Grain growth of ice from aqueous solutions of sugars, salts and amino acids

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Introduction
Salts and organic matters exist in icy bodies and comets. Chemical evolution from simple molecules to more complex organic compounds is a hot issue concerning the origin of life. Mixtures of ice and organic matters can play an important role for chemical evolution. Sugahara and Mimura (2015) conducted shock experiments on a mixture of alanine, ice, and silicate under cryogenic conditions simulating comet impacts and reported the oligomerization of alanine. For precise understanding of the reaction, it is necessary to observe morphology of ice including organic matters at low temperature. Effects of salts, amino acid and sugar to morphology and grain growth of ice are important research targets for food science as well as planetary science. In this study, we investigate grain-growth kinetics of ice crystallized from salt, sugar or amino-acid solutions from in-situ optical observations at low temperature.
Experimental procedure
Pure water, NaCl solutions, amino-acid (aspartic acid and glutamic acid) solutions and sugar (glucose, sucrose, maltose, maltotriose and maltotetraose) solutions were prepared as samples. These sample solutions were set between two cover glasses with a gap of ~40 μm on a heating-cooling stage and sample chamber was filled with dry nitrogen gas. These sample solutions were rapidly cooled to −30 °C at a rate of 10 °C/min. After the samples were frozen, the sample temperature was increased at a rate of 10 °C/min and was kept for 300 min at −5 °C. Optical images and movies were collected in situ under a polarizing microscope with crossed nicols. Phase identifications were conducted by Raman spectroscopy.
Results and Discussion
Figure 1 shows representative optical photographs of ices after 300 minutes reaching at −5 °C. All solutions froze into aggregates of fine ice crystals in a moment before reaching at −30 °C. In pure water, no homogenous grain growth was observed after 300 min at −5 °C, but abnormal grain growth up to approximately 50 mm was observed. In the case of a salt solution, after reaching at −5 °C, ice grains grew to a homogeneous size of 35 mm in average and the solution existed in triple junctions between ice crystals. In amino acid solutions, notable grain growth was not observed and fine grains remained. The abnormal grain growth similar to the case of pure water was observed in some cases of amino acids. Moreover, grain-growth rate in amino acid system was much lower than the case of pure water. This result suggests that amino acid inhibits grain growth of ice. In sugar solutions, when number of carbon ring changed from 2 to 4, appearances of samples changed drastically.
This study confirmed that morphology and grain-growth kinetics of ice are strongly affected by chemical composition of starting solutions. These results are useful to understand chemical reactions occurring in ice and will contribute to improve frozen preservation of foods.

Keywords: sugars, salts, amino-acids, grain growth, observation in situ

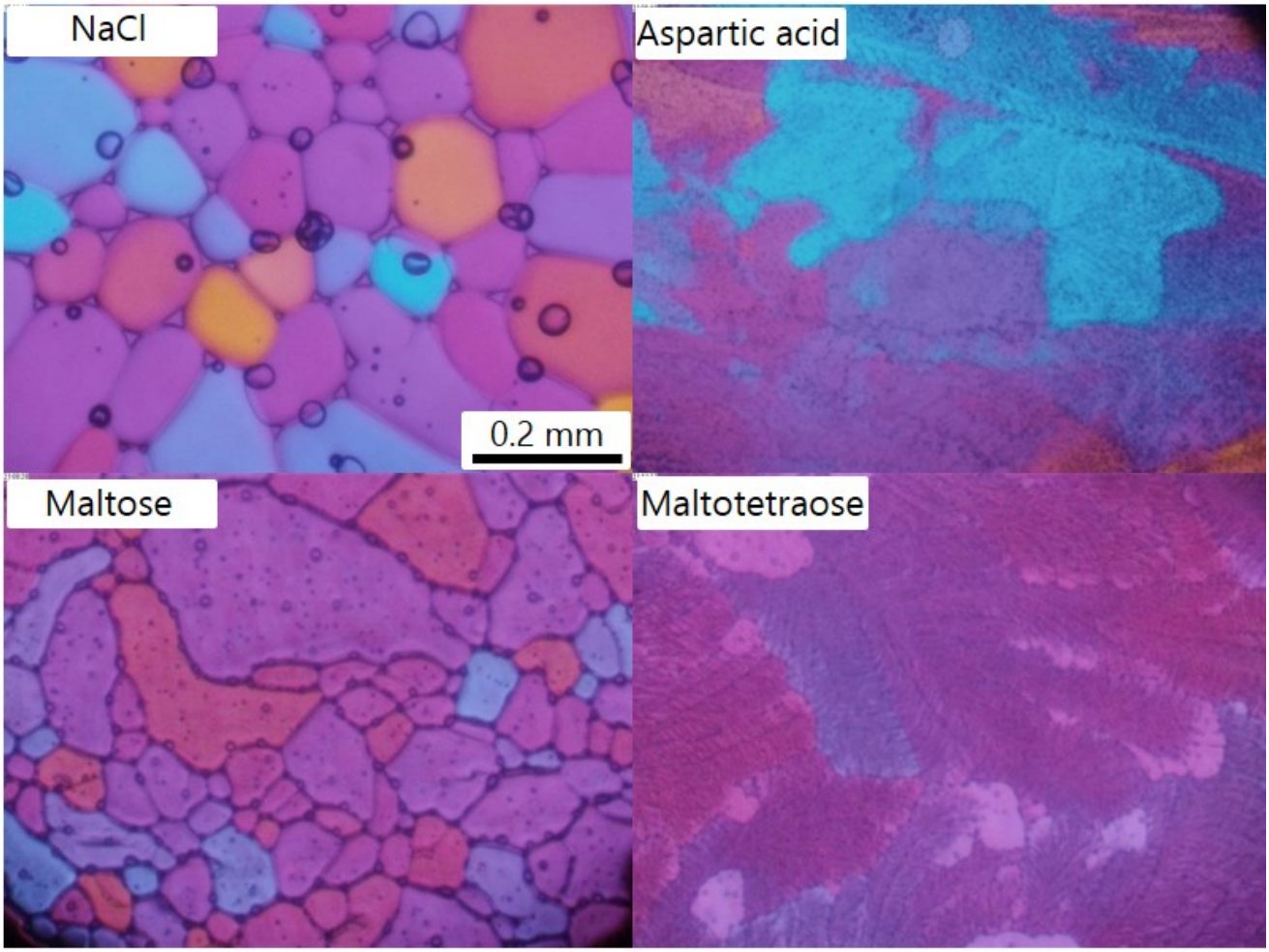

Figure 1. Representative optical images (crossed nicols) of ice crystals obtained 300 min after reaching at -5 °C. The contrasts of these images depend on crystal orientations.

