3D OBSERVATION OF POROUS MATRICES IN PRIMITIVE CM-CO CHONDRITES BASED ON SR-NANO-XCT IMAGING.

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Introduction: Carbonaceous chondrites are well-known samples that preserve primitive and pristine features of the solar system. Especially, primitive carbonaceous chondrites (PCC) are thought to experience little alteration and metamorphic processes. Matrix is one of the dominant components of chondrites. Recent studies revealed that matrices in PCC contain unique components resembles CP-IDPs that is one of the most primitive materials [e.g. 1,2]. However, their origin of matrices is still controversial. It is well known that carbonaceous chondrite matrix (CCM) has fine, complex and heterogeneous texture from the 2D investigation. 3D observation based on X-ray CT is a very strong tool to understand such complex material. Furthermore, the recent advance of synchrotron radiation nano-scale X-ray CT (SR-nanoXCT) enables us to investigate fine structures such as CCM. Here, we show the 3D structure of matrices in primitive carbonaceous chondrites based on SR-nanoXCT and discuss their formation history.

Samples and Methods: We investigated matrices of four PCC classified CM-CO clan; Paris (CM3), ALH 77307 (CO3), DOM 08006 (CO3), and MIL 07687 (CO3). The surface of the matrix was investigated by SEM-EDS. Relatively porous matrices were chosen to investigate. Micro-sized CT samples (~25 × 25 × 25 µm) were picked up with a FIB/FE-SEM system (FEI Helios nanolab G3). CT data were obtained at beamline BL47XU, SPring-8, SR facility in Japan. CT images were acquired at X-ray energies of 7 keV and 7.35 keV. X-ray linear attenuation coefficients (LAC) were obtained and mineral phases were estimated using a dual-energy tomography (DET) method [3].

Results and discussion: We classified matrices into 3 types based on the observed constituent material and texture. *Type1:* The observed matrices in ALHA 77307 and DOM 08006, and one of the matrices in Paris (M1) mainly consisted of amorphous silicates including submicron-sized Fe-rich phases (Fig. 1a). Fine pores were uniformly distributed in the matrices. Notably, fibrous material was abundant in the matrix. It is hard to estimate the mineral phases of most fibrous material because of their small sizes, but one largest material in Paris was estimated to be olivine or low-Ca pyroxene (Fig. 1b). It is probably enstatite whisker as the case of some carbonaceous chondrites [e.g. 1]. The type 1 matrix is likely to be the most primitive in this study.

Type2: The observed matrix in MIL 07687 mainly consisted of amorphous silicate with Fe,Ni-metal as type 1 (Fig. 1c). On the other hand, this matrix contained many large lathes of serpentine. Pores were uniformly distributed in the matrix. There were unique components with a spherical structure; a layered structure composed of a serpentine shell, Fe,Ni-metal core, and a dark mantle in CT-images possibly consisting of organic materials. Coexistence of amorphous silicates, Fe,Ni-metal, and well-grown serpentine indicates that matrix had suffered very local alteration, or it is a mechanical mixture of primitive matrices like type1 and pre-accretionary altered products.

Type3: Another matrix in Paris (M2) mainly consists of relatively large olivine grains (~0.5–2.0 µm). It contains minor sulfide and Fe-rich oxide/hydroxide, which is an alteration product of Fe,Ni-metal (Fig. 1d). Pores are distributed among olivine grains. The 3D observation certifies that this is not an artifact product during sample preparation such as plucking of the mineral grains at the surface. Olivine is one of the well-known materials that crystallize during condensation in the gas nebular [e.g. 4]. It might be formed by condensation processes.

Conclusion: 3D observation based on SR-nanoXCT reveals the presence of whisker-like materials, wide-spreading pores, and unique spherical components in matrices of PCC. These features are hard to be distinguished from the 2D investigation. Further mineralogical investigation using TEM will help us to better understand the building blocks in the early solar system.

References: [1] Vacarro E. (2017) PhD thesis, The Open University. [2] Leroux H. et al. (2015) *Geochimica et Cosmochimica Acta*, 170:247-265. [3] Tsuchiyama A. et al. (2013) *GCA*, 116:5-16. [4] Ebel D. S. (2006). *Meteorites and the early solar system II*, 1:253-277.

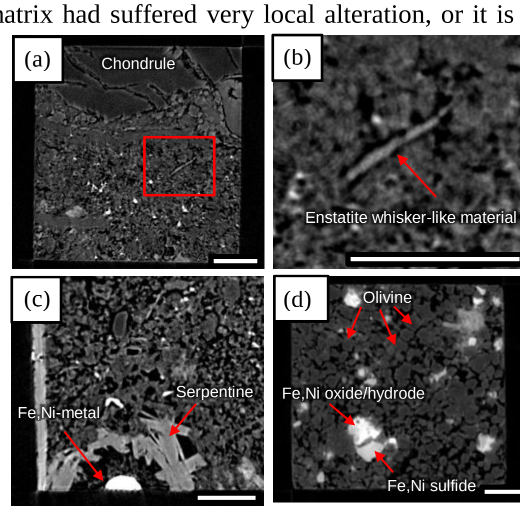

Fig. 1. CT images at 7.35 keV of (a) type 1 matrix in Paris (M1), (b) enlarged image in (a) showing a whisker-like material, (c) type 2 matrix in MIL 07678, and (d) type 3 matrix in Paris (M2). Silicates are shown in dark grey, pores in black, and Fe-rich materials in light grey to white. Scale bar = 5 µm.