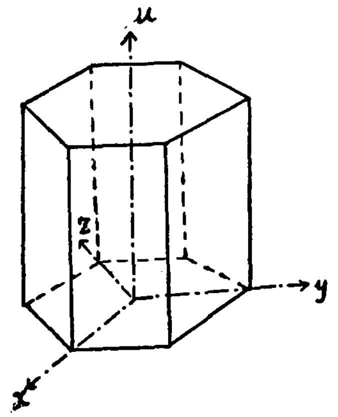
II. Zinc Crystal

By optical measurement on about ten single-crystal plates, the directions of the reflecting facets of the crystal were found to coincide with those of the crystal faces forming a hexagonal prism. Thus we can imagine two possible cases of the crystal faces developed by etching, the first consisting of the faces (0001) and (10$\bar{1}$0), and the second (0001) and (11$\bar{2}$0). To select the actual one from these two, we must know the orientation of the crystallographic axes of the zinc crystal in reference to the specimen; and this was done by taking a Laue-photograph. In such a manner, the indices of the crystal faces developed by etching the zinc crystal were ascertained to be (0001) and (10$\bar{1}$0) as shown in Fig. 5. The results of observation on one specimen are given in Table II as an example.

Table II

	Φ	Θ	Φ	Θ	Φ	Θ	Φ	Θ
By optical method	290°	45°	30°	8°	88°	42°	164°	32°
By X-ray analysis	290°	45°	30°	8°	85°	42°	160°	33°
Indices of the crystal faces	0001		10$\bar{1}$0		01$\bar{1}$0		$\bar{1}$100	

Fig. 5



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