REVIEW

HIGASHI, A., *ed*. 1988. *Lattice defects in ice crystals – X-ray topographic observations*. Sapporo, Japan, Hokkaido University Press.

X-RAY topography is a technique for producing images of crystals which reveal dislocations, stacking faults, and other long-range distortions of the lattice. It was first developed by Andrew Lang in the late 1950s, and observations on ice were published by Hayes and Webb in 1965. Since then, Professor Higashi and his group at Hokkaido University have used the technique extensively for the study of lattice defects in crystals of ice. This book, edited by Higashi and containing chapters by his principal collaborators, is a survey of their work over the past 20–25 years. It is very well produced and contains many topographs reproduced at a size and with a clarity that was not possible in most of their earlier publications. Some of the topographs have not been previously published.

The technique can be understood by imagining a crystal placed in an X-ray beam so as to produce Bragg diffraction. If the beam is wide and highly collimated, each point on the diffraction spot corresponds to X-rays diffracted from a particular place on the crystal, and the spot is therefore an image of the crystal. Lattice distortions in the crystal modify the diffraction conditions and produce contrast in the image. In practice, using conventional X-ray generators, the collimation and diffraction conditions cannot be maintained over the whole of the crystal at the same time, and arrangements for scanning the crystal have to be introduced. In this way, topographs can be obtained showing several square centimetres of a specimen a few millimetres thick. Early topographs required exposure times of several hours but, by using increasingly powerful X-ray generators, the exposure times for topographs taken at Hokkaido have been reduced to a few minutes. A recent advance is to make use of synchrotron radiation, and the book includes one set of topographs obtained in this way at the Photon Factory at Tsukuba. However, the extensive programme of work described has been greatly facilitated by the fact that the authors have had their own X-ray equipment close to the cold room in their laboratory.

X-ray topography is very well suited to the study of ice, and the fact that no book such as this exists about any other material supports the claim that ice is the best material for study by this means. This is partly because ice has a low molecular weight and X-ray absorption, and partly because of properties of the lattice defects in it.

The book shows first the dislocation structure in single crystals of natural ice from Mendenhall Glacier. The details are, however, not very clear because the dislocation density is not sufficiently low. X-ray topography produces no magnification, the image being recorded actual size on fine-grain plates or film and only enlarged photographically thereafter. This means that good topographs require crystals of unusually low dislocation density. Higashi's group has therefore devoted much effort to the growth of high-quality crystals, and they have obtained large crystals of ice with dislocation densities as low as $100\,cm^{-2}$ in their laboratory. The book contains topographs illustrating features of the growth process and the consequences for the structure of adding traces of impurity to the water before freezing.

A major chapter deals with the generation, multiplication, and motion of dislocations that is associated with plastic deformation. Because X-ray topography can only be used when the dislocation density is low, the observations are confined to the very early stages of deformation. Knowing that macroscopic deformation occurs by slip on the basal plane, it is a surprise to discover that fast-moving edge dislocations on non-basal planes play an important role in the generation of the dislocation distribution required for slip. Signs of this were seen in early topographs, but it has taken many years to appreciate their significance. The book describes early estimates and later systematic measurements of the velocities of dislocations as functions of stress and temperature.

The study of stacking faults is an important part of the work described. Areas of stacking fault parallel to the basal plane and surrounded by partial dislocation loops are formed in ice by the condensation of point defects. By careful study of the topographic images and the way in which the loops expand or contract under stress or changes in temperature, Higashi's group have been able to show that the dominant point defects in ice are interstitials. They have determined their diffusion coefficient and shown that it is the same as that obtained for self-diffusion by more conventional methods. The topographs showing large areas of crystal containing stacking faults and prismatic dislocation loops are amongst the most impressive in the book. They show what an "almost perfect" crystal is "really like" inside!

The final chapter describes studies of large-angle grain boundaries in ice. Such boundaries with misorientations close to those required by the coincidence-site lattice model are shown to have facets and to include grain-boundary dislocations which accommodate the fact that the fit is not perfect.

We all know that ice is a material that displays beauty in many forms. This book belongs to that class of books which by their production and their content reveal this beauty to us. It should be an essential volume in any collection that aims to show what ice is like, and it is a fine memorial to the contribution that Akira Higashi and his colleagues have made to glaciology.

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