

コンドライト隕石の¹⁴²Nd同位体異常の再検討 ¹⁴²Nd isotope anomaly in chondrite revisited

横山 哲也^{1*}, 高橋 宏和¹, 山崎 洋¹
Tetsuya Yokoyama^{1*}, Hirokazu Takahashi¹, Hiroshi Yamazaki¹

¹ 東京工業大学地球惑星科学専攻

¹Department of Earth and Planetary Sciences, Tokyo Institute of Technology

A variety of isotope anomalies have been documented in chondrites and differentiated meteorites for some elements such as Cr, Ti, Mo and Ru, suggesting heterogeneous isotope distribution in the early Solar System. For Nd, chondrites are known to have ¹⁴²Nd/¹⁴⁴Nd ratios 20 ppm lower than terrestrial materials. The finding most likely suggests the occurrence of large scale silicate differentiation that fractionated Sm-Nd in early history of the Earth when short-lived ¹⁴⁶Sm existed. However, most of the Nd isotope data in chondrites were determined by incomplete sample digestion which could not dissolve acid resistant, isotopically anomalous presolar grains. Thus, the origin of ¹⁴²Nd/¹⁴⁴Nd anomalies in chondrites is still debated.

To resolve this issue, we have developed a new method for determining Nd isotope ratios in meteorites with ultra-high precision using thermal ionization mass spectrometry (TIMS: TRITON plus at Tokyo Tech), coupled with complete sample decomposition technique using a pressure digestion system (DAB-2, Berghof, Germany). Meteorite samples were put in Teflon inserts together with a mixture of HF, HNO₃ and H₂SO₄. The insert was placed in a stainless jacket, tightly sealed and heated at 240 °C for 12 hours under high pressure. The existence of H₂SO₄ facilitates digestion of acid resistant presolar SiC. Subsequently, the insert was opened and dried at 120 °C for 12 hours to evaporate HF and HNO₃. Then the solution was transferred to a quartz glass beaker and completely dried at 300 °C. The dried sample was dissolved in 1M HCl and passed through cation exchange resin and Ln spec to isolate Nd. The separation efficiency was Ce/Nd < 2.1x10⁻⁴ and Sm/Nd < 1.0x10⁻⁹, respectively. In the TIMS analysis, we have modified three points; chemical form of sample loaded on filament, temperature control of filaments and determination of Ce interference. The improved method increased ¹⁴²Nd⁺ beam intensity from 2 V to 20 V, resulting in an excellent analytical precision of ¹⁴²Nd/¹⁴⁴Nd (2 ppm, 2SD) for repeated analysis of 500 ng of JNdi-1.

Using the techniques, we determined Nd isotope compositions in four chondrites; Murchison (CM2), Saratov (L4), Chergach (H5) and NWA4814 (R4), as well as terrestrial samples. These chondrites have ¹⁴²Nd/¹⁴⁴Nd ratios of 23 +/- 3ppm lower than the terrestrial samples, although the ¹⁴⁵Nd/¹⁴⁴Nd, ¹⁴⁸Nd/¹⁴⁴Nd and ¹⁵⁰Nd/¹⁴⁴Nd ratios were not resolvable from the terrestrial. This indicates that Nd isotopes were homogeneously distributed in the early Solar System, and the deficit of ¹⁴²Nd/¹⁴⁴Nd is the result of the ¹⁴⁶Sm decay in the depleted mantle produced by silicate differentiation in the early Earth. Our result supports the existence of enriched hidden reservoir whose chemical composition is complementary with depleted mantle that formed early history of the Earth while ¹⁴⁶Sm existed.

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