Microstructure of a matrix in primitive carbonaceous chondrite Acfer 094: investigation for pristine planetary materials

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CP-IDPs are porous aggregates of submicron-sized amorphous silicates (GEMS), olivine, pyroxene, Fe-Ni sulfides, Fe-Ni metal and organics [e.g.,1]. These textures are believed to have formed by accretion of dusts in the early Solar System. It implies that pristine dusts in the early Solar System contain abundant amorphous silicates and organics in addition to crystal grains. Meanwhile, most carbonaceous chondrites contain little amounts of amorphous silicate and organic. Although a few least altered carbonaceous chondrites contain abundant amorphous silicates and organics in their matrix [e.g.,2,3], the detailed characteristics and origin of them remain unknown. In this study, we investigated microtextural characteristics of a matrix in the most primitive carbonaceous chondrite Acfer 094 by using FE-SEM, synchrotron radiation X-ray CT (SR-XCT), TEM and NanoSIMS. Our goal is to understand how the carbonaceous chondrite parent bodies were formed in the early Solar System.

The Acfer 094 meteorite contains abundant matrix materials (~60 vol.% of whole meteorite). The matrix basically shows compact texture without pores. Our FE-SEM observations show that a lot of small (~a few tens of μm^2) ultra-porous lithology (UPL) are widely distributed in the matrix. The proportion of UPL in the matrix is small (~0.3 vol.%). In SR-XCT experiments, we confirmed some UPL located under the polished surface of the Acfer 094 thin section. These results ensure that the pores in UPL were originally contained in the Acfer 094 meteorite (not be formed by polishing). The estimated density of UPL and the matrix are ~1.4 g/cm^3 and ~2.4 g/cm^3, respectively. The density of UPL is close to those of CP-IDPs (~0.7 g/cm^3) [1].

TEM observations show that UPL consists mainly of GEMS-like amorphous silicates, olivine, pyroxene, and pyrrhotite with a few hundred micrometer in size, and contains abundant pores among them. The pores are partially filled by spongy organics. The estimated porosity of UPL (~40 %) is as high as CP-IDPs (~70 %) [1]. The matrix consists of almost same materials with UPL but contains small amounts of hydrous minerals suggesting weak aqueous alteration.

We acquired C, O and N isotopic compositions in UPL and matrix by NanoSIMS ion imaging method. The isotopic compositions of C and N in UPL and matrix show similar within the analytical errors. O isotopic compositions are slightly enriched in heavy isotopes compared to bulk Acfer 094 meteorite [4]. It is noted that O isotopic compositions of the amorphous materials are plotted along the mass fractionation line of those of GEMS. It may imply that the amorphous materials have the same origin with GEMS.

These results show that UPL shares characteristics of isotopes, mineralogy, and microtexture with CP-IDPs, and thus may have the same origin with them. We infer that UPL originally having ice is one of the most primitive materials in the Solar System and was probably one of building blocks of carbonaceous chondrite parent bodies. We consider that in the carbonaceous chondrite parent body formation region of the early Solar System, probably in vicinity of the snow line, ice-bearing UPL and compact matrix materials, which formed by removal of ice from UPL, were accreted (with chondrules and CAIs) in the Acfer 094 parent body. Subsequently, weak aqueous alteration was occurred in the Acfer 094 parent body when the ice was melted.

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