Helium isotope imaging for CM chondrites

Tomoya Obase[1], *KEN-ICHI BAJO[1], Hisayoshi Yurimoto[1]

1. Department of Earth and Planetary Sciences, Hokkaido University

Noble gases derived from solar wind implantation are preserved in meteorites known as solar-gas-rich meteorites. Approximately twenty percent of CM chondrites contain solar wind noble gases [1–3], and they might have been exposed to the ancient solar wind. The compaction ages of Murchison and Nogoya have been estimated to be 4.2 and 4.4 billion years (Gyr), respectively, based on the ^{244}Pu fission track density analysis of isolated olivine grains in the fine-grained matrix [4]. Thus, the solar wind noble gases in the two chondrites were obtained prior to the final compaction at 4.2–4.4 Gyr ago. The ancient solar wind tells us about the activity of the young Sun. The distribution of solar wind noble gases in meteorites is the result of brecciation and regolith formation processes on the parent body. Brecciation processes have caused a redistribution of noble gases due to mechanical mixing of rocks from different locations in a parent body. In this study, we used polished sections of the Murchison and Nogoya CM chondrites to investigate the ^{4}He distribution with 1 μm lateral resolution using LIMAS [5] because the clastic matrices of Murchison and Nogoya preserve large amounts of solar wind noble gases [6].

The primary beam current of LIMAS for ^{4}He ion imaging (He-imaging) was 30 nA with a beam diameter of ~1.5 μm. Mass resolving power was set at 26,000 at m/z 4 to separate ^{4}He and ^{20}Ne from interference ions. Imaging size was 100 ×126 pixels in a 100 μm ×100 μm area. To convert the ion intensities obtained from He-imaging to He concentrations, depth profiling of ^{4}He implanted (20 keV, 2 ×10^{15} cm^{-2}) olivine was performed as a standard. Under these conditions, the detection limit for ^{4}He was ~3 ×10^{19} cm^{-3}.

We analyzed different five areas of Nogoya and ten areas of Murchison. The He-imaging shows that regions with a detectable concentration of ^{4}He (>3 ×10^{19} cm^{-3}) are very rare. We have found a particle with high ^{4}He concentration embedded in the matrix of Nogoya. After He-imaging, scanning electron microscopy observation with energy dispersive X-ray microscopy shows that the particle is chromianspinel. Subsequently, high resolution He-imaging at ~200 nm of 1 nA shows that the particle is enriched in ^{4}He of 2 ×10^{21} cm^{-3} at the outer edge. Assuming that this particle is a fragment of a chondrule [7], the particle was fractured in the parent body after chondrule formation, acquired solar wind in the process of brecciation, and finally underwent rock formation by compaction. The distribution of He can reveal the process of solar wind acquisition from the young Sun and subsequent incorporation into the parent body that occurred in the early solar system.

References: [1] Black (1972) Geochem. Cosmochem. Acta, 36, 377. [2] Smith et al. (1978) Earth Planet. Sci. Lett., 39, 1. [3] Krietsch et al. (2021) Geochem. Cosmochem. Acta, 310, 240. [4] Macdougall and Kothari, (1976) Earth Planet. Sci. Lett., 33, 36. [5] Bajo et al. (2024) under review. [6] Nakamura et al. (1999) Geochem. Cosmochem. Acta, 63, 241. [7] Brealey and Jones (1998) Rev. Mineral., 39, pp 3-1–3-398.

Keywords: SIMS, Noble gas, Isotope imaging

