NITROGEN ISOTOPE ANOMALY OF IMPACT MELTS IN THE ISYEYEVO CHONDRITE.

N. Sakamoto, Hokkaido University (N21W10 Kita-ku, Sapporo, Japan, naoya@cris.hokudai.ac.jp).

Introduction: Nitrogen isotopes in metal-rich carbonaceous chondrites are known to exhibit a wide range of bulk $\delta^{15}N$ values, exceeding 1000‰ [1]. In situ SIMS analysis have revealed that nitrogen is located around sulfides in metal clasts and in impact-melt areas [2]. Subsequent studies identified ^{15}N-enriched chondritic clasts and carbonaceous materials within lithic clasts, which have been proposed as carriers of the nitrogen isotope anomaly [3,4]. However, bulk measurements indicate that the anomaly is more pronounced in metal than in silicate clasts [1], and the anomalous lithic clasts constitute only a small volume fraction. In this study, we performed nitrogen isotope imaging using a stigmatic large-geometry SIMS to investigate ^{15}N-enriched materials in the Isheyevo CH/CB_b chondrite.

Experimental: Thick sections of the Isheyevo chondrite were polished and coated with a 10 nm layer of gold. Petrographic observations were conducted using SEM-EDS, and isotopic analyses were performed using a CAMECA ims-1270e7 equipped with a SCAPS ion imager at Hokkaido University. A 15 nA Cs^+ primary ion beam illuminated 100 µm × 100 µm areas under Köhler illumination. Sputtered secondary ions—$^{1}H^-$, $^{2}D^-$, $^{12}C^-$, $^{13}C^-$, $^{12}C^{14}N^-$, $^{12}C^{15}N^-$, $^{16}O^-$, $^{18}O^-$, and $^{30}Si^-$—were mass-separated by a large-radius magnetic sector. Non-nitrogen isotopes were measured only in selected areas. The exit slit was narrowed to exclude interfering ions such as $^{11}B^{16}O^-$ for $^{12}C^{15}N^-$ ($M/\Delta M$ = 6570). Selected ions were quantitatively imaged using the SCAPS detector.

Results: Analysis of over 100 areas yielded the following results: (1) Lithic clasts exhibit high $\delta^{15}N$ values specific to each clast, with intra-clast variation (e.g., a clast with a $\delta^{15}N$ value of 400‰ contains relatively homogeneous subregions of 600‰, and tiny hotspots reaching several thousand per mil); (2) Impact melts show $\delta^{15}N$ values of 1000–1800‰, mostly near 1300‰; (3) Glassy veins also exhibit high $\delta^{15}N$ values similar to impact melts, though altered regions show lower $\delta^{15}N$; (4) A limited number of Ni-rich metal domains show $\delta^{15}N$ values comparable to those in impact melts; (5) In contrast, hydrogen, carbon, and oxygen isotopes show no significant anomalies.

Discussion: The Isheyevo meteorite exhibits a high bulk nitrogen isotopic composition ($\delta^{15}N$ = +1122‰) [5]. Excluding localized hotspots, the highest $\delta^{15}N$ values are found in impact melts, which are ubiquitously distributed throughout the meteorite. In contrast, most lithic clasts exhibit lower $\delta^{15}N$ values, close to those of silicate clasts reported in [1]. Moreover, based on CN^- detection, no other significant nitrogen-rich phases have been identified so far in this study. Therefore, the ^{15}N-rich nitrogen identified in the impact melts is likely to correspond to the nitrogen residing within Fe,Ni metal or a more labile phase shielded by Fe,Ni metal, as suggested by [5].

Possible mechanisms for the incorporation of ^{15}N-rich nitrogen into impact melts include: (1) melting of nearby nitrogen-bearing phases, (2) isotopic fractionation during impact, and (3) trapping of ambient gas. Although impact melts occur at metal–lithic clast boundaries, their higher $\delta^{15}N$ values suggest they are not derived from the lithic clasts having lower $\delta^{15}N$. If fractionation occurred, hydrogen or other isotope anomalies should also be present, which were not observed. If gas was trapped in metal during impact, it must have been enriched in ^{15}N.

If impact melts are the primary carriers of high $\delta^{15}N$ in Isheyevo and in other metal-rich carbonaceous chondrites exhibiting similarly elevated values, this suggests that ^{15}N-rich gas may have existed in their formation regions. Nitrogen in the Isheyevo impact melts shows a $\delta^{15}N$ value similar to that detected in cometary NH_3 [6]. The fact that the Sun has the lightest nitrogen isotopes among solar system materials [7], and that ammonia can exist in both gas and ice phases, is somewhat reminiscent of the oxygen isotope anomaly [8]. As with presolar grains in the case of oxygen, small carbonaceous materials may give the appearance of complexity in the nitrogen isotope record; however, isotopic anomalies shared across multiple meteorites might be better interpreted within a similar context to that used for oxygen. If so, the nitrogen isotope anomaly could be explained by the mixing of heavy NH_3 and the Sun.

References: [1] Prombo C.A. and Clayton R.N. (1985) *Science*, 230:935-937. [2] Sugiura N. et al. (2000) *Meteoritics & Planetary Science*, 35:987–996. [3] Sugiura N. and Zashu S. (2001) *Meteoritics & Planetary Science*, 36:515–524. [4] Bonal L. et al. (2010) *Geochimica et Cosmochimica Acta*, 74:6590–6609. [5] Ivanova M. et al. (2008) *Meteoritics & Planetary Science*, 43:915–940. [6] Rousselot P. et al. (2014) *The Astrophysical Journal Letters*, 780:L17. [7] Marty B. et al. (2011) *Science*, 332:1533-1536. [8] Sakamoto N. et al. (2007) *Science*, 317:231–233.