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Anisotropic impurity effect for ice crystal growth in supercooled water

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Antifreeze protein (AFP) and antifreeze glycoprotein (AFGP) molecules adsorb on ice-water interfaces and control the ice crystal growth. However, there still remain many missing pieces of the puzzle for the growth control mechanism. The basic observations from the viewpoint of crystal growth, for example, in-situ observations of morphologies, precise measurements of growth rates, understandings of the adsorption states of these molecules on ice-water interface, are important to clarify the mechanism of crystal growth control. We carried out various experiments on free growth of ice crystals in supercooled water both on the ground and under the microgravity condition without any influence of convection, which is realized in the International Space Station. Based on these experiments, we discuss about the anisotropic effect of AFGP molecules as an impurity for ice crystal growth [1].
In situ observation of ice crystal growth in a supercooled water including AFGP molecules labeled by the fluorescent molecules indicated that growth of the prismatic (and/or pyramidal) faces was inhibited by the adsorption of AFGP molecules. Growth inhibition for these faces is explained by the pinning effect of adsorbed AFGP molecules, which is the well-known impurity effect for the crystal growth. In contrast, long-term continuous measurements of growth rates performed in ISS clarified that the growth of basal face is promoted by the effect of AFGP molecules. Namely, the adsorbed AFGP molecules may work as the inhibitor for prismatic and pyramidal faces but as the promotor for basal faces. These results indicate the anisotropic impurity effect depending on the crystallographic orientation of interfaces. On the contrary, we found that the growth rates of basal faces were periodically changed as a function of growth time. The growth enhancement and oscillation observed on the ice basal faces are the previously unknown impurity effects for crystal growth of not only the ice crystal but also the other crystals. A preliminary explanation for this anisotropy will be given on the basis of the preferential adsorption of AFGP molecules on the prismatic and/or pyramidal faces [2,3].
Our findings will lead to a better understanding of a novel process for ice growth kinetics, and shed light on the role that crystal growth kinetics has in the onset of the mysterious antifreeze effect in living organisms, namely, how this protein can prevent freezing of living organisms under sub-zero temperature condition.

References:
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[2] S. Zepeda, E. Yokoyama, Y. Uda, C. Katagiri and Y. Furukawa, Cryst. Growth Des. 8, 3666-3672, (2008), doi:10.1021/cg800269w.
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Significance statement

We present about the anisotropic effects of antifreeze glycoprotein molecules adsorbed on the ice/water interface for its growth, based on the results of ground and space experiments.

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