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The Effects of H2SO4 on the Mechanical Behavior and Microstructural Evolution of Polycrystalline Ice

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It is well established that the Earth's large continental ice sheets contain a variety of naturally occurring impurities, both soluble and insoluble. Understanding how these impurities affect the rheology, intrinsic thermodynamic properties, and fate of these ice sheets is much less understood. To investigate the effects that trace amounts of H2SO4 have on the flow and ductility of polycrystalline ice, a series of mechanical tests were conducted at -6℃, -10℃, -12.5℃, and -20℃ using laboratory-prepared specimens of polycrystalline ice doped with 1-15 ppm of H2SO4. Parallel tests were performed on identical, but undoped specimens of polycrystalline ice. Mechanical testing included constant-load tensile creep tests at an initial stress of 0.75 MPa and compression tests at constant displacement rates with initial strain rates ranging from 1 x 10-6 s-1 to 1 x 10-4 s-1. It was found that H2SO4-doped specimens of ice exhibited faster creep rates in tension and significantly lower peak stresses in compression, when compared to the undoped ice. Post-mortem microstructural analyses were performed using cross-polarized light thin section imaging, X-ray computed microtomography, Raman spectroscopy, and electron backscatter diffraction. These analyses showed that H2SO4-doped specimens had a larger grain size at strains ≤15%, and an earlier onset of micro-cracking at lower strain rates than the undoped ice. Strain-induced boundary migration was the predominant mechanism of recrystallization in both doped and undoped specimens. Further, a liquid-like phase containing H2SO4 was found to be present at the grain boundaries of the H2SO4 doped ice at temperatures close to the melting point.

Significance statement

Following the mechanical testing in tension and compression of laboratory prepared specimens of polycrystalline ice doped with sulfuric acid, differences in the microstructural evolution between the doped and undoped ice were attributed to the presence of a liquid phase at grain boundaries and triple junctions due to impurity segregation.

Author: Prof. HAMMONDS, Kevin (Montana State University)

Co-author: Dr BAKER, Ian (Dartmouth College)

Presenter: Dr BAKER, Ian (Dartmouth College)

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