Deformation experiments of ice-silica mixture and the temperature dependence on the flow law

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Water ice found on the surface of Mars and icy satellites has some dusty or rocky component. Ice caps on Mars are expected to contain water ice and dust covered on the surface of Mars. Most of icy satellites have some rocky component from the observational data like mean density and albedo (Sill and Clark, 1982). Therefore, it is important to study the rheology of ice-dust or rock mixtures. Also, it is expected that ice caps on Mars and icy satellites have dust or rock with various mass fraction. Moreover, the surface temperatures on Mars and icy satellites are very low. Therefore, we must study the rheology, particularly flow law, with various mass fraction of solid particle and the dependency of temperature to clarify the effect of solid particles on the icy features on the surfaces of these bodies. So, we did experiments at the room temperature from -10 to -25 deg C to clarify the effect of temperature on the flow law. Furthermore, we examined the activation energy of ice-solid particles mixtures which might be deform by activated process justified from the above results.

We made the samples by mixing ice particles (0.3-1mm in the diameter) with silica glass beads (1micron in the diameter). We prepared the samples by using two methods to make different internal structures. One was a pressure-sintering method (p.s.s.) that we compressed the mixtures of ice grains and beads by using a piston at about 50MPa. Another was a frozen sample method (f.s.) that we mixed ice grains, beads, and water in a mold. The silica contents were 30 and 50wt.% for p.s.s., and 30, 50, and 80wt.% for f.s. For 50 and 80wt.% of f.s., we froze the suspension of beads. All samples had a cylindrical shape, and were frozen in a cold room at the temperature of -10 deg C in more than 1day. We conducted uniaxial compression tests under constant strain rates from 8.6×10^{-7} to 9.7×10^{-4} s^{-1} in a cold room at -10, -15, -20, and -25 deg C.

We obtained the flow law by the relationship between applied strain rate, de/dt, and the maximum stress, s, shown on stress-strain curve as follows, $de/dt = A_0 \exp(-Q/RT)s^n$, where Q is the activation energy, R is the gas constant, T is the temperature in Kelvin, and A_0 and n are constant. As a result, the n did not change when the temperature was lower at the same silica content and the internal structure of sample. Furthermore, when the temperature was -20 and -25 deg C, the deformation mode of f.s. with 50 and 80wt.% transited from ductile deformation to brittle failure. The brittle failure for these mixtures occurs at higher temperature than that of pure ice at the same strain rate (Arakawa and Maeno, 1997). So, it is expected that the growth of cracks leading to brittle failure accelerates for f.s. in comparison with pure ice. Also, it seems that the deformation mode of p.s.s. is not brittle failure because the cracks stop growing when they grow in ice grains and reach the boundaries of ice grains. Finally, we calculated the activation energy Q of ice-silica mixtures. Here, we calculated those of p.s.s. and f.s. with 30wt.% because the deformation mode of f.s. with 50 and 80wt.% was brittle failure at lower temperature. Also, to calculate the Q, we used the average values of n because it was almost constant, irrespective of the temperature. As a result, the Q for mixtures was about 130 kJ/mol and was close to that of pure ice, Q=120 kJ/mol, at the temperature higher than -8 deg C (Barnes et al., 1971). They revealed that grain boundary sliding (gbs) plays a role in the deformation of pure ice at higher than -8 deg C. Thus, gbs may be also play a role in the deformation of mixtures at lower than -10 deg C due to the silica beads in the boundaries of ice grains.