Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS24-03 Room:106 Time:May 23 11:30-11:45

Isotopic compositions and morphology of isotopically anomalous organic matters in carbonaceous chondrites

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[INTRODUCTION] Organic matters with D- and ^{15}N-enrichment have been reported from carbonaceous chondrites. It has been considered that they have been produced in the cold molecular cloud and in outer solar nebula (e.g. Busemann et al., 2006, Hashiguchi et al., 2011), however, their origin and evolution are still unclear. Because insoluble organic matter (IOM) extracted from carbonaceous chondrites exhibited heterogeneous hydrogen (H) and nitrogen (N) isotopic composition (Busemann et al., 2006), the chondritic organic matters seem to have various origin or evolution. Therefore, characterization of the individual isotopically anomalous organic matters is important. Our previous study reported various morphologies of D-rich organic matters in a carbonaceous chondrite (Hashiguchi et al., 2011). The morphology may record the history of chondritic organic matters.

CR2 and CM2 chondrites have experienced some degree of aqueous alteration on the parent body (Brearley, 2006). Chemical or isotopic evolution of chondritic organic matters may record in the CM2 and CR2 chondrite. In this study, we report H and N isotopic compositions and morphology of isotopically anomalous organic matters in CR2 and CM2 chondrites found by in-situ analysis.

[EXPERIMENTAL] Polished thin sections of Murchison (CM2) and Northwest Africa (NWA) 801 (CR2) were used in this study. H and N isotopes were measured by in situ isotope ratio imaging (isotopography) using isotope microscope system (Cameca ims-1270 + SCAPS) (Yurimoto et al., 2003). Isotopically anomalous spots were located and observed by FE-SEM-EDS system (JEOL JSM- 7000F, Oxford INCA Energy).

[RESULTS] Total of 28 isotopically anomalous carbonaceous spots were found in isotopographs of 0.04 mm^2 and 0.08 mm^2 for Murchison and NWA 801, respectively. Maximum of the D- and ^{15}N-enrichments were 7,920 permil in delta-D and 2,620 permil in delta-^{15}N, respectively. Larger D-enrichments are not associated with larger ^{15}N-enrichments in a carbonaceous spot. Most of the isotopically anomalous carbonaceous spots found in Murchison were enriched in ^{15}N, whereas fraction of D-rich and ^{15}N-rich carbonaceous spots in NWA 801 are comparable. These carbonaceous spots are single or aggregated globules. They showed no clear correlation between the morphology and the H and N isotopic compositions.

[DISCUSSIONS] D- and ^{15}N-enrichment and association of H and N components suggest that the isotopically anomalous carbonaceous spots are corresponding to organic matters. The decoupled D- and ^{15}N-enrichment suggests the isotopically anomalous organic matters are attributed to multiple isotopic fractionations in molecular cloud or in outer solar nebula including ion-molecule reaction (Millar et al., 1989; Rodgers and Charnley 2008), grain-surface reaction (Watanabe and Kouchi 2008), and self-shielding effects (Le Petit et al., 2002; Lyons et al., 2009).

It is suggested that aqueous alteration process decreases D/H ratio of organic matters in carbonaceous chondrites (Herd et al., 2011). Degree of aqueous alteration of typical CM2 chondrite would be larger relative to CR2 chondrite (Brearley, 2006). Therefore, less abundant D-rich organic matters in Murchison may be result from loss of isotopically heavy H by aqueous alteration.

Single or aggregated organic globules with D- and/or ^{15}N-enrichments in carbonaceous chondrites also were observed by previous studies (Nakamura-Messenger et al., 2006; Hashiguchi et al., 2011), suggesting that they were ubiquitous in early solar nebula. Although H isotopic compositions seemed to be affected by aqueous alteration, no clear correlation with the isotopic compositions and morphology. This result may suggest that organic matters with various morphology and/or various isotopic compositions have been formed in molecular cloud and/or in outer solar nebula.

Keywords: Chondritic organic matters, Carbonaceous chondrites, Isotopic composition, Morphology, Isotope imaging