THREE-DIMENSIONAL STRUCTURTES AND ELEMENTAL DISTRIBUTIONS OF STARDUST IMPACT TRACKS. A. Tsuchiyama[1], T. Nakamura[2], T. Okazaki[1], K. Uesugi[3], T. Nakano[4], T. Akaki[2], K. Jogo[2], Y. Iida[1], and Y. Suzuki[3]. [1]Department of Earth and Space Science, Graduate School of Science, Osaka University, Toyonaka 560-0043, Japan, Japan (akira@ess.sci.osaka-u.ac.jup), [2] Department of Earth and Planetary Science, Faculty of Science, Kyushu University, Hakozaki, Fukuoka 812-8581, Japan, [3]Synchrotron Radiation Research Institute, SPring-8, Sayo, Hyogo 679-5198, Japan, [4]Geological Survey of Japan, Advanced Industrial Science and Technology, Tsukuba 305-8567, Japan,

Introduction: Cometary particles have been successfully recovered by using silica aerogel collectors in the Stardust mission [1]. Impact tracks formed during the cosmic dust capture have a variety of shapes, showing diversity of the cosmic dust [2]. We investigated 3-D structures and elemental distributions of Stardust tracks using synchrotron radiation x-ray analyses (tomography and XRF) as one of the preliminary examination team of Stardust samples.

Experiments: Four keystones having impact tracks (C2126,2,67,0, track 67 namekuji, bulbous; C2126,2,68,0, track 68 skyrocket, carrot-like; track 47 gobou, cylinder-carrot likeg; and FC13,0,47,0, track 32, carrot-like, ~0.3 mm) were analyzed at beamline BL47XU of SPring-8 (Table 1). X-ray transmission images (radiographs) of each keystone, except for track 67 namekuji, were taken at 7.090 and 7.135 keV (pixel size: 0.195 x 0.195 μm^2) to recognize a whole track and captured particles along the track. Then, XRF analysis was performed at 15 keV using a Ge-SSD to determine the elemental abundances along the track and individual particles (Fig.1a). The abundances of S, Ca, Cr, Mn, Fe, Ni, Zn, Cu, Ga, Ge, As and Se were obtained using Orgueil CI chondrite as a standard.

Three-dimensional structures of the tracks were obtained by projection microtomography [3] at 10 keV with 1500 projections for each slice. The voxel (pixel in 3-D) size was 0.195 x 0.195 x 0.195 or 0.467 x 0.47 x 0.47 μm^3 depending on the track size. Imaging experiments were made by five times for tracks 68 skyrocket and 47 gobou and the slices were tiled to obtain the whole track structures (Fig.1c).

Results and discussion: Tomography of FC13,0,47,0 showed that the track hade been partly destroyed while making the keystone. Thus, the analyses were made for the three samples.

Cavities of the impact tracks and condensed (compressed or melted) aerogel on the track walls were easily recognized in CT images (Fig.1b). Captured particles were distributed along the track walls as well as the track terminals (Fig.1c). These particles correspond to crystalline or amorphous-rich types [4]. 3-D external shapes of the tracks were constructed from the CT images. Track 67 namekuji has only a bulb with terminal particles without thin tracks (Fig.2a). Track 68 skyrocket has a bulb with cracks near the entrance (Fig.2c) and bifurcated into 5 or 6 thin tracks near the bottom (Fig.2b). Terminal particles are always present in all the bifurcated tracks. Track 47 gobou had already lost its terminal particle before the analysis (Fig.2d). The track is not straight although it is not bifurcated. This might be due to spinning of the projectile.

We can obtain quantitative sizes of the tracks based on the voxel size of the CT images (Table 1). The track shapes by assuming cylindrical symmetry are shown in Fig.3a. Even in the thinnest track of gobou, bulbous portion is present near the narrow entrance. The bulbous portions and thin tracks correspond to fragile and very fine-grained material and less-fragile (and possibly crystalline) grains, respectively [2].

The largest terminal particle of track 68 skyrocket (P1 in Fig.1a) has an elemental abundance close to CI, but the elemental abundances differ among particles and between particles and tracks [5]. Based on the Fe distribution in the particles and the tracks, 66% of Fe is present in the tracks and 34% of Fe is in the particles. While large amounts of Fe and Ni are present in the bulb, the amounts divided by the track volume of the analyzed region, V, are not large (Fig.3b). Moderately volatile elements, such as S, Zn, As and Se, do not depleted compared with Fe and CI in the bulb and enriched in the thin track near the bottom. This shows that volatilization of the moderately volatile elements is not responsible for the formation of the bulb.

The whole mass of a cosmic dust particle can be estimated from the Fe content of a whole track, m(Fe), by assuming the Fe concentration of CI (Table 1). Then, the whole dust volume, V_{grain}, can be estimated by assuming its density (1 g/cm^3 is assumed in Table 1). The dust volume is approximately 1/10000 of the track volume, V_{track}. The ratios of m(Fe)/V_{track} relate with the track shapes; the most bulbous track of namekuji has the lowest value. As the impact velocities of the cosmic dust are almost constant (6.1 km/s) in the Stardust mission [1], the kinetic energy is only a function of the dust mass. If the track volume is correlated with the kinetic energy, the difference of $m(\mathrm{Fe})/V_{track}$ should be due to difference of the mass including volatile materials; a small value of $m(\mathrm{Fe})/V_{track}$ should correspond to volatile-rich dust. As the moderately volatile elements were not largely depleted, the volatile material may be some organics and possibly ice.

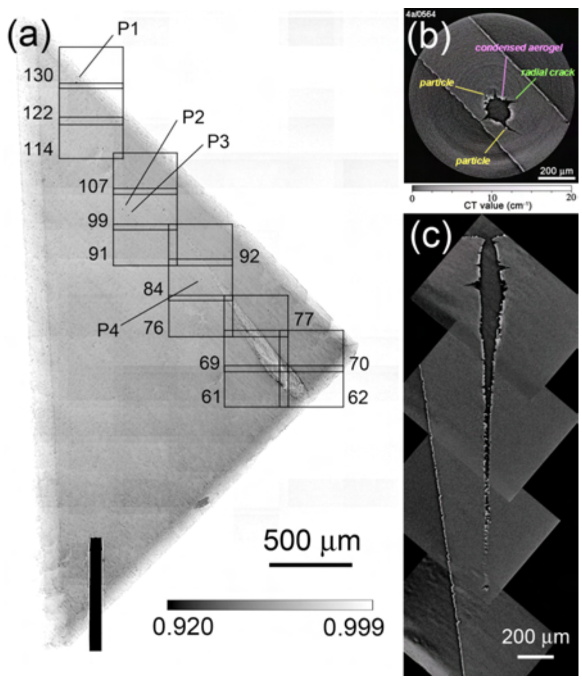

Figure 1. C2126,2,68,0 (skyrocket). (a) Tilted radiograph. Areas for XRF analyses are shown by boxes (400 x 260 μm^2). Four particles (P1-P4) were also analyzed by smaller areas (40 x 40 μm^2). A gray scale shows an x-ray transmittance. (b) A CT slice. (c) A CT image cut nearly parallel to the track.

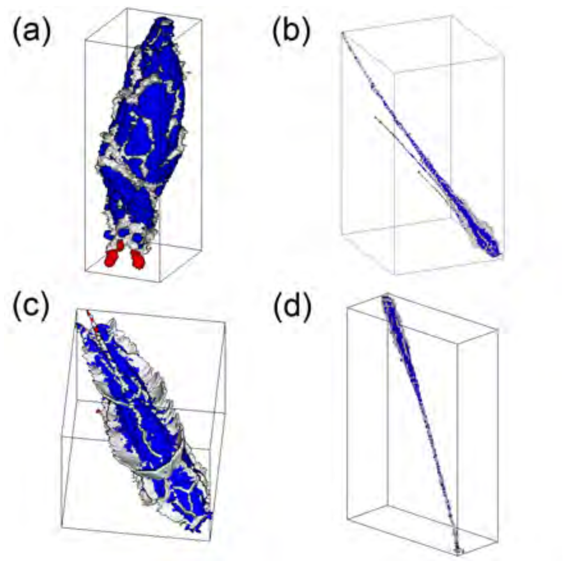

Figure 2. External shapes of impact tracks. (a) Track 67 namekuji (113 μm). (b) Track 68 skyrocket (2484 μm). (c) A bulbous portion near the entrance of (b). (d) Track 47 gobou (884 μm). Gray: track cavity. Blue: condensed aerogel. Red: captured particle.

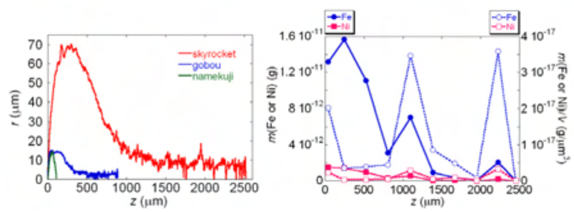

Figure 3. Track shapes and elemental distribution. (a) Mean track radius, r, *vs.* distance from the entrance, z. (b) Distribution of Fe and Ni along track 68 skyrocket.

References: [1] Brownlee D. et al. (2006) *Science*, *314*, 1711. [2] Hörtz F. et al. (2006) *Science*, *314*, 1716.[3] Uesugi et al. (2003) *Journal de Physique*. IV France, *104*, 45. [4] Nakamura T. et al. (2007) *LPS XXXVIII*, abstract. [5] Flynn G. F. et al. (2006) *Science*, *314*, 1731.

Table 1 Summary of the impact tracks analyzed.

Track	L_{track}	V_{track}	entrance	m(Fe)	V_{grain}*	$m(\mathrm{Fe})/V_{track}$	V_{grain}/V_{track}
	μm	μm^3	μm	g	μm^3	g/ μm^3	
67 namekuji	113	3.66×10^{4}	7.1x3.9	1.80×10^{-13}	2.03	4.92×10^{-18}	5.56×10^{-5}
68 skyrocket	2484	7.79×10^{6}	79.9x60.5	6.66×10^{-11}	752	8.55×10^{-18}	9.66×10^{-5}
47 gobou	>884	$>1.57\times10^{5}$	43.2x30.0	$>1.26\times10^{-12}$	>14.2	$>8.03\times10^{-18}$	$>9.07\times10^{-5}$

* Whole dust grain volume was estimated from the Fe mass by assuming the CI concentration and 1 g/cm^3 density.