Strength measurements pf carbonaceous chondrites and cosmic dust analogs using micro compression testing machine

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It is important to know mechanical properties (e.g., strength) of extraterrestrial materials for understanding entry of meteoroids and cosmic dust into Earth, surface features of small solar system bodies, and dust evolution in the early solar system. This is also important for sample return missions, especially for development of their sampling devices. However, the strengths of carbonaceous chondrites, which are candidate materials for primitive small bodies as sample return mission targets, have not been measured, except for Marchison (CM2)[1]. This is due to a lack of samples with sufficient sizes for conventional strength measurement because most of carbonaceous chondrites are precious and fragile. The strength of cosmic dust has not been also known because they are too small to be measured. However, strengths of small grains (about 100 microns) can be evaluated using a micro compression testing machine. In this study, this technique was applied to carbonaceous meteorites and cosmic dust analogs.

Four carbonaceous meteorites (CM: Murchison and Murray, CI: Ivuna and Orgueil, Tagish Lake (TL): carbonate-rich and poor lithologies) were used in the experiments. They were crushed, and fragments of about 100 microns were picked up. Aggregates of spherical particles (amorphous silica of 0.1 and 0.5 microns in diameter connected with a small amount of glycol phthalate) were also prepared as cosmic dust analogs. They were observed under SEM before compression test. The compression test was made using Shimadzu MCT-W500 with a flat diamond indenter of 500 microns in diameter (load: 9.8-4903 mN, displacement: 0-100 microns). Tensile strength was obtained from a load-displacement curve [2]. The compressed samples were recovered and observed under SEM.

Tensile strength of Murchison (2.0+/-1.5 MPa) is smaller than the compressive strength (50 MPa [1]). This is consistent with general relation between tensile and compressive strengths. Ivuna and TL (carbonate-poor) have the lowest strength (0.7+/-0.2 and 0.8+/-0.3 MPa, respectively), which is similar to silica aggregates of 0.1 micron (1.0+/-0.3 MPa). Large variations of Murray (8.8+/-4.8 MPa), Orgueil (2.8+/-1.9 MPa) and TL (carbonate-rich) (6.7+/-9.8 MPa) may be due to heterogeneities of the meteorites (chondrule fragments and/or different degrees of consolidation). Tensile strength of silica aggregates of 0.5 micron (0.04+/-0.01 MPa) is smaller than that of the 0.1 micron aggregates because the 0.5 micron aggregates are much porous than the 0.1 micron ones.

[References]
[1] Y. Miura et al. (2008) Abstract in this meeting.
[2] Y. Hiramatsu et al. (1965) Nihon Kougyo Kaishi, 81, 1024-1030. (in Japanese)