Composition, Mineralogy, and Three-dimensional Structures of Particles Derived from Short-period Comet Wild 2

More than 10000 small rock particles have been successfully recovered from the comet Wild 2 [1]. The Stardust spacecraft arrived at a position 200 km from the comet in 2004, collected numerous particles swept from the comet, and then returned to Earth in 2006. The silica aerogel collectors, which are superlight materials with a density of approximately 10 mg/cc onboard the spacecraft, have captured the cometary particles that traversed at 6 km/s against the collectors. As part of the preliminary examinations that were conducted by the international organization, we performed compositional, mineralogical, and morphological characterizations of the cometary particles using synchrotron radiation. The ultra-high photon density of the SPring-8 X-ray beam enabled us to detect very minor elements and minerals in the Stardust cometary particles.

Elemental abundance: X-ray fluorescence analysis was performed at beamline **BL47XU** using monochromated X-ray with an energy of 15 keV. The elemental abundance was obtained from both particles and tracks that are carrot-shaped holes in which the cometary particles decelerated (Fig. 1), because we need to determine the composition of a particle prior to its entry into the aerogel. Figure 2 shows the elemental abundance obtained from a large track that contains four particles [2]. The abundances of major elements such as S, Ca, Cr, Mn, Fe, and Ni are close to the solar abundance, but the abundance of minor elements is higher than the solar abundance. We analyzed four tracks and individual tracks show different compositional features. However, when we summarized all of the data from more than 20 tracks obtained by an international team [3], the elemental abundance of the cometary particles is close to the solar abundance including both major and minor elements. This demonstrates that the cometary particles are very pristine “raw materials” that formed our solar system.

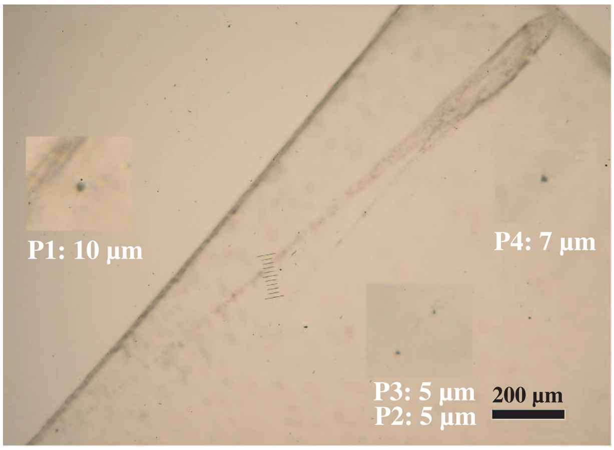

Fig. 1. A piece of aerogel with tracks and particles. A large particle came in from the upper right, broke into four pieces (P1 to P4), and stopped at the ends of the tracks. Evaporated materials are distributed along the tracks.

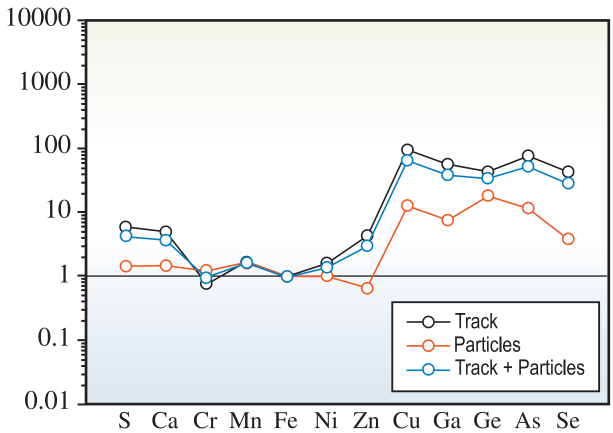

Fig. 2. Elemental abundance of tracks and particles (sum of P1 to P4) shown in Fig. 1. The abundance is normalized to Fe and solar abundance.

Mineralogy and structures of cometary particles: individual particles are obtained from the aerogels and exposed to X-ray for diffraction and tomography. X-ray diffraction analysis on more than 30 particles was carried out at beamline **BL37XU** at SPring-8 and 3A and 9C at KEK, while microtomography on 4 particles was performed at beamline **BL47XU**. Figure 3 shows the X-ray diffraction pattern and three-dimensional structures of a cometary particle [4]. The particles consist of anhydrous silicates such as olivine and pyroxene (Fig. 3(a)). No hydrous phases have been detected so far. This suggests that solid materials in the comet Wild 2 are not hydrated despite of the presence of water ice. The internal structure of the particle (Figs. 3(b) and 3(c)) is similar to that of igneous rocks with poikilitic texture: olivine occurs within low-Ca pyroxene without pore spaces between them. This suggests that the particle was once melted before incorporation into the comet in the early solar system. Melting during capture in the aerogel is not possible, because the periphery of the particle was not melted with the surrounding aerogel. The presence of this kind of particles suggests that high temperature (>1550 °C) events occurred in the early solar system and the particle that were melted during the events were incorporated into a region of the outer solar system where comets have formed.

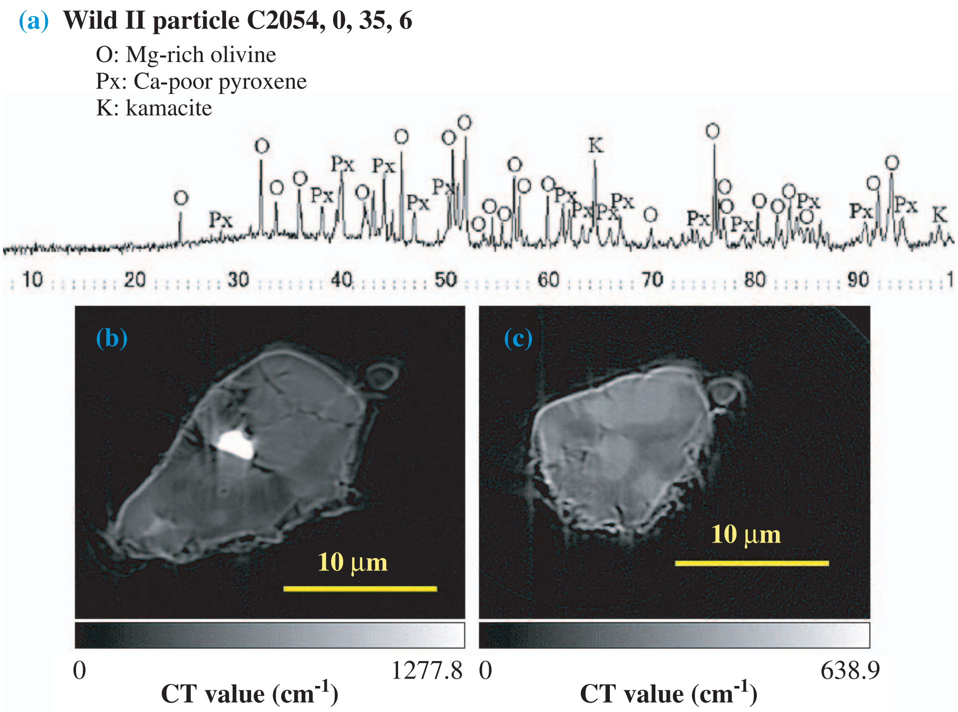

Fig. 3. X-ray diffraction pattern **(a)** and micro tomography images **(b)** and **(c)** of a cometary particle. In **(b)** and **(c)**, olivine grains (light grey) occur within Ca-poor pyroxene (dark grey).

Tomoki Nakamura[a,*] and Akira Tsuchiyama[b]

[a] Department of Earth and Planetary Science, Kyushu University
[b] Department of Earth and Space Science, Osaka University

*E-mail: tomoki@geo.kyushu-u.ac.jp

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