Experimental Study of Stress Wave Attenuation in Porous Sintered Glass Beads Targets. M. Setoh[1], A. M. Nakamura[1], K. Hiraoka[2], Y. Yamashita[1], S. Hasegawa[3], N. Onose[3], K. Okudaira[3] and P. Michel[4], [1]Graduate School of Science, Kobe University, 1-1 Rokkoudai-cho, Nada-ku, Kobe, 657-8501, Japan (Setoh@kobe-u.ac.jp), [2]Graduate School of Science and Technology, Kobe University, [3]JAXA/ISAS, [4]Observatoire de la Cote d'Azur.

Introduction: Porous structures are thought to be common among asteroids [1]. Generally, the outcome of collisional disruption is dependent upon material strength [2]. However, porosity plays a complicated role. On one hand, with increasing porosity, the target body becomes weaker from the point of view of its static strength. On the other hand, the increasing volume of void space decreases the transmission efficiency of the stress wave in the target body. Love et al. [3] conducted hypervelocity impacts of soda lime glass projectiles into four porous sintered glass beads targets with different porosity and compressive strength, and showed that the increase of target porosity leads to a greater localization of the impact damage.

In our previous collisional disruption experiments, the values of impact strength in low velocity (10-260 m/s) impact experiments were found to be more than one order of magnitude lower than both our high velocity (2120-3280 m/s) runs and the previous results with impact velocity of 6000 m/s [3][4][5]. This is probably due to the difference in both the initial pressure and the degree of attenuation of the stress wave in the specimen when the experiments are conducted either at high or at low impact velocities. This suggests that not only the porosity but also the impact velocity strongly influences the outcome, everything else being equal.

In order to study the attenuation rate of the shock wave in porous targets, Yanagisawa and Itoi [6] conducted collision experiments with impact velocities from 3.7 to 7.3 km/s. They studied the relation between the velocities of fragments and the distance from the impact point. Their results showed that the stress attenuated with –3 power of the distance from the impact point in the case of mortar, porous alumina and water. On the other hand, in the case of sand, the stress attenuated more rapidly. In this work, we studied the attenuation rate of the particle velocity in sintered glass bead targets from the antipodal fragment velocity.

Targets: We prepared disc targets with three different thicknesses. Glass beads in a mold of diameter 100 mm and height over 30 mm were heated from room temperature to 615 °C over 25 min, and the temperature was kept at 615 °C for 240 min, at which point the heater was switched off. After cooling down the targets, we cut the targets into discs of three different thicknesses, about 10 mm, 20 mm and 30 mm.

Experiments I (low velocity impact): The first impact experiments were carried out in air using a light-gas gun at Kobe University. The projectiles were glass spheres of 3.2 mm in diameter. The impact velocity was about 260 m/s. All the shots were recorded by a high-speed video camera (Photron FASTCAM-PCI) at 2,000 frames per second.

Experiments II (high velocity impact): The second impact experiments were carried out in vacuum using a two-stage light-gas gun at ISAS. The projectiles were nylon sphere of 7 mm in diameter. The impact velocity was from 1.7 km/s to 2.1 km/s. All the shots were recorded by a high-speed video camera (SHIMAZU Hyper Vision HPV-1 and TMR E-2) at about 63,000 and 3,000 frames per second, respectively.

Experiments III (high velocity impact): The third impact experiments were carried out under the same condition with the experiments II but with targets of slightly lower porosity.

Comparison of the results: For all impact experiments, antipodal velocity was measured. First, X-Y coordinates of the ejecta in each image were measured. The coordinates of the ejecta and the associated times from the instant when the projectile hit the target were plotted on a graph, and the ejecta velocities were calculated using the plot. The antipodal ejection velocities of thickest targets were lower than those of the thinnest targets. Each individual ejecta group from the thickest targets in high velocity experiments was identifiable. On the other hand, the degree of fragmentation was so high in the thinnest targets in high velocity experiments that the ejecta formed a cloud.

In low-velocity experiments, a small crater was formed in the thickest targets, whereas a penetration hole made by the projectile was opened in the thinnest targets. In those cases, the antipodal ejection velocity might not be necessarily related to the attenuation rate of the stress wave. When the relation between the thickness of the target normalized by the projectile diameter and the antipodal fragment velocities normalized by the impact velocities was examined, the power-law index was -2.0 $\pm$ 0.05 in the high velocity impacts, -2.4 $\pm$ 0.7 in the low velocity impacts for the 39% porosity targets and -2.2 $\pm$ 0.2 in the high velocity impacts for the 32% porosity targets. Thus, the attenuation rate of the particle velocity was not found to depend much on both of the impact velocity and target

porosity. However, these results are different from previous ones on different kinds of porous materials such as sand, mortar and the porous alumina, suggesting that the material properties of porous targets have a strong influence on the disruption outcome.

References: [1] Britt, D. T. et al. (2002) In *Asteroids III* (Eds. Bottke Jr., W. F. et al.), pp. 485-500. [2] Holsapple, K. et al. (2002) In *Asteroids III* (Eds. Bottke Jr. W. F. et al.), pp. 443-462. [3] Love, S. et al. (1993) *Icarus*, 105, 216-224. [4] Setoh, M. et al. (2007) *Lunar and Planetary Science* XXXVIII, No.1338, abstract No.1263. [5] Setoh, M. et al. (2007) *Earth, Planets, Space*, 59, 319-324. [6] Yanagisawa, M. and Itoi, T. (1994) ASP conference Series, 63, 243-250.

Table I : Experiment conditions

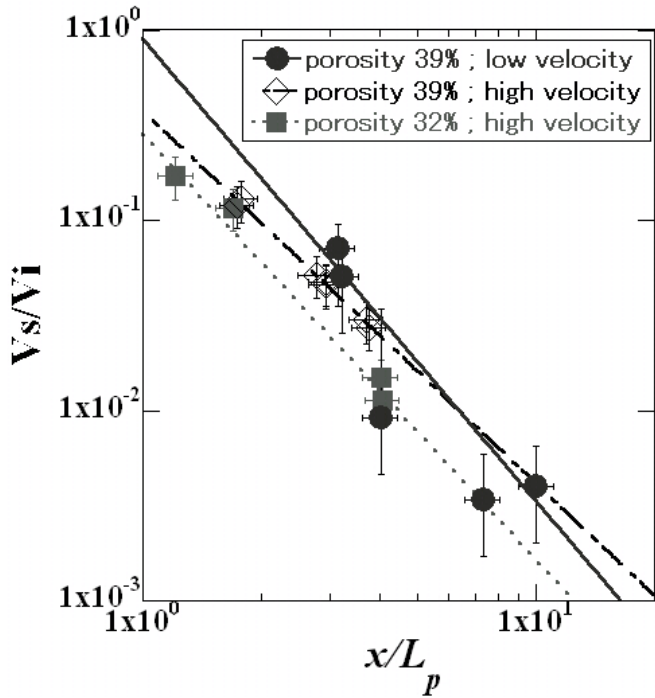|	No. of shots	Target shape	Target porosity [%]	Target thickness x diameter [mm]	Impact velocity [m/s]
Experiments I	5	Disc	39 ± 2	(11.5±1.5, 20±2, 29±2)x *100*	260
Experiments II	6	Disc	39 ± 2	(11±1.5, 19.5±1, 27±1)x *100*	1700 - 2100
Experiments III	4	Disc	32 ± 2	(8.5, 12, 28.2, 28.5)x *100*	1900 - 3390

Fig.1 The relation between ejecta velocity normalized by impact velocity and the distance from impact site normalized by projectile diameter.