3D observation of whisker-like material in the porous matrix of the Paris CM chondrite by SR-XCT

*Masahiro YASUTAKE[1], Epifanio Vacarro[2], Kentaro Uesugi[3], Akihisa Takeuchi[3], Tsukasa Nakano[4], Akira Tsuchiyama[1]

1. Division of Earth and Planetary Science, Graduate School of Science, Kyoto University, 2. National History Museum, London, 3. JASRI/SPring8, 4. GSJ/AIST

Introduction The chondritic-porous interplanetary dust particles (CP-IDPs) are well-known material, that preserves primitive and pristine features of the early solar system. Enstatite whisker is one of the materials that characterizes CP-IDPs. It is thought that enstatite whiskers are condensates formed in the inner solar system and transferred to the outer regions, where comets formed [e.g. 1, 2]. Recently, whisker-like enstatite crystals were found in the primitive carbonaceous chondrites [3, 4]. However, the whisker-like materials they found could be a cut-plane of thin enstatite plate. By the 2D observation, it is hard to solve this matter. 3D observation based on synchrotron radiation X-ray nano-CT is a strong tool to understand the crystal shape, mineral phase, and rough composition. We conducted a 3D observation to better understand the characteristics of whisker-like materials in primitive carbonaceous chondrites.

Methods We investigated the Paris primitive CM chondrite. Paris was reported to have a very primitive matrix that includes GEMS-like materials [5]. A section of this meteorite was observed and elemental maps of the primitive matrix were obtained by FE-SEM/EDS. A house-shaped CT sample (~25 x 25 x 30 μm) was extracted from the primitive matrix by using a FIB-SEM. CT data of the micro-samples were conducted at beamline BL47XU, SPring-8. CT images were acquired at energies of 7 keV and 7.35 keV with voxel sizes of ~32.2 nm and ~ 33.9 nm, respectively. Mineral phases were estimated using dual-energy tomography (DET) method using the X-ray linear attenuation coefficient (LAC) [6].

Result and Discussion The observed matrix is a part of the fine-grained rim of Type I porphyritic olivine pyroxene chondrule. The matrix is porous and consists mainly of amorphous silicates that include sub-micron sized Fe-rich phases. Whisker-shaped materials are abundant in the CT sample observed. However, fibrous alteration materials were also reported in the matrix of Paris [5]. The whisker-like materials observed might include such products in addition to enstatite. The size of the largest whisker is ~6 μm x ~700 nm x ~350 nm (Fig. 1) and similar to ribbon-type enstatite whisker in the CP-IDPs [1]. This whisker has a curved shape unlike those in CP-IDPs. Probably it reflects deformation during accretion to the parent body and/or planetary processes such as planetary collision.

The LAC values of most whisker materials are hard to obtain quantitatively because refraction of X-ray at the edges of the narrow whiskers enhanced their LAC values. The LAC values of the largest whisker are less affected by refraction and have the range of ~170-180 cm^{-1} and ~250-270 cm^{-1} at 7.00 and 7.35 keV, respectively. These values are consistent with those of pyroxene ($En_{80}Fs_{20}$) and clearly distinguishable from the values of fibrous alteration products (cronstedtite, tochilinite, and ferrihydrite) [5]. The above results suggest that this whisker material is an enstatite whisker. The possibility of olivine whisker (~Fo_{85}) cannot be excluded but forsterite whiskers have not been reported so far. Thus, it is reasonable to consider that the enstatite whiskers accreted to the carbonaceous chondrite parent body.

Crystallographic features such as defects and direction of elongation are still not examined. Investigation of crystallography is required to constrain the formation processes of whiskers, and it will enable us to compare the enstatite whiskers in carbonaceous chondrites with those in CP-IDPs.

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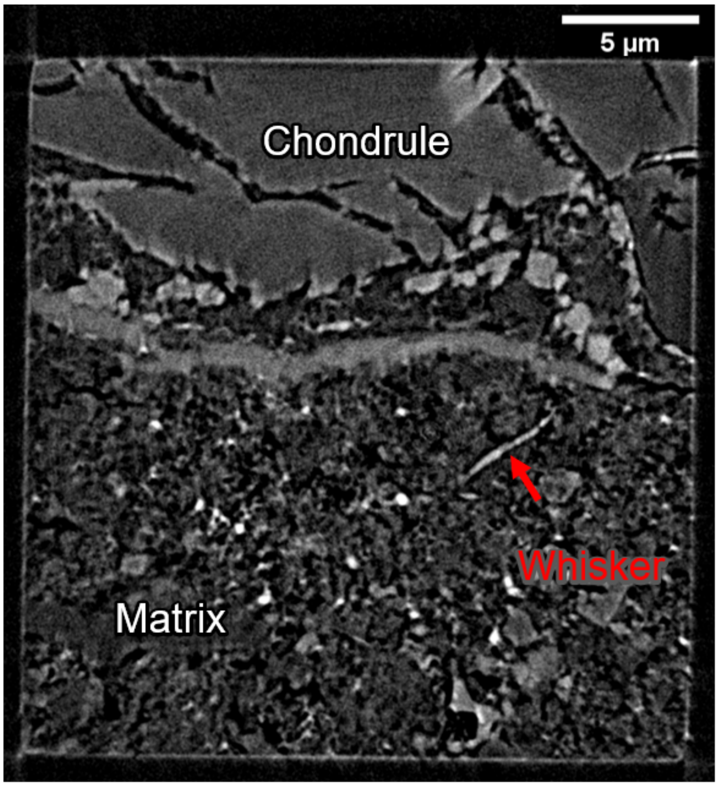

Fig. 1. CT image of porous matrix in Paris acquired at 7 keV. Silicates are shown in light grey. Amorphous silicates are shown in dark grey. Metal and sulfide are shown in white. The enstatite whisker is shown by red arrow.

