Crystallography

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X-ray diffraction analysis of cometary particles captured by the Stardust mission

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Introduction

The Stardust mission has succeeded to recover many cometary particles swept out from a short-period comet 81P/Wild 2. The particles are very small and most of them have diameter less than 10 microns. Therefore, characterization of these small particles requires most-advanced analytical techniques. We have utilized synchrotron radiation X-ray to characterize bulk mineralogy of individual stardust particles.

Experimental procedures

Cometary particles were captured into on-board aerogel at 6 km/sec velocity against the spacecraft. Individual particles were extracted from aerogel and mounted on a thin glass fiber of 3-micron thickness using a small amount acetone-soluble bond. The operation was carried out at NASA/JSC. Each particle was placed in the Gandolfi camera for exposure to synchrotron X-rays with a wavelength of 2.161 ± 0.001 Å for 3 hours to produce a powder X-ray diffraction pattern. The analysis was performed at beam line 3A; for details of these procedures see [1].

Results and discussion

We analyzed 28 particles, among which 25 particles were taken from track 35 and 3 particles from track 44. Track 35 is 11.7 mm length with a large bulboid space in front and a long, straight main track with a terminal particle at base. Several subtracks with terminal particles are also present. Among 25 particles analyzed, 23 were picked up from the wall of the bulb and 2 from terminal particles. On the other hand, the track 44 is much larger (~ 0.8 cm) than the track 35, but it is still in the aerogel tray, so precise size of the track is unknown. Three particles were pulled from the wall of the track.

The results of X-ray diffraction showed that stardust particles can be classified to two types: crystalline type and amorphous-rich type. The crystalline type shows very sharp diffractions of silicates and Fe metal, whereas amorphous-rich type shows very broad reflections of Fe metal and sulfide with or without minor amounts of silicates. Among 28 particles investigated, only three are classified to crystalline type and the rest is amorphous-rich type. Two particles of crystalline type and two particles of amorphous-rich type are analyzed by micro-tomography at SPring-8 after X-ray diffraction [1]. The results indicate that crystalline-type particles consist mostly of relatively coarse (more than 1 micron diameter) silicate crystals such as olivine and low-Ca pyroxene and the crystals contact each other without any pore spaces. On the other hand, the amorphous-rich type is porous aggregates showing network structure with numerous voids.

The crystalline-type particles are not melt product during capture into the aerogel, because no mixing with melted silica aerogel is observed. Therefore, these particles are relict of indigenous material of comet Wild 2. The presence of plagioclase, which requires slow cooling for crystallization, supports this interpretation. These crystalline particles formed via high-temperature episodes that predate formation of comet Wild II. This finding, together with CAI materials in other tracks [2], indicates that Wild II contains high-temperature materials that are difficult to produce at regions of Kuiper belt.

References

[1] Nakamura T. et al. (2007) *Meteoritics & Planet. Sci.*, submitted. [2] Brownlee D. et al. (2006) *Science, 314,* 1711.

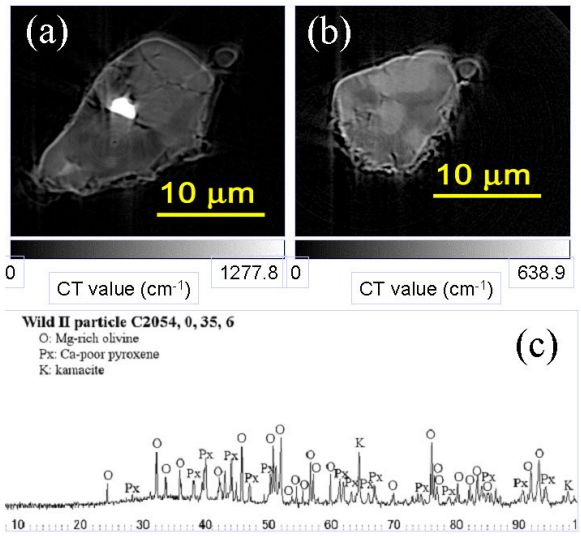

Fig. 1. Crystalline particle C2054, 0, 35, 6. (a-b) Micro-tomography taken at Spring-8 [1] shows it consists of relatively coarse crystals with very low porosity. (c) X-ray diffraction pattern showing that the particles contain olivine, pyroxene, and kamacite. The reflections from olivine and pyroxene are very sharp, being consistent with large crystal size in tomography images (a-b).