ESRF

Experiment title:
Synchrotron x-ray topographic study on dislocation distributions in ice single crystals from the 3348 m Vostok ice core (Antarctica)

Experiment number:
HS 100

Beamline:
ID 19

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Introduction

The deformation of ice is a topic of growing interest, studied increasingly in relation to the dynamics of polar ice sheets. Knowledge of the mechanical behavior of ice is necessary for dating ice cores and interpretating them in terms of paleoclimate. The main feature of the plasticity of ice crystals is its outstanding anisotropy. As a consequence, in a polycrystal, a non-uniform state of internal stress develops, which is at the origin of the initiation of dynamic recrystallization in deep ice cores in Greenland and Antarctica.

The time scale of the 3350m long ice core recovered at Vostok (East antarctica) provides an age of about 400,000 years. Grain size of several cm was observed in recrystallized ice below 3000m. This large grain size appears to be related to the occurrence of continuous recrystallization and, probably, to "abnormal grain growth"(De La Chapelle et al., in press). From these authors, the dislocation density within these crystals should be less than $1 \times 10^{10} m^{-2}$.

The main goal of this first study was to use the Synchrotron radiation topography technique at ESRF (ID 19 **beam** line) to investigate the distributions of dislocations (sub-boundaries and dislocations within sub-grains) in recrystallized ice of the Vostok ice core. The information gained by this analysis will permit to validate physical deformation models established to simulate texture development and the instantaneous mechanical behavior of anisotropic ices found in polar ice sheets (Castelnau et al., 1996; in press).

Experiment

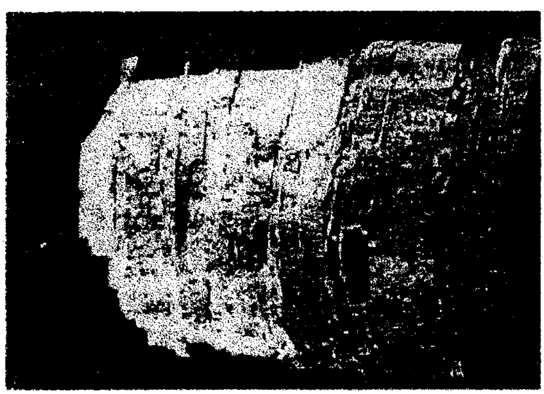
A cooling system was specially constructed to maintain ice samples at sub-zero temperature. A combined system with a liquid nitrogen flow and a resistance heater was used to ensure the temperature regulation between -1 ° to -100°C. To avoid sublimation, the temperature was fixed at -60°C in all experiments, temperature which allowed no visible sample destruction after 20 hours of experiment. Ice samples of about 1x1x1x cm3 were glued on the copper sample holder. The c-axis orientation was determined in cold room with polarized light making more easy the investigation of diffraction planes.

Most of experiments were performed with monochromatic radiation at 0.69Å. The diffraction planes (0002), (1170) and $(1\bar{1}00)$ were investigated. The angular distributions of domains or subgrains were established by measuring approximated “rocking curves”. White radiation topography was also used to record several reflections simultaneously. In this case, the synchrotron beam was collimated at 100x100 μm^2.

First results

Measurements were done on Vostok ice single crystals from the depths: 2595, 3126 and 3316m. Topographs have been obtained with basal and prismatic diffracting planes. Two typical images are shown below. A structure with sub-basal plates was found with the (0002) diffraction plane. A subgrain of a size of about lmm can be seen. The halfwidth of the rocking curve is about 3’. Generally, the rocking curve of the of the (0002) reflection was smaller than in other directions. Topography images obtained with diffraction on the $(1\bar{1}00)$ planes exhibit an undulating structure with misorientations between bumps and hollows less than 4’. The layered structure observed in figure la could be associated with twist sub-boundaries, resulting from basal slip. As a consequence, these sub-boundaries would yield a distorsion of prismatic planes, giving the diffraction contours observed in figure lb, where a $(1\bar{1}00)$ reflection was used. Ice crystals from deep ice probably also contain strong strain fields induced by the ice pressure (about 30 MPa. at 3300 m) and associated with sub-boundaries or grain boundaries.

On figure lb, some contrast is observed at the limits of the contours, that corresponds to weak beam conditions. This contrast could be associated with dislocations. An estimation of the dislocation density within subgrains is probably difficult with such strong strain fields. But, angular distributions of subgrains could be established and compared with simulations (De La Chapelle et al., in press).



lmm

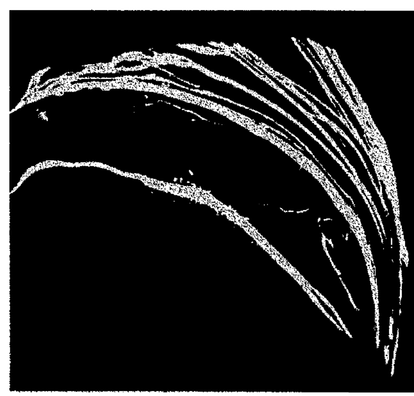


Figure la

Figure lb

A monochromatic beam topographs with basal (a) and prismatic (b) diffracting planes; λ= 0.69 A

S. De La Chapelle, 0. Castelnau, V. Lipenkov and P. Duval, J. *of Geophysical Res.,* in press.
0. Castelnau, P. Duval, R.A. Lebensohn and G.R. Canova, J. *of Geophysical Res., 101,1996*
0. Castelnau, G.R. Canova, R.A. Lebensohn and P. Duval, Acta *Mater.* in press

These preliminary results were presented at the “Colloque Plasticité 97” in Lausanne (17-19 march 1997)