

Grain-size sensitive creep of ice II at low differential stresses

Tomoaki Kubo[1]; William B. Durham[2]; Laura Stern[3]; Stephen Kirby[3]

[1] Kyushu Univ.; [2] LLNL; [3] USGS

Knowledge of the rheology of high-pressure phases of water ice is crucial for understanding the thermal structure and internal dynamics within medium- and large-size icy moons of the outer planets. In previous studies of ice at relatively high differential stresses, the flow laws of the several high-pressure phases were inferred to lie mainly in the dislocation creep regime. Because stresses in the interior of icy moons are thought to be very low (less than 0.1 MPa), it is indispensable to investigate dominant creep mechanisms at low stress conditions. In this study, we have carried out creep experiments of fine-grained ice II at confining pressures of 200-250 MPa and temperatures of 200-220 K using a gas-medium triaxial deformation apparatus to measure rheology at lower stress conditions. Microstructures of deformed ice II aggregates were examined by cryogenic SEM. We make fine-grained ice II by multiple I-II transitions at lower temperatures and larger overpressure conditions from the equilibrium boundary. Grain sizes of ice II made by single, double and triple I-II transitions are estimated to be about 50, 20-30, and 10 micron, respectively. Clear differences in creep behavior between ice II made by single and triple I-II transitions were observed at stresses of 4-18 MPa and strain rates of 10^{-8} - 10^{-7} s⁻¹. In the former case, the stress exponent is about 5, which is consistent with the flow law previously obtained at differential stresses above 20 MPa. In the latter case, the ice II is much weaker and the stress exponent is about 2.3. These experimental results imply that the grain-size sensitive creep of ice II dominates plastic strain at low stress conditions, making ice II the second phase of ice (after ice I) to manifest a change from a grain-size insensitive rheology to a weaker grain-size sensitive rheology at low stresses and finer grain sizes. The implications for icy moons are towards more convective instability and lower internal stresses, temperatures, and/or grain sizes. It has been known that ice II is the strongest in high-pressure polymorphs of water ice in the dislocation creep regime. Ice II in the grain-size sensitive creep regime is also stronger than ice I by two orders of magnitude at the grain size of 10 micron and the stress of 0.5 MPa.