Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SIT039-P11 Room:Convention Hall Time:May 24 14:00-16:30

Deformation experiments of two-phase aggregates of H2O and CO2 ices

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We have conducted creep experiments on two-phase mixtures of dry ice (CO2) and H2O ices at CO2:H2O volume ratios of 4:96, 8:92, 21:79, 46:54, 75:25, under confining pressures of 20-100 MPa and temperatures of 170-190 K using a gas-medium triaxial deformation apparatus. Two-phase aggregates of CO2 and H2O ices were mixed as powders, hydrostatically compacted. Hydrostatic compression pressures to reach zero porosity were between 60 MPa and 140 MPa and were generally lower for samples with higher CO2 content. The compacted two-phase aggregates were then deformed at constant strain rates from 3e-7 to 1e-5/s. The measured flow stress is in the range of 2-25 MPa.

The creep experiments revealed that the flow strength of the two-phase aggregate decreases drastically with increasing CO2 content. The range of the stress exponents and the activation energies in the aggregate flow law are 3.6-7.0 and 51-41kJ/mol, respectively. These values gradually change from those of one end member to those of the other. The rheology of the two-phase aggregate roughly matches an average of isostress and isostrain models. The flow strength in the 4 vol.% CO2 aggregate is almost half of that in pure H2O ice at the strain rate of 1e-6/s. The presence of 4 vol.% CO2 ice in H2O ice decreases viscosity by more than one order of magnitude at a differential stress of 0.1 MPa. Microstructural observations of the deformed samples are important future studies.

CO2 ice has been observed on the surface of Mars's residual south polar ice cap and is likely to be present on most icy bodies in outer solar system. The present study clearly demonstrates that presence of small amounts of CO2 ice can drastically decrease the flow strength of the two-phase aggregate. It is important to consider the influence of the rheological behavior of two-phase aggregates of CO2 and H2O ices on tectonics and internal dynamics of icy bodies, as well as the stability of the Mars polar cap. Present results can be used to constrain allowable concentrations of CO2 ice to support the Martian south polar ice cap, and suggest that the presence of small amounts of weak non-water ices such as CH4, N2, and CO2 possibly has important roles on viscous relaxation of craters, surface tectonics, and internal convection of icy bodies of outer solar system.

Keywords: H2O ice, CO2 ice, two-phase aggregate, rheology, icy body