Diffusion studies of water ice and its high-pressure phases: Implications for rheology

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Water ice is a primary constituent of the crusts and mantles of the large icy bodies such as Galilean satellites and Edgeworth-Kuiper belt objects. Understanding rheological properties of water ice including its high pressure phases are essential to understanding the dynamics of the large icy bodies. The real icy crusts and mantle include other constituents such as ammonia, Mg- and Na- sulfates, methane hydrate, and non-water ices. The influence of the sub-constituents on the dynamics is never negligible. The dynamics model based on the unary water system, however, will give some important implications, and be the useful approximation.
Our motivation for the rheological studies of water ice is the first step to understanding the dynamics of the real large icy bodies.The differential stress driving the convections of the icy crust and mantle is very low below 0.01 MPa. The deformation experiments at low-stress conditions are technically difficult. Thus the rheological properties of water ices must be examined by another approach. Newtonian-rheological model is most plausible under such low-stress condition. The Newtonian-rheological properties can be inferred from their diffusivities and the theories of diffusion creep. The ordinary isotope-diffusion method using the mass-spectrometer cannot be applied to the ice diffusion study. To defeat this problem, we have developed the isotope-diffusion method using micro-Raman spectroscopy. First, to conduct the diffusion experiments, the method for the quantitative analysis of isotope tracers using micro-Raman spectroscopy was constructed. The diffusion experiment of poly-crystalline ice I_h under confining pressure was carried out by using this technique, and the grain boundary diffusion coefficient was constrained. Further, we applied this method to the high pressure experiment using diamond anvil cell, and the diffusion coefficients of high-pressure phases were determined. In my presentation, I would like to talk about our efforts to determining the rheological properties of the ices and its high pressure phases through the diffusion studies following a short review for the previous studies. In addition, I will also discuss the condition requires to trigger convection in the large icy bodies based on the results of the diffusion experiments.

Keywords: ice, diffusion, rheology, high pressure, icy bodies

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