EXPERIMENTAL STUDY ON THE COLLISIONAL DISRUPTION OF SINTERED SNOWBALL WITH VARIOUS POROSITY. Yu-ri Shimaki¹, Masahiko Arakawa¹, and Minami Yasui¹, ¹Graduate School of Environmental Studies, Nagoya Univ. (464-8601, Furo-cho, Chikusa-ku, Nagoya, Japan; shimaki@eps.nagoya-u.ac.jp).

Introduction: There are many icy bodies in the solar system, such as comets, icy satellites, and EKBOs. They are supposed to experience various collisional phenomena such as cratering, impact disruption, and re-accumulation of impact fragments; a re-accumulation process is especially important related to the origin of a rubble-pile body. Impact fragments with the velocity smaller than the escape velocity of icy bodies can be captured to build the rubble-pile structure. The re-accumulation process could be strongly affected by physical properties of parent bodies. Therefore, it is important to study the effects of physical properties of icy bodies on collisional disruption.

The effect of porosity on the impact strength of snow target with the porosity from 10 to 55 % was revealed by previous work [1]. They found that the impact strength increased with the increase of porosity. However, tiny icy bodies like planetesimals or these precursor might have the porosity over 40 %. Collisional growth of ice dust aggregates has been simulated numerically and these highly porous aggregates have the porosity over 90 % [2]. They could stick together even at the impact velocity higher than several 10 m/s, so that icy planetesimals with high porosity grow in sizes. It is supposed that the interior of icy planetesimals could be heated by radioactive heating and/or impact compaction, then the porosity might decrease in their thermal evolution by sintering and plastic deformation of ice grains so called pressure sintering. Therefore, it is necessary to study impact phenomena of porous ice with variable porosity between > 90 % and 40 %, so we conducted impact experiments by using snowball target with the porosity of 40 % prepared at various sintering duration and snowball target with the different porosity of 40, 50, 60, and 70 %. Fragment mass and velocity distribution were measured together with the antipodal velocity and impact strength. We also measured the static tensile strength of snow by means of Brazilian test and studied the correlation with the impact strength.

Experimental methods: Impact experiments of snowballs with the porosity from 40 to 70 % were conducted by using an one-stage He gas gun set in a cold room; the room temperature was from -10 to -20 °C. Snowballs with the diameter of 60 mm were sintered for 1 hour to 1 month, at the temperature of -10, -15, and -20 °C for each sample. It was impacted by a projectile of snowball or ice cylinder at the velocity from 30 to 450 m/s. Impact disruption of snowball target was observed by a high speed video camera to measure the velocity of fragments. All of the snow fragments were recovered to measure the mass distribution of the fragments and the impact strength of sintered snow.

Results: Impact disruption modes. 4 types of impact disruption modes were found in Fig.1; they are cratering, disruption, sticking, and penetration. Sticking and penetration were only observed for the target with the porosity larger than 60 %. Then, it could be considered that disruption mechanism might change from crack propagation to compaction and pore collapse when the porosity is larger than 60 %.

![Figure 1: Impact disruption mode speculated by all experiment results.](image)

Sintering duration. The sintering duration t of snowball with the porosity of 40 % was changed from 1 hour to 1 month, and impact strength and tensile strength were found to have a power law relationship to the sintering duration, t, and n is about 0.2 for both cases (Fig.2). Antipodal velocity, which is a fragment velocity measured at the opposite site of the impact point, was shown to be independent on the sintering duration.

Porosity. The porosity of snowball was changed from 40 to 60 % at the constant sintering duration of 1 day and it was found that the tensile strength increased with the decrease of porosity but the impact strength was almost same (Fig.3). But, the antipodal velocity was found to slightly increase with the increase of the porosity,
and this difference could be caused by the penetration depth of projectile (fig.4). Finally, when the target porosity is larger than 70%, the antipodal velocity is much higher than that of the lower porosity because the impact disruption mode was penetration: projectile could go through the target.

There are 4 regions according to the surface and internal structures of the impact bodies; regolith layer formation, rubble-pile structure, cratering, and disruption.


Implication for re-accumulation process of icy planetesimals. The re-accumulation condition of icy planetesimal was calculated by using antipodal velocity (fig.5). Sloped lines show re-accumulation condition of icy body (dotted line), snow body with the porosity of 40 (long-dashed line) and 60 % (dashed line). This shows that re-accumulation condition is unchanged for the porosity less than 60 %. Solid line shows disruption condition of snow body with the porosity of 40 % sintered for 1 day.

Figure 2: The effect of sintering duration on tensile strength (dashed line) and impact strength (solid line) of snowball with the porosity of 40 % at -15 °C.

Figure 3: The effect of porosity on tensile strength and impact strength of snowball sintered at -15 °C.

Figure 4: The relationship between velocity and energy density (kinetic energy divided by target mass).

Figure 5: Re-accumulation condition of small icy bodies. The mass ratio of impactor and target body is 1:1000.