Density and porosity measurement of Antarctic micrometeorites and presence of submicron pores

Takahiro Okazawa[1]; Akira Tsuchiyama[1]; Takaaki Noguchi[2]; Hajime Yano[3]; Takahito Osawa[4]; Tomoki Nakamura[5]; Kentaro Nakamura[6]; Tsukasa Nakano[7]; Kentaro Uesugi[8]; Hideyuki Yasuda[9]

[1] Earth and Space Sci., Osaka Univ.; [2] Ibaraki Univ; [3] Dept. of Planetary Sci., JAXA/ISAS; [4] Lab. Earthquake Chem., Grad. School of Sci.,

Univ. Tokyo; [5] Earth and Planetary Sci., Kyushu Univ.; [6] Earth and Space Sci. Osaka Univ.; [7] Geological Survey of Japan/AIST; [8] JASRI; [9] Dept. Adaptive Machine Sys., Osaka Univ.

http://www.ess.sci.osaka-u.ac.jp/~akira/indexj.html

Density and porosity are one of the most important physical properties for materials. It is generally difficult to measure the densities and porosities of micrometeorites (MMs) precisely due to their small sizes. The volumes and porosities can be measured from the 3-D structures of MMs, which can be obtained by x-ray microtomography using SR. The masses can be measured by an ultra-microbalance and the densities can be obtained precisely together with the CT results. In the present study, twelve Antarctic micrometeorites (AMMs) (0.1-0.3 mm in size) were imaged using x-ray microtomography system (Uesugi et al., 2001) at BL47XU of SPring-8 with the spatial resolution of about 1.3 microns. The volumes and porosities were obtained by image analysis of the 3-D CT images. The masses of nine of the AMMs were measured by an ultra-microbalance (Mettler-Toledo: UMX2 with the lower limit of 0.1 micron, which corresponds to a MM of 0.1 mm in size). The mineral phases included in seven of the AMMs were determined by SR-XRD at the beamline 3A of Photon factory. Finally, some of the samples were cut physically and observed under SEMs to compare CT images. Two samples were scraped and polished with almina lapping paper and observed under a conventional SEM (JEOL: JSM-5510LV). Five samples were cut by an ultra-microtome and observed under FE-SEM (JEOL: JSM-6500F) with high resolution.

Prior to the density measurement, we evaluated the accuracy of the present method by using standard materials (quartz, olivine, rutile and magnetite) of similar sizes as the AMM samples. The measured densities were compared with those obtained for larger pieces of the same mineral samples by conventional hydrostatic method. The both are almost the same within the accuracy of 2% except for magnetite with larger x-ray adsorption. The error of the density is largely due to the error of the mass measurement.

The porosities of the AMMs were obtained in 3-D by considering closed pores in the samples. The porosities of scoriaceous and non-scaoriaceous samples were 5-28 and 0-6 vol.%, respectively. There are many pores which seem to be closed in 2-D cross sections but actually are open to the outside in 3-D. Bulk and solid volumes with and without closed pores, respectively, were obtained and finally bulk and solid densities were calculated together with the masses. The bulk and solid densities of five scoriaceous MMs are 2.0-2.2 (mean: 2.2(0.1)) g/cm3 and 2.3-3.1 (mean: 2.6(0.3)) g/cm3, respectively. The bulk and solid densities of four non-scoriaceous MMs are 1.7-2.6 (mean: 2.0(0.4)) g/cm3 and 1.7-2.7 (mean: 2.1(0.4)) g/cm3, respectively. Love et al. (1994) estimated the bulk densities of IDPs roughly by the elemental composition and SEM/TEM observation (2.2 g/ cm3 in average). This is slightly larger than the present mean bulk density for the non-scoriaceous MMs.

Hydrous silicates were detected in two of the AMMs (CI- and CM-like) by SR-XRD. The modes of the constituent minerals were estimated roughly from the 3-D CT images of the samples and their densities were estimated based on the densities of the minerals. They were 3.4 and 2.6 g/cm3 and sufficiently larger than the measured densities of 2.1 and 1.8 g/cm3, respectively. This discrepancy suggests that small pores of the size below the spatial resolution of the CT system are present in the samples. High-resolution observation of the samples prepared by the ultra-microtome under the FE-SEM confirmed the presence of submicron pores. The presence of such pores may explain the low densities of asteroids (Ida: 2.6 g/cm3; Chapman et al., 1995 and Mathilde: 1.3 g/cm3; Yeomans et al., 1997). It was also observed under the SEM that some voids, which were clearly recognized in CT images, were filled with scraps if the samples were prepared by alumina lapping paper. This shows that sample preparation by an ultra-microtome is inevitable for observation of voids in cross sections.