DEPENDENCE ON PROJECTILE DENSITY OF IMPACT TRACK MORPHOLOGY IN SILICA AEROGEL. Rei Niimi[1], Akira Tsuchiyama[1], Toshihiko Kadono[2], Kyoko Okudaira[3], Sunao Hasegawa[4], Makoto Tabata[4], Takayuki Watanabe[5], Masahito Yagishita[5], Nagisa Machii[6] and Akiko M. Nakamura[6]. [1]Department of Earth and Space Science, Osaka University, [2]Institute of Laser Engineering, Osaka University, [3]University of Aizu, [4]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, [5]Department of Environmental Chemistry and Engineering, Tokyo Institute of Technology, [6]Graduate School of Environmental Studies, Kobe University.

Introduction: Cometary dust particles of Wild2 have been successfully collected and returned in Stardust Mission [1]. Hypervelocity capture (6.1 km s^{-1}) of those particles mandated various degrees of heating, fragmentation and evaporation of the projectiles during their capture process in silica aerogel [2]. Nevertheless, an impact track formed by each particle can be an indicator of its original properties [3]. Particle size dependence of track properties has been studied in several papers [4, 5] and impact tracks in Stardust aerogel formed by several sized soda lime glass beads of different sizes were used for calibration of Wild2 dust size distribution [6]. In the work of Iida et al. [7], three-dimensional structures of Stardust impact tracks were analyzed and Wild2 dust density was estimated based on their track formation model. However, density dependence of track properties has not been investigated precisely yet. Therefore, we carried out impact experiments into silica aerogel (20 mg cm^{-3}) using projectiles of several densities. We used the uniform density aerogel, not graded density Stardust aerogel in order to clarify the relation between projectile properties (size and density) and track morphology under simplified conditions. This work should be followed by Wild2 dust density calibration experiments using Stardust aerogels for more precise investigation.

Experiments: Impact experiments were carried out with a two-stage light-gas gun at ISAS, JAXA. The projectiles we used were polystyrene (PS) (1.06 g cm^{-3}), sintered silica (~1.3 g cm^{-3}), soda lime glass (SLG) (2.5 g cm^{-3}), alumina (3.9 g cm^{-3}), and copper (8.9 g cm^{-3}). All the projectiles except for sintered silica were spherical in shape. Size of these impactors ranged from ~30 to ~100 μm in diameter and they were fired into 20 mg cm^{-3} silica aerogel at ~6 km s^{-1} to simulate the capture of Wild2 dust. Conditions for the impact experiments are summarized in Table 1. All the individual impact tracks were observed with an optical microscope.

Results and Discussions: Shapes of the impact tracks varied according to projectile materials. PS and sintered silica formed bulbous tracks (type B or C) while SLG, alumina and copper formed slender tracks (type A). These results are consistent with the observation of terminal grains. We did not find remarkable mass loss for SLG, alumina and copper. On the other hand, PS and sintered silica seemed to have ablated or fragmented. In particular, for 31 μm PS and ~100 μm sintered silica tracks, no terminal grains were found and bowl shaped tracks were formed.

Track length. As reported in prevopis studies (e.g. [4]), track length (L_t) increases linearly with projectile size. Therefore we normalize L_t with projectile diameter (d_p) and plot versus projectile density (ρ_p) in Fig. 1(a). This result shows L_t/d_p increases linearly with ρ_p especially for type A tracks. This linear relation is consistent with the track length model by Niimi et al. [8]. Deviation from the linearity for low density projectiles (PS and sintered silica) is due to their ablation or fragmentation.

Maximum track width. When D_m is scaled with d_p, we do not find strong depence of ρ_p on D_m (Fig 1(b)). This indicates that D_m might be an criterion of projectile size as suggested in previous studies ([6] and [7]). In more detail, however, it seems that SLG (2.5 g cm^{-3}) has the lowest value and track becomes wider both when ρ_p decreases and increases from the SLG density. The increase of width at low density value is caused by ablation or break-up of PS and sintered silica projectiles. As mentioned above, track length is shortened from the linearity of type A tracks at these low densities. This is because penetration energy of these projectiles was transferred to expansion energy of track width due to their ablation or fragmentation. On the other hand, heavier projectiles might produce higher shock pressure and strong shock waves, and expand the tracks wider. However, we still do not know the exact relation between ρ_p and D_m because we only have one track of copper projectiles, which was formed by the largest density projectile. Accordingly, statistical data of copper projectiles should be examined in the future. For further study, a track expansion model should be constructed for explanation of such experimental data of D_m.

Aspect ratio: a track parameter for impactor's density estimation. As shown above, L_t depends on both d_p and ρ_p while D_m strongly depends on only d_p. Therefore, aspect ratio of each track (L_t/D_m) is not largely affected by d_p by cancelling the d_p denendences on L_t and D_m but changes mostly with ρ_p, as shown in Fig. 1(c). This indicates impact track shapes formed by different sized but same projectiles have similar morphology, and therefore L_t/D_m is a reliable criterion of ρ_p when we estimate an impactor's density from a track shape. This is consistent with the track formation model by Iida et al. [7], which suggests that Wild2 dust density can be estimated with this parameter. For more accurate calibration, detailed function form of ρ_p versus L_t/D_m should be investigated using Stardust aerogel and projectiles of various densities together with more reliable model for track expansion.

Conclusions: We carried out ~6 km s^{-1} impact experiments into 20 mg cm^{-3} silica aerogel using projectiles of several densities. Our results have shown that track length (L_t) depends on projectile size and density while maximum track width (D_m) mainly depends only on projectile size. Therefore, aspect ratio (L_t/D_m) does not change with projectile size, but only with projectile density. This means that when we estimate projectile properties from a track shape, L_t/D_m is a good indicator of an impactor's density. This can be applicable for Stardust impact tracks; densities of Wild2 dust particles will be estimated more precicely by examining the relation between projectile density and aspect ratio of a track in Stardust aerogels.

References: [1] Brownlee *et al.* (2006) Science **314**, 1711-1726. [2] Zolensky *et al.* (2006) Science **314**, 1735-1739. [3] Hörz *et al.* (2006) Science **314**, 1716-1719. [4] Burchell *et al.* (2009) Planet. Space. Sci. **57**, 58-70. [5] Hörz *et al.* (2009) Meteo. Planet. Sci.**44**, 1243-1264. [6] Burchell *et al.* (2008) Meteo. Planet. Sci. **43**, 23-40. [7] Iida *et al.* (2010) Meteo. Planet. Sci. **45**, 1302-1319. [8] Niimi *et al.* (2010) Icarus, in press.

Table 1. Conditions for impact experiments into 20 mg cm^{-3} silica aerogel. All the projectiles except sintered silica are spherical shaped. Projectiles were shot at ~6 km s^{-1} to simulate Stardust capture speed.

Projectile	**Projectile density ($g\ cm^{-3}$)**	**Projectile diameter (μm)**	**Impact velocity ($km\ s^{-1}$)**	**Number of tracks analyzed**
Polystyrene	1.06	31±2	5.88	3
Polystyrene	1.06	58±5	5.95	3
Polystyrene	1.06	109±13	6.07	2
Sintered silica (irregular shaped)	~1.3	sieved with 95 and 106 mesh	5.71	1
Soda lime glass	2.5	30±2	5.77	4
Soda lime glass	2.5	52±4	5.95	5
Soda lime glass	2.5	98±3	6.12	2
Alumina	3.9	30±2	6.17	2
Alumina	3.9	48±4	6.00	6
Alumina	3.9	105±4	6.06	4
Copper	8.9	60±1	5.96	1

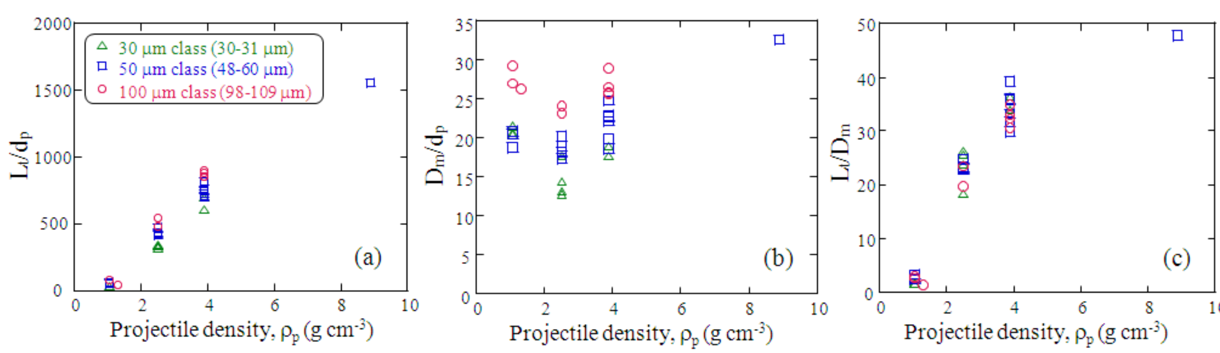

Figure 1. Projectile density, ρ_p, dependence of track length, L_t, (a), maximum track width, D_m, (b) and aspect ratio, L_t/D_m, (c). Track length and width are normalized by projectile diameter, d_p, so that relations between those parameters and projectile density become apparent. Since we used ~30, ~50 and ~100 μm projectiles, projectile sizes are classified into three types.