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Finding of Nitrogen-rich Organic Material in Antarctic Ultracarbonaceous Micrometeorite

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Introduction:

Ultracarbonaceous micrometeorites (UCMMs), first discovered by Nakamura et al. (2005) [1], are unique extraterrestrial materials that represent large sizes of high carbon contents. The mineralogical and isotopic investigations of UCMMs by [2] have revealed the association of extreme D-rich organic matter with both crystalline and amorphous silicates, which appears to be compatible to cometary origin. However, there have been only two UCMMs reported so far, and little has been known about the nature of UCMMs. In this study, for an UCMM, which was found in ~200 MMs collected in 250 kg of the surface snow near the Dome Fuji Station, Antarctica, we have carried out the systematic studies applying isotope microscopy, focused ion beam (FIB) extraction, scanning transmission X-ray microscopy (STXM) and transmission electron microscopy (TEM) observation to study the origin and formation of UCMMs.

Experimental:

A polished thick section of a UCMM was used in this study. Isotope imaging of the UCMM was performed by a Hokudai isotope microscope system (Cameca ims-1270 SIMS with SCAPS). A Cs+ primary beam in an aperture illumination mode was used to achieve uniform secondary ion emission from a sample area. The normal incident electron gun was used to compensate for sample charging. A tungsten strap was deposited on the surface of the UCMM, and an FIB section with ~100 nm thickness was extracted from the UCMM by a JIB-4501 FIB-SEM microscope at Ibaraki Univ. C-, N-, and O- X-ray absorption near edge structure (XANES) spectra of the FIB section were acquired using STXM at the beamline 5.3.2.2., Advanced Light Source, Lawrence Berkeley National Laboratory.

Results and discussion:

The 12C14N and 32S distributions in carbonaceous matters from the UCMM show that the carbonaceous matter has the heterogeneously-distributed N- and S-rich signatures relative to the surrounding epoxy. The isotope-ratio images for hydrogen, carbon and nitrogen of the FIB section show that there is no significant difference in isotopic compositions of the UCMM from those of epoxy within analytical uncertainties (dD = ~ +100 per mil with a error of plus or minus 300 per mil, d13C = ~ 0 per mil with a error of plus or minus 70 per mil, d15N = ~ +100 per mil with a error of plus or minus 110 per mil).

A STXM carbon map shows that organic carbon is distributed all over the FIB section. Using a nitrogen map, organic N-rich and poor regions are identified, respectively. N-XANES spectra of N-rich regions exhibit intense peaks of imine, nitrile, and amide, while that of N-poor region shows a less characteristic spectrum. Aromatic C=C are likely assigned to pyridine in the N-rich regions, while that in the N-poor region is similar to those of typical chondritic and/or IDP organics [3].

The N-rich regions within a large range of the UCMM with a sufficient S/N has not been generally observed in chondritic organic matter and IDPs. It is noted that the N-XANES spectral patterns of the N-rich regions are very similar to those observed from the three samples of Comet 81P/Wild 2 dust particles, one of which was an organic globule [4, 5]. Nitrogen isotopic composition of the Comet Wild 2 organic globule is indistinguishable from terrestrial values [4], which is consistent to that in this study. In addition, that the N-rich and N-poor regions co-exist with a sharp boundary within the particle is intriguing. This may indicate that there exists more than one precursor for extraterrestrial organic matter. Further studies on the possible relationships of the UCMM with IDPs and meteorites from the comprehensive perspectives of mineralogy, isotope, and organic chemistry will be expected.

References:

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