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Observations of grain boundary structures and inclusions in the NEEM ice core by combination of light and scanning electron microscopy

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Dynamics of ice sheets is governed by the flow of the ice and this flow results from the internal deformation of the ice aggregate. The deformation properties of the ice are known to be dependent on several factors, such as microstructure (e.g. crystal grain size and orientation) and impurities. It is well known that ice from glacial periods in ice sheets has a high impurity concentration, and the deformation is reported to be faster than that of non-glacial ice (Faria et al., 2014). However, the mechanisms of the deformation are still not well understood. For a better understanding of ice sheet dynamics, it is a prerequisite to elucidate deformation mechanisms of such impurity-rich ice.

The microstructure of a material is a factor that influences mechanical properties and is also an indicator of the dominant deformation mechanisms. The effects of impurities on the deformation and the microstructure depend on chemical compositions, states (viz. insoluble inclusions or soluble ions) and locations of the impurities in the crystal lattice. Therefore, in order to better understand the deformation mechanisms in ice, investigation of relationship between the microstructure and characteristics of the impurities is important.

We examined the relationship between grain boundaries and inclusions. Light microscopy (LM) is commonly used to map grain boundary structures on a large area of the ice samples (up to 10 $\times$ 10 cm); however, observation of small inclusions < 1 μm is limited due to the spatial resolution of LM. For observations of small impurities in ice cores, scanning electron microscopy (SEM) is useful although limited area (1 $\times$ 1 cm) can be examined, and sublimation/surface diffusion on ice in the SEM could move the impurities from their original locations.

In order to examine the relationship between the grain boundary and the inclusions, we have combined LM and SEM. We first mapped large areas of the ice samples with LM, and then chose several smaller areas within the mapped area for SEM observations. Energy dispersive X-ray spectroscopy (EDS) was also performed during SEM observations to characterize the chemical composition. Our approach was applied to NEEM glacial ice (1548 m depth, 19.2 kyr BP). The initial results show inclusions observed by LM formed aggregates of sub-micrometer-sized particles, whose main constituents were silicates.

Reference

Faria, S. H., I. Weikusat and N. Azuma (2014). The microstructure of polar ice. Part II: State of the art, Journal of Structural Geology 61: 21-49.