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Three-dimensional observation of organic nanoglobules by microtomography and evaluation of CT images by image simulation

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Spherical organic matters called organic nanoglobules of a few hundred micrometers in typical size were found in carbonaceous chondrites, IDPs, and dust from comet 81P/Wild2 [1-3]. Most of them have hollow structures. It has been suggested that the organic nanoglobules were formed from organics-ice particles in the molecular cloud or the protoplanetary disk in the solar system [4]. Aqueous alteration of organic matters is also suggested as alternative possible formation processes [1]. If one of the hypotheses is true, hollow regions of the globules might be filled with H2O-rich ices or fluids. However they have not been detected because they had been lost during destructive observations, such as transmission electron microscope (TEM) observation, in the previous studies.

In the present study, we tried to observe organic globules non-destructively using synchrotron radiation-based absorption-contrast imaging X-ray microtomography [5] in order to determine the existence of fluids in the hollows of nanoglobules. The imaging experiments were made at the beamline BL47XU of SPring8 with the photon energy of 7.0 keV. CT images were reconstructed from 1800 projections and successional CT images of about 800 slices were obtained for the 3-D structure of Tagish Lake meteorite. The voxel size in the CT images is 40.8 nm^3. Then, we microtomed some samples and observed ultra-thin sections under a TEM. Comparison between the CT and the TEM images showed that nanoglobules can be observed in the CT images. But CT images of nanoglobules are affected by X-ray refraction. So we could not determine materials in nanoglobules from CT images alone. There are many spherical objects as candidates of organic nanoglobules in the CT images.

In order to identify nanoglobules and to determine whether or not any fluids are present in the hollows, we tried to evaluate CT images by simulating CT images by considering X-ray absorption and refraction for nanoglobules with hollow or water, which are surrounded by saponite, a main constituent mineral of Tagish Lake meteorite matrixes. We calculated transmittance of X-rays that pass the sample with absorption and refraction and reach a detector. Actual tomography experiments were performed under an imaging system with a Fresnel zone plate (FZP). The location of the detector in the simulation corresponds to a focal spot of the FZP. Simulated CT images were made by reconstruction with the pixel sizes of the detector (40.8 nm) and measured point spread function (FWHM = 360 nm). Simulated CT images indicated that nanoglobules containing water cannot be distinguished from those without hollow in CT images. When organic rims are thin, CT images of nanoglobules with hollow cannot not be distinguished from those of simple spherical pores. The effective spatial resolution of nanoglobules is about 300 nm. Comparison between CT images of nanoglobules identified by the TEM observation and simulated CT images suggested that this nanoglobules might not contain any water.

The simulation also revealed that three-dimensional shape of nanoglobule can be estimated by CT images. Three-dimensional distribution of nanoglobules can be also obtained by CT images. We can grind the sample to the position right above a nanoglobule detected by tomography and analyze a fluid in the nanoglobule using a microanalysis, such as nano SIMS, if fluid is reserved.

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