P084-P001 Time: May 27 17:15-18:45

Survey of matrix materials from CR chondrite using isotope imaging ~in situ discovery of objects with heavy carbon~

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Primitive meteorites contain grains of stardust that originated from stellar outflows and supernova ejecta prior to the formation of the Solar System. Grains whose isotopically anomalous compositions indicate a stellar origin include diamond, silicon carbide, graphite, colundum..

Some meteorites and interplanetary dust particles (IDPs) exhibit large excesses in deuterium and/or 15N. These anomalies represent the partial preservation of materials that experienced extreme chemical mass fractionation in the cold, dense molecular cloud predating our Solar System. The largest D/H ratios observed so far in extraterrestrial materials occur in IDPs, reaching the values of some molecules in interstellar molecular clouds (Messenger, 2000).

Since studies about presolar grains were limited to highly refractory phases from acid residue, it is feasible to detect other phases, which is easily destroyed during chemical isolation process, with isotope anomalies. Also, it is unsolved problem what are carriers with molecular cloud materials. In this study, isotope imaging survey is applied to meteoritic thin section in order to discover anomalous objects isotopically.

In this study, polished thin section of CR2 chondrite NWA-530 is used. Some CR chondrite reveals large D excess (Guan et al., 1997) and 15N excess (Ash et al., 1993). Polished thin section was analyzed using scanning electron microscopy (SEM). Back scattered electron (BSE) images and elemental compositional map obtained by energy dispersive spectrometer (EDS) provide information of matrix objects.

Isotope imaging technique was developed by Kunihiro et al.(2001) and Yurimoto et al.(2003). Isotope imaging technique composed by stacked CMOS active pixel sensor (SCAPS) and secondary ion mass spectrometry (SIMS). Isotope imaging technique can provide us isotopic information of more than 10000 grains within analyzed area simultaneously. In order to achieve uniform secondary ion beam emission from the imaging area, rastered Cs+ primary beam with 20 keV was irradiated on 90 micron x 90 micron sample surface. A normal incident electron gun was used for charge compensation of the rastered area. Secondary ion images were acquired 12C-, 13C-, 16O-, 18O-, 27Al-, 28Si-, and 30Si-. Images of 12C, 16O, and 28Si were acquired repeatedly before and after images of 13C, 18O, and 30Si, respectively because of correction of signal fluctuation with sputtering. Isotope images were obtained by dividing each secondary image.

40 isotope images of carbon, oxygen, and silicon were obtained. Isotope images contain matrix objects, fragments of chondrules, refractory inclusions, and dark inclusions. Spatial resolution of isotope image was 2~3 microns. Precision was 4%, 1%, and 2% for carbon, oxygen, and silicon isotopes, respectively. Correction of instrumental mass fractionation and matrix effect were not done in this study, because purpose of this study is discovery of large anomalous objects isotopically. Values of isotope ratio is represented by delta value relative to average value of matrix area.

Oxygen isotope images revealed existence of a few micron olivine with 16O-rich composition (d18O=-40permil). The results is similar to oxygen isotope study of matrix from Vigarano meteorite (Kunihiro et al., 2002). However objects with large isotopic anomalies were not detected. Silicon isotope images show homogeneous isotope distribution within analytical error. Carbon isotope images reveal existence of objects with 13C rich composition. One grains within dark inclusion have large heavy carbon (d13C=+3800permil). The grain is considered to be graphite from investigation using SEM and intensity of secondary carbon ion. Other 5 objects also have heavy carbon (d13C=+300 ~ +1000permil). These phases could not be identified due to its very small sizes. In order to identify these phases and origin, hydrogen and nitrogen isotopic composition will be needed.