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INFLUENCE OF THE SURFACE LAYER ON THE PLASTIC
DEFORMATION OF ICE SINGLE CRYSTALS

BY

JIRO MUGURUMA

BUILDING RESEARCH
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NATIONAL RESEARCH COUNCIL

REPRINTED FROM
PHYSICS OF ICE
PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON PHYSICS OF ICE
HELD IN MUNICH, GERMANY
SEPTEMBER 9 - 14, 1968
P. 213 - 216

RESEARCH PAPER NO. 415
OF THE
DIVISION OF BUILDING RESEARCH

OTTAWA

PRICE 10 CENTS

OCTOBER 1969

NRC 11026

L'INFLUENCE DE LA COUCHE SUPERFICIELLE
SUR LA DEFORMATION PLASTIQUE DES
MONOCRISTAUX DE GLACE

SOMMAIRE

Après que l'on eût ôté la couche superficielle endommagée de monocristaux de glace, on a assisté à une augmentation considérable de la résistance au cisaillement mesurée au cours du glissement sur le plan basal à une vitesse de déformation constante. Ce phénomène montre que les sources superficielles de dislocations ont un effet marqué sur la déformation.

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INFLUENCE OF THE SURFACE LAYER ON THE PLASTIC
DEFORMATION OF ICE SINGLE CRYSTALS

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Abstract

The removal of the mechanically disturbed surface layer of ice single crystals greatly increases the maximum stress for basal glide in constant strain rate tests. This shows that surface dislocation sources have a pronounced effect upon the deformation.

The results of various studies of the deformation behaviour of ice single crystals in constant strain rate tests /1-4/ show a wide variation in the shape of the stress-strain curve. This variation has been considered to be due to the differences between crystals in the dislocation density.

In this note, evidence is presented to show that not only the quality of the crystals, but also the method of specimen preparation, strongly influences the yield behaviour of single crystals of ice. The results are interpreted in terms of surface sources of dislocations.

The specimens used were rectangular plates cut from single crystals in such a way that the basal plane was 45°

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to the long axis of the specimen and normal to its largest face. These plates were prepared either by planing with a fine blade or by polishing with fine emery paper until they were 5 mm in thickness, 20 mm in width and 25 mm gauge length. In some specimens, additional surface layer was removed either by a chemical method /5/ or careful slight melting. Deformation in compression and at a constant rate of crosshead movement was achieved with a Hounsfield tensometer driven by a synchronous motor and equipped with a load cell and gear train for varying the strain rate.

Curves A and B (figure 1) are typical results for specimens with and without chemical polishing. It can be clearly seen that the maximum stress for the specimen polished chemically (curve A) is about twice as great as the one that has only been polished mechanically. In order to increase the maximum stress, it was found necessary to remove a layer of approximately 200 μ in thickness by chemical polishing.

A characteristic increase in the maximum stress could be obtained only for crystals that would have had a fairly high maximum stress without additional removal of

Fig.1 The effect of surface condition on the compressive stress-displacement curve of ice single crystals in basal glide at -10°C . (Crosshead speed = 0.063 mm/min; specimen length = 25 mm).
 Curve A: Result for chemically polished crystal.
 Curve B: Result for mechanically polished crystal.
 Curve C: Result for crystal that appeared to have quite a high initial density of dislocations

surface, as exhibited by curve B. According to the general relationship for the plastic strain rate /6/, crystals with high maximum stress have initially a low density of mobile dislocations; those with low maximum stress have a high density. Curve C is an example of the behaviour of crystals that appeared to have had quite a high initial density of dislocation according to the above relationship. For these crystals, the removal of surface did not have any effect upon the maximum stress.

In order to establish that surface sources of dislocations are of primary importance in the deformation behaviour, specimens without additional surface removed were annealed in a kerosine bath at -3°C for 120 hours. The maximum stress of some of the annealed specimens was almost the same as that obtained for specimens with surface removed by chemical polishing. On the other hand, crystals with low maximum stress (curve C) had the same maximum stress after annealing as similar crystals without annealing. This indicates that the dislocations generated at the surface layer due to mechanical polishing are more easily removed from the crystal by image forces than internal dislocations.

If the surface sources are a dominating factor, it would be expected that slip bands in a specimen without surface removed would be faint and more closely spaced because many surface sources would be active and the displacement per slip band would not need to be so large to produce a given strain. The slip bands of the specimen with surface removed should be clear and more widely spaced because fewer dislocation sources would operate and a larger displacement per slip band would be required to produce the same strain. Observations proved the validity of these assumptions and provided additional evidence that surface sources of dislocations play a very important role in the deformation process of ice crystals.

The results show that the surface layer of ice crystals does not appear to act as a strong barrier to dislocation movement, but does act as a source of dislocations. This emphasizes that surface treatment is of primary importance when carrying out studies on the structure-sensitive properties of ice crystals.

Detailed results will be published.

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