Structure analysis of the hyper velocity impact tracks of the particles captured by silica aerogel on the International Space Station

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In Japan's first astrobiology experiment "Tanpopo", attempts have been made to capture cosmic dust by installing ultra-low-density silica aerogel at the Japanese Experiment Module "Kibo" of the International Space Station (ISS) [1]. This mission was conducted with the aim of verifying the hypothesis that the origin of life was supplied from outside the earth [2]. Silica aerogel had been used in NASA's cometary dust sample return mission "Stardust" [3]. Impact tracks formed by collision of cometary dust against aerogel were classified into 3 types, A, B and C, based on their shapes [4]. The track shapes have useful information for estimating the size and density of dust particles [5]. The purposes of this research are (1) to find impact tracks formed by cosmic dust in Tanpopo aerogel and (2) to describe the three-dimensional shapes of impact tracks with different origins (cosmic dust and space debris) and finally to clarify the relation between the track shape and the origin.

At SPring-8 BL47XU, three-dimensional shapes were obtained with imaging absorption tomography for 8 impact tracks (D1-231, D1-298, D1-362, E1-200, E1-304, F1-328, F1-389, F1-623), which were found in Tanpopo aerogel faced to the space direction. The imaging experiments were made at 7, 8, 9 keV with the voxel size of 0.24 or 0.465 μm. CT images at 8 keV were used to extract track shapes. Track length (L_t), maximum track diameter (D_m), aspect ratio, and other shape properties were obtained. These values were compared with Stardust tracks. Dual-energy tomography (DET) [6] was applied to estimate the materials of particles captured in the tracks. Another track (E2-000) was observed only with an optical microscope. For D1-231, D1-298, D1-362 and E2-000, the aerogel was compressed and real solid particles in the tracks were searched with an optical microscope.

The 9 tracks in total were classified into 5 types based on their shapes. Type 1 (E2-000) is a track formed by cosmic dust, where two pyroxene particles were identified at the tip of the track [7]. The track shape resembles Stardust type B track, but its entrance widely spreads. Type 2 (D1-231) is somewhat similar to Stardust type A track. Type 3 (E1-200 and E1-304) is a track having abundant cracks developed on the wall with a narrow entrance. Type 4 (F1-328 and F1-389) is extremely asymmetrical in its shape and has cracks similar to Type 3. Type 5 (D1-362 and F1-623) is a bowl-shaped track with a large entrance. The relationship between L_t and D_m of these tracks was almost the same as that of Stardust tracks except for Type 5. However, their specific shapes of Types 2, 3 and 4 are significantly different from Stardust tracks. The cracks of these tracks are similar to those seen at the end of Stardust type A and B tracks, indicating that they were formed by a relatively low-speed impact. Similar tracks to Type 5 were reported in the aerogel in the exposure experiment on the Mir Station. They may be due to high-speed collision of weakly-adhered aggregates [8]. From the quantitative analysis of such impact tracks, there is a possibility of obtaining knowledge about new parameter areas which could not be obtained by conventional research. DET results showed that most of fine particles in the tracks do not contain Fe and Ni. Low values of their linear absorption coefficients are smaller than that of cosmic dust. They should be formed by impact of weekly-adhered aggregates that were broken into very small pieces by the impact and mixed with condensed aerogel. Two particles with relatively high linear absorption coefficient were confirmed in D1-231 and D1-362. They were confirmed by and optical microscope after compressing.

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