Three-dimensional structures and elemental distribution of Stardust impact tracks: estimation of volatile components.

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Impact tracks in the Stardust aerogel collector have a variety of shapes, showing diversity of the Wild-2 cometary dust. We have investigated 3-D structures and elemental distributions of Stardust tracks using SR-tomography and SR-XRF as one of the preliminary examination of Stardust samples to obtain information on physical and chemical conditions of the dust capture process and a clue to reconstruct of the original dust.

Four keystones having impact tracks (track 67 Namekuji, bulbous, 0.1 mm long; track 68 Skyrocket, carrot-like, 2.8 mm long; and track 47 Gobou, cylinder- to carrot-like, 0.9 mm long) were imaged at BL47XU of SPring-8 by projection microtomography at 10 keV with the voxel size of 0.195 or 0.467 microns depending on the track size. XRF analysis was also performed for the same samples on the same sample stage at 15 keV using a Ge-SSD to determine the elemental abundances (S, Ca, Cr, Mn, Fe, Ni, Zn, Cu, Ga, Ge, As and Se) along the track and of individual grains.

Cavities of the impact tracks and condensed (compressed and/or melted) aerogel on the track walls were easily recognized in CT images. Grains disaggregated by the capture were distributed along the track walls as well as the track terminals. These grains correspond to crystalline or amorphous-rich types. 3-D external shapes of the tracks were constructed from the CT images. Namekuji has only a bulb with terminal grains without thin tracks. Skyrocket has a bulb with cracks near the entrance and bifurcated into 5 or 6 thin tracks near the bottom. Terminal grains are always present in all the bifurcated tracks. Gobou had lost its terminal grain during preparation of a keystone. The bulbous portions and thin tracks should be formed by fragile and very fine-grained material and less-fragile (and possibly crystalline) grains, respectively. The single track of Gobou is curved, and this might be due to spinning of the projectile.

We can obtain quantitative shapes and sizes of the tracks based on the voxel size of the CT images. Even in the thinnest track of Gobou, bulbous portion is present near the narrow entrance. The whole track of Skyrocket has an elemental abundance close to CI, but the elemental abundances differ among grains and between grains and tracks. 66% of Fe is present in the track while 34% of Fe in the large grains. Moderately volatile elements, such as S, Zn, As and Se, are not depleted compared with Fe and CI in the bulbous portion as well as in the thin tracks. This shows that volatilization of the moderately volatile elements is not responsible for the formation of the bulbous portion.

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. Then, the whole dust particle volume, V_p, can be estimated by assuming its density (1 g/cm^3). The dust volume is the order of 1/10000 of the track volume, V_t. The ratio of $m(\mathrm{Fe})/V_t$ correlates with the track shape; 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, the kinetic energy is only a function of the dust mass. If the track volume is correlated with the kinetic energy, the difference of $m(\mathrm{Fe})/V_t$ should be due to difference of the mass including volatile materials; a small value of $m(\mathrm{Fe})/V_t$ should correspond to volatile-rich dust. As the moderately volatile elements were not largely depleted, the volatile material may be some volatile organics and possibly ice.