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Mineralogy and internal structures of individual Stardust particles

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More than 10000 small rock particles have been successfully recovered from a comet Wild II [1]. As a part of preliminary examinations, we performed mineralogical, and morphological characterization of cometary particles using synchrotron radiation.

Individual particles were first analyzed by synchrotron X-ray diffraction (SXRD). The analyses were performed at beam line 3A of the Photon Factory Institute of Material Science, High Energy Accelerator Research Organization and beam line 37XU of Japan Synchrotron Radiation Research Institute (SPring-8); for details of these procedures see [2]. Following SXRD analyses, four particles with different SXRD characteristics were selected. They were imaged and analyzed analyzed by micro-tomography at beam line BL437XU of SPring-8. The imaging experiments were made using imaging tomography [3] at 8 keV with 3600 projections for each slice.

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 SXRD showed that stardust particles can be classified to only 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 also analyzed by micro-tomography. 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.

A stardust particle C2054, 0, 35, 6 is approximately 15 microns in size. It consists of Mg-rich olivine, low-Ca pyroxene and kamacite. All reflections are very sharp, indicating that the particle is well crystalline. Tomography shows that it is a non-porous particle. All minerals are coarse and several microns in size. The internal texture is poikilitic: subhedral olivine crystals occur within anhedral pyroxene. The texture suggests that the particle was crystallized from a melt: olivine crystallized first followed by pyroxene at around 1550 oC.

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 II. The presence of plagioclase in C2054, 0, 35, 4, 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 [1], indicates that Wild II contains high-temperature materials that are difficult to produce at regions of Kuiper belt.

References: [1] Brownlee D. et al. (2006) Science, 314, 1711. [2] Nakamura T. et al. (2007) Meteoritics & Planet. Sci., submitted. [3] Uesugi K. et al. (2006) Proc. SPIE, 6318, in press.