Investigation of heterogeneous deformation of ice-sheet ice from deformation experiments and microstructural observations using artificial ice

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Variations of Greenland and Antarctic ice-sheets play important roles in climate and sea level changes. Although the behaviors of ice-sheets have large temporal and spatial scales, the importance of microstructure and microphysics of ice-sheet ice has been suggested (Faria et al., 2014). Deformation mechanisms of simple-structured and large-grained ice have been investigated by many laboratory experiments; however, actual ice-sheet ice has complicated microstructures related with environment during snow-deposition and subsequent flow process. Ice from glacial periods has characteristic structures compared to interglacial ice; higher impurity concentrations, smaller grains and fast deformation. This means that the deformation of ice-sheet ice is heterogeneous. Although the fast deformation of ice from glacial period has been investigated by previous studies, there are still large uncertainties since various factors are involved in deformation and flow of ice-sheet ice (Miyamoto et al., 1999). To clarify the causes of faster deformation of ice from glacial periods, systematic laboratory experiments that control each deformation parameter are required. Since the temperature and stress conditions of Greenland ice-sheet are located within the boundary zone between dislocation and diffusional creep on the deformation mechanism map; the effects of diffusion and grain boundaries are important. However, the effects of diffusion and grain boundaries (i.e., grain size) have not been sufficiently considered in previous ice-sheet flow laws.

We performed deformation experiments and microstructural observations using artificial ice to clarify the deformation parameters that lead to the faster deformation of ice from glacial periods. Polycrystalline ice of various initial grain sizes with and without micro-silica-particles and bubbles are prepared. The diameter and dispersed amounts of dispersed micro-particles were 0.3 μm, and 0.01 and 0.1 wt.%. The initial grain sizes of fine- and large-grained ice are ranged from 30 to 100 μm and from 0.2 to 5 mm, respectively. We conducted mechanical tests under various temperatures and load stresses. Our experiments revealed different trends for softening-hardening effect due to micro-particle dispersion, grain-size-dependence and microstructural evolution in fine- and large-grained ice. Strain rates of fine-grained ice become larger at finer-grains (i.e., there is a grain-size-dependence), while those of large-grained ice are almost constant regardless of the difference of initial grain size. Micro-particle-dispersed ice with large-grains indicated a hardening-trend compared with pure-water ice, while little direct effect on the deformation in the fine-grained ice. Not only mechanical properties, but also microstructural evolution showed different behaviors depending on initial grain size. In this presentation, we discuss the causes of heterogeneous deformation of ice-sheet ice based on systematic deformation experiments and detailed microstructural observations using various-structured artificial ice.

References

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