3D microstructure of a matrix in primitive carbonaceous chondrite MIL 090657: aqueous alteration and aggregation

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MIL 090657 meteorite (CR2.7) is one of the primitive carbonaceous chondrites (CCs), which have received very small degrees of aqueous alteration and characteristically contain amorphous silicates [1]. So far, we realized that a matrix of this meteorite consists of three lithologies, L1, L2 and L3; L1 composed of submicron euhedral silicate grains, L2 mainly consisting of GEMS (glass with embedded metal and sulfide)-like materials, which is one of the main component of cometary dust, and L3 having hydrated silicates [2,3]. L2 contains abundant organic materials (also L1) and is considered as one of the most primitive materials in the solar system. The samples examined were ultra-microtomed sections of two grains of the meteorite ~100 μm in size. We further examined the cross section of the rest of the samples embedded in a resin (potted butt) using SEM. Based on the SEM results, house-shaped samples ~30 μm in size were extracted from the surface of the potted butt using FIB and imaged using SR-XCT. From the 3D structures, we found new three lithologies (L4, L5 and L6) in addition to lithologies similar to L1 and L2 (L1’ and L2’). However, TEM observation is necessary because of their very fine textures. In this study, we performed TEM observation of these lithogolies in addition to new XCT observation in order to (1) search for the most primitive lithology like L2 and (2) elucidate aqueous alteration and accretion processes of this meteorite.

We made a new CT sample and preformed imaging experiments of the samples including previous ones using SR-XCT at SPring-8 BL47XU. Mineral phases, voids, organic materials and densities were estimated from absorption and phase contrasts of CT images with the spatial resolution of ~100 nm. Ultra-thin sections were extracted from the CT samples and observed by TEM.

The lithology similar to L2 examined in this study (L2’) is mainly composed of amorphous silicates as well as L2 in the microtomed sections. However, L2’ is less abundant in organic materials and electron diffraction patterns of amorphous silicate and the presence of magnetite and carbonates show that L2’ are aqueously altered in some degree. GEMS-like materials in L2 have been aqueously altered; Fe-Ni metal nanoparticles were oxidized, amorphous silicates were hydrated and very poorly-crystallized hydrated silicates formed. We could not find most primitive lithology like L2 in this study. L5 is mainly composed of MgO-rich poorly-crystallized hydrated silicates and contains carbonates, framboidal magnetite and Ca phosphates. L6 are mainly composed of FeO-rich hydrated silicates. Both L5 and L6 have been aqueously altered. The chemical compositions of matrix of each lithology are different; Fe/Mg is smallest in L5 and highest in L6.

The boundaries among L2’, L5 and L6 are relatively distinct in TEM images. The triple junction of these lithologies forms as a line and the three lithologies are not piled up sequentially. Largely-elongated fragments of L2’ are present in L5 close to and almost parallel to the L2’-L5 boundary, suggesting L2’ flowed as grains during accretion of the two lithologies. Aqueously altered L5 should have relatively high degree of consolidation while less-altered L2’ should be less consolidated and had relatively large grain-fluidity. The L1-L2 boundary is relatively distinct in TEM images and the L1-L4 boundary can be distinguished with the resolution of ~1 μm in CT images.

The above results suggest that different lithologies with different degrees of aqueous alteration and consolidation were accreted together within a very small area ~100 μm in scale at least for the samples examined in this study. The parent body of MIL 090657 meteorites should have heterogeneous structures in a small scale.

[1] Davidson et al. (2015) 46th LPSC, 1603. [2] Cao et al. (2016) 47th LPSC,2427. [3] Sugimoto et al. (2016), Goldschmidt Workshop on Experimental Cosmochemistry, 15. [4] Sugimoto et al. (2017) JpGU, PPS10-P09.

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