Molecular and Isotope Analyses of Organic Matter in a Primitive Clast in the Zag H Chondrite

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The Zag meteorite is a halite-bearing H3-6 chondrite [1]. The Zag contains xenolithic clast with abundant organic matter which was proposed to be originated from Ceres [2,3]. Here we report coordinated organic analyses by STXM-XANES and NanoSIMS, in order to understand the nature and origin of the organic matter. Our systematic research of the Zag clast may also provide an important linkage to the recent remote sensing observations obtained by the DAWN mission to Ceres [e.g., 4,5].
Carbon-rich areas were located in the clast grains separated from the Zag meteorite with SEM-EDS, and then lift-out sections were prepared with a FIB instrument. C, N, O-X-ray absorption near-edge structure (C,N,O-XANES) spectra of the sections (~100 nm-thick) were obtained using scanning transmission X-ray microscopes (STXM) on beamline 5.3.2.2 at Advanced Light Source, Lawrence Berkeley National Laboratory, and BL-13A at the Photon Factory, KEK. Subsequently, H, C, N, O isotopic images were collected using a CAMECA NanoSIMS 50L ion microprobe.
The STXM elemental map of C-rich region of the Zag clast shows that sub-micrometer organic grains were scattered over the FIB section, some of which have a vein-like structure. The organic matter was somewhat associated with Fe (probably Fe-sulfides). The Fe (+Ni) and C association was also observed in the clasts in Sharps (H3.4) chondrite, suggesting a potential of catalytic gas-solid reactions such as Fischer-Tropsch type (FTT) synthesis [6,7].
C-XANES spectra of the organic grains showed large peaks at 285.2 eV assigned to aromatic carbon, and at 290.3 eV assigned to carbonate (either organic or inorganic), with some features at 287.4 eV (enol C=C-OH), and 287.9 eV (aliphatic), and 288.8 eV (carboxyl). The C-XANES spectra have some similarity with organic matter from Comet Wild 2, rather than with primitive chondritic IOM [8], except for the abundant carbonate in the Zag clast.
NanoSIMS isotope imaging analyses revealed that δ^{15}N and δD have highly heterogeneous distributions within the organic matter. The average δ^{15}N value was 393 ±82 ‰with a hot spot (2639 ±722 ‰), and the average δD value was 813 ±206 ‰with a hot spot (4,150 ±1,710 ‰). The δ^{15}N was similar to the value of insoluble organic matter (IOM) from Bells (an unusual CM chondrite) and CRs, although δD was less than these IOM [9]. It may indicate that some hydrogen have been exchanged with isotopically light water in the clast parent body.
Both molecular structure and isotopic signatures indicated highly pristine (less altered) nature of organic matter in the clast, and it may be related to cometary organics and/or primitive chondritic IOM.

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