

Detection of Soluble Organic Matter in Antarctic Micrometeorites

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Introduction: Earth is habitable even in the inner planetary region where volatiles are depleted, so that there should be sources and mechanism to supply them to earth. It has been revealed by the recent exploration of outer planets and comets that volatile components such as water and organics exist abundantly in the outer planetary region, where it is colder than in the inner planetary region. According to the researches, the existence of organic matter cannot be ignored for understanding the nature of small bodies in the outer planetary region (e.g., bodies in Edgeworth Kuiper Belt bodies or Oort Cloud). Antarctic MicroMeteorites (AMMs) are considered as those samples which should have been ejected from small solar system bodies such as asteroids and comets to interplanetary space and captured into the Earth [1]. The size of MMs is defined as less than 2 mm. The accretion rate of MMs reaching the Earth's surface has been estimated tens of thousand tons in the previous study, which is about ten times as much as the annual influx of meteorites to the Earth [2]. Since soluble organic matter (SOM) and insoluble organic matter (IOM) are present in the MMs, it is considered that MMs rather than meteorites dominantly contributed to the supply of volatile components to the inner planetary region where they were deficient [3].

In order to understand chemical characteristics of organics in AMMs, we are aiming for the detection of SOM in them. While it is difficult to determine the structure of IOM because they are Kerogen-like macromolecules, the structure of SOM can be determined. Therefore, it can be the key of elucidating the evolution of materials (chemical reaction) in the low temperature environment of the outer solar system specifically. In the previous study, samples collected from ice sheets of the Antarctica were collected by filtration, so that no molecular species were evidently identified to have originated from primitive MMs. [4, 5] In this study, ice blocks were sublimated as it was in order to prevent the leakage of SOM during sample collection.

Samples & Methods: About 330 g ice blocks were sublimated in a decompressed environment without melting it by using the ice sublimation apparatus in five times. The ice used in this study was collected from an iceberg around Ongul Island. The apparatus consists of a vacuum chamber with a sample holding jig and a dish for collecting sublimation residue set in the climate chamber. For identification of AMMs, the obtained residues were investigated using a JEOL JSM-6510LA scanning electron microscope equipped with an energy dispersive X-ray spectrometer (SEM-EDS) at Institute of Space and Astronautical Science (ISAS) at low vacuum mode (~50Pa) with 15kV in acceleration voltage. As a result, five particles composed of silicate minerals containing Mg and Fe were found. However, just three particles were available for the following analysis. The EDS spectrums of 3 samples (SI-AMM-P2, SI-AMM-P10, and SI-AMM-P16 (Table 1)) are shown in Figure 1. The composition of them was consistent with that of AMMs. The optical images showed that they seem to have partially melted spots. These three particles were pressed onto a gold plate fixed to the surface of an aluminum holder. In order to compare the results of them, two Murchison meteorites were prepared as well. In order to observe the distribution of organic substances in the particles, μ -Fourier transform infrared spectroscopic analysis was performed at ISAS using JASCO FT/IR-6100 + IRT-5000 with a ceramic IR light source, a germanium coated KBr beam splitter, a liquid-nitrogen-cooled mid-band Mercury-Cadmium-Telluride (MCT_M) detector, and $\times 16$ Cassegrain mirror. 5000. Reflection spectra were obtained through a square optical aperture $50 \times 50 \mu\text{m}^2$ with a spectral resolution of 4 cm^{-1} , in the wavenumber range of $4000\text{-}700 \text{ cm}^{-1}$. The IR absorption spectra of 512 scans were accumulated and then averaged over each sample. The background spectra were collected on each of the gold disks. The advantage of this measurement is that organic functional group information on the entire particle surface can be obtained non-destructively. These particles were subsequently analyzed by a desorption electrospray ionization coupled with orbitrap mass spectrometry (DESI-Orbitrap MS) at Kyushu University using Omni Spray Ion Source 2D produced by Prosofia coupled with Q-Exactive Plus produced by Thermo Scientific. The spray solvent was 100% methanol. The positive ions were collected in full scan mode (m/z 50.0-500.0) with mass resolution of 140,000 ($m/\Delta m$ at m/z 200). The negative ions were collected as well. Negative ions were not collected except for ones of SI-AMM-P2 because of time limitation.

Results & Discussion: The result of IR mapping measurement of the three particles showed that there was inhomogeneity in the intensity distribution of aliphatic C—H stretching ($\sim 2900 \text{ cm}^{-1}$) and C=O stretching ($\sim 1700 \text{ cm}^{-1}$) in those particles. DESI-Orbitrap MS detected a total of 49 ions from three particles. 20 ions could not be assigned with the combination of C, H, N, O, and Na. Although each particle partly had the same masses, the mass defect plots showed that each particle had completely

different feature. CHN compounds and CH₂ homologs were not detected in them. In previous studies, it was reported that many CHN compounds and their CH₂ homologues were identified in the methanol extraction fraction of Murchison meteorite. [6] The same trend was observed in the two Murchison meteorites. Thus, it was found that they had almost no ions consistent with Murchison meteorites. In the future, we will obtain clear evidence of AMMs and investigate the environment in which the particles exist through analysis of μ -Raman.

Table 1. List of samples

Sample	Initial major axis(μ m)	Initial minor axes(μ m)	Morphological feature
SI-AMM-P2	53.2	36.6	Rounded
SI-AMM-P10	73.1	30.9	Irregular
SI-AMM-P16	51.3	40.6	Sub-rounded

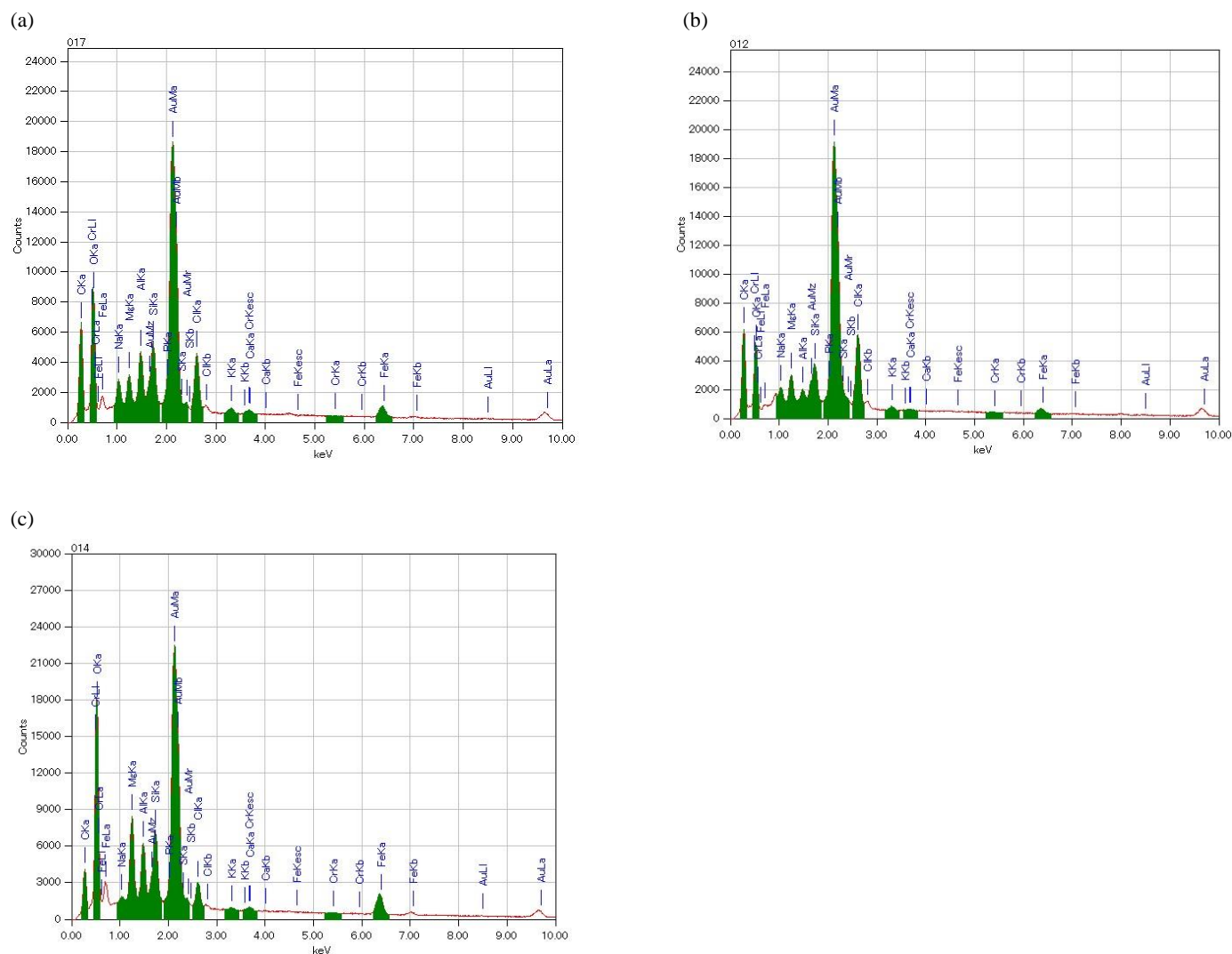


Figure 1. The EDS spectra of (a) SI-AMM-P2, (b) SI-AMM-P10, and (c) SI-AMM-P16. All of them show chondritic chemical compositions, which indicate they are Antarctic Micrometeorites.

References

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