Application of scanning-imaging x-ray microscopy to fluid inclusion candidates in carbonates of carbonaceous chondrites.

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In order to search for such fluid inclusions in carbonaceous chondrites, a nondestructive technique using x-ray micro-absorption tomography combined with FIB sampling was developpped and applied to a carbanaceous chondrite [1,2]. They found fluid inclusion candidates in calcite grains, which were formed by aqueous alteration. However, they could not determine whether they are really aqueous fluids or merely voids.

Phase and absorption contrast images can be simultaneously obtained in 3D by using scanning-imaging x-ray microscopy (SIXM) [3]. In rrefractive index, n=1-δ+$i\beta$, in the real part, 1-δ is the refractive index with decrement, δ, which is nearly proportional to the density, and the imaginary part, β, is the extinction coefficient, which is related to the liner attenuation coefficient, μ. Many phases, including water and organic materials as well as minerals, can be identified by SIXM, and this technique has potential availability for Hayabusa-2 sample analysis too. In this study, we examined quantitative performance of *d* and *m* values and the spatial resolution in SIXM by using standard materials, and applied this technique to carbonaceous chondrite samples.

We used POM ($[CH_2O]_n$), silicon, quartz, forsterite, corundum, magnetite and nickel as standard materials for examining the $\delta$and μvalues. A fluid inclusion in terrestrial quartz and bivalve shell (Atrina vexillum), which are composed of calcite and organic layers with different thickness, were also used for examining the spatial resolution. The Ivuna (CI) and Sutter's Mill (CM) meteorites were used as carbonaceous chondrite samples. Rod- or cube-shaped samples 20-30 μm in size were extracted by using FIB from cross-sectional surfaces of the standard materials or polished thin sections of the chondrites, which was previously observed with SEM. Then, the sample was attached to a thin W-needle and imaged by SIXM system at beamline BL47XU, SPring-8, Japan. The slice thickness was 109.3 nm and the pixel size was mostly 100 nm.

It was found that μand *d* values obtained by SIXM (μ_{SIXM} and d_{SIXM}) are proportional to the theoretical values (m_{calc} and d_{calc}), respectively, exept for large μvalues (>~1000 cm^{-1}), and the following relations were obtained; μ_{SIXM} = 0.909(8)×μ_{calc} and δ_{SIXM} = 0.908(6)×δ_{calc}. We can quantitatively identify fluid in inclusions of the terrestrial quartz and organic layers in the shell with the spatial resolution of >~1 μm. If they are less than ~1 μm, we cannot quantitatively identify them due to overlapping of the point sprad function.

A hexagonal platy inclusion with facets, or negative crystal (0.7 x 2.3 μm) was found in a calcite grain of the Sutter's Mill meteorite as a fluid inclusion candidate [4]. The δvalue of this inclusion is less than that of water, indicating that any aqueous fluid was not included. As its shape strongly suggests that it was once formed as a fluid inclusion during hydrous alteration in a parent boby, and then the fluid must be escaped. We cannot detect any aqueous fluids in other fluid inclusion candidates, such as a spherical inclusion (~1.8 μm) in a calcite grain of the Sutter's Mill meteorite, which seems to have a bubble inside [1], and a relatively large inclusion with facets in dolomite in the Ivuna meteorite.

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