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Ice-binding proteins from a sea-ice diatom, their effect on ice growth and physical properties

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Ice-binding proteins (IBPs), produced by polar and cold-tolerant organisms, have the ability to bind to ice, affecting its growth. They are key elements in biological adaptation to cold environments, and no other particles, neither natural nor synthetic, show comparable effect in controlling ice growth. However, the details of the protein-ice interactions have not been clarified yet. Different IBP families affect ice in different ways, and the relevant common traits, as well as the differences of the ice binding mechanisms, are still under investigation.

Here we present the IBP from the polar sea-ice diatom Fragilariopsis cylindrus (fcIBP). It belongs to a protein family defined by a domain (DUF 3494) extremely successful among polar microorganisms. We studied the effects of the fcIBPs on single crystal free growth using optical bright field and interferometric microscopy. We studied crystal morphology changes and growth rates dependent on supercooling and protein concentration. We saw differential effects of the protein on the growth of crystallographic planes, dependent on fcIBP dynamics in the different directions. We relate this to differential affinity and adsorption time of the protein to the basal and prismatic planes. Switching to a more macroscopic level, we analyzed the effect of the proteins to physical properties of polycrystalline ice. We show the strong inhibition of fcIBPs on grain growth. We observed the evolution of microstructure in fine-grained samples over several weeks, instead of the hours often used for annealing experiments with IBPs. Furthermore, we show that the effect of IBPs on the driving factors for ice deformation during creep, i.e. on internal dislocations due to incorporation within the lattice and on the mobility of grain boundaries due to pinning, make these proteins particularly interesting in studying the process od ice deformation.

Significance statement

Our results of single crystal growth morphology and rates contribute to a better understanding of ice growth mechnisms and interaction with nanoparticles. We also show the effects of fcIBPs on polycrystalline ice physical properties, providing relevant results for basic research on fcIBP-ice interaction mechanisms and for potential fcIBPs applications.

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Track Classification: Ice Binding Proteins