Thermal alteration of minerals during hypervelocity capture in silica aerogel

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1. Introduction: Silica aerogel is a ultra-low density SiO_2 gel. It has been used to capture micrometeoroids on space crafts and space stations and cometary dust in the Stardust mission. However, the assessment of the effect of frictional heating during capture is incomplete. We have been reporting some results of the assessment of the frictional heating (Okudaira et al., 2002 and 2004). In this paper, we would like to report detailed mineralogical investigation of captured particles.

2. Sample and experiment: Fine-grained powders of serpentine (lizardite), cronstedtite, and Murchison meteorite were used as projectiles. The powders were set in sabots and shot by two-stage light gas gun at JAXA/ISAS and Kent University. Captured particles were extracted from aerogel in the clean room at Ibaraki University. Bulk mineralogy of each grain was investigated by synchrotron radiation X-ray diffraction (SR-XRD) at the Photon Factory, KEK. TEM samples were prepared by ultramicrotomy at Ibaraki University. Microstructure of the surfaces of the particles was investigated by AEM and FE-SEM.

3. Results and its implication: Experiments (less than 4 km/s) were performed for serpentine and cronstedtite. SR-XRD experiments of these minerals could not detect any remarkable change from starting materials. TEM observation of the serpentine showed that the surface was partially decomposed. The interior of the serpentine is intact. Cronstedtite has two distinct rims by TEM observation. The outer rim was composed of vesiculated glass and the inner was composed of partially decomposed cronstedtite. The interior of the cronstedtite is unchanged. Chemical compositions of their partially decomposed layers are almost identical to those of their interiors. The vesiculated glass of the captured cronstedtite has intermediate compositions between silica aerogel and cronstedtite.

In the experiments shot at around 6 km/s, no changes from starting materials were detected in the serpentine, cronstedtite, and Murchison by SR-XRD. Remarkable textural and mineralogical change occurred on these materials when observed by FE-SEM and TEM.

Serpentine has texture similar to cronstedtite shot at around 4 km/s. It has an outer rim composed of vesiculated glass and an inner rim of partially decomposed serpentine. Cronstedtite contains abundant vesiculated glass. The entire grains were composed of complicated mixture of vesiculated glass, partially decomposed cronstedtite, and intact cronstedtite. The shapes of them are similar to those of button-shape tektites. SR-XRD and TEM observation revealed that captured powder of Murchison contain tochilinite as well as Fe-bearing serpentine and cronstedtite. FE-SEM and TEM observation of them revealed that the grains have texture similar to that of the cronstedtite. However, their degree of melting and vesiculation is lower than that of cronstedtite.

Because decomposition temperature of tochilinite is 245 oC (Gooding and Zolensky, 1992), minerals having such a low decomposition temperature can survive during hypervelocity capture into silica aerogel. Because relative velocity of cometary dust during the encounter of the Stardust space craft and the Wild 2 comet was 6.4 km/s, minerals that have decomposition temperature as low as that of tochilinite would have survived in the aerogel. However, the texture of cometary particles would have been greatly modified during capturing process because cometary particles are loose aggregates of very fine components.

We could not detect mineralogical changes of all the captured grains in our study based only on SR-XRD. We might not distinguish original features and their modification during capture only based on non-destructive methods during the investigation of the Stardust samples. Development of extraction method of very fine-grained captured particles from aerogel and handling of them probably becomes a key technology for the investigation of particles in silica aerogel.