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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

In Chapter 1, we review the background of (i) nucleosynthesis for trans-iron elements, (ii) carrier grains of trans-iron elements that contributed to the Solar System, and (iii) nucleosynthetic isotope anomalies observed in meteorites.

In Chapter 2, we have developed a technique that enables high-precision Nd isotopic analysis with thermal ionization mass spectrometry (TIMS) to detect nucleosynthetic isotope variability in whole-rock meteorites. To achieve high-precision analysis, we investigated the long-term fluctuation in high-precision Nd isotope measurements. Comprehensive measurements of a standard material JNdi-1 (n = 76) were conducted by applying three distinct methods (static, dynamic, and multistatic) during an eight-month analytical period. We found the dynamic method the most effective to minimize the influence of Faraday cup degradation, although a marginal isotopic shift was observed even for data obtained by the dynamic method throughout the entire analytical period. Our dynamic method allows to determine ^{142}Nd/^{144}Nd, ^{148}Nd/^{144}Nd, and ^{150}Nd/^{144}Nd ratios simultaneously. The reproducibilities of ^{142}Nd/^{144}Nd, ^{148}Nd/^{144}Nd, and ^{150}Nd/^{144}Nd ratios were ±4.1, ±6.3 and ±8.8 ppm (2 SDs), respectively, which are 1.5–4.1 times better than those obtained in previous studies.

In Chapter 3, we further investigated the secondary instrumental fractionation in TIMS instrument, which cannot be ignored in the extraordinary high-precision Nd isotope measurements. We performed multiple Nd isotope measurements (n = 125) for a standard material JNdi-1 with the dynamic method. We found small but resolvable fluctuations in the obtained ^{142}Nd/^{144}Nd, ^{148}Nd/^{144}Nd, and ^{150}Nd/^{144}Nd ratios of JNdi-1 that cannot be eliminated by the normal mass fractionation correction using the ^{146}Nd/^{144}Nd ratio, most likely due to the secondary instrumental fractionation induced by the accumulation of materials (e.g., H_3PO_4 activator) emitted from measured samples onto the surface of ion lens assemblage. The secondary instrumental fractionation observed in the ^{142}Nd/^{144}Nd ratio can be corrected using the simultaneously measured ^{150}Nd/^{144}Nd ratio. After the second-order correction, the reproducibilities of ^{142}Nd/^{144}Nd ratio have been improved from ±5.6 ppm to ±4.2 ppm (2 SD).

In Chapter 4, we present high-precision Nd isotope compositions for whole-rock ordinary and carbonaceous chondrites determined with our method described in Chapters 2 and 3. The ordinary chondrites had uniform and non-terrestrial μ^{142}Nd, μ^{148}Nd, and μ^{150}Nd values, with data that plot along the mixing line between *s*-process endmember and terrestrial components in μ^{150}Nd versus μ^{148}Nd, μ^{142}Nd versus μ^{148}Nd, and μ^{142}Nd versus μ^{150}Nd diagrams. In contrast, the carbonaceous chondrites were characterized by larger anomalies in their μ^{142}Nd, μ^{148}Nd, and μ^{150}Nd values compared to

ordinary chondrites. Importantly, the data for carbonaceous chondrites plot along the *s*-process and terrestrial mixing line in a μ^{150}Nd versus μ^{148}Nd diagram, whereas they have systematically lower μ^{142}Nd values than the *s*-process and terrestrial mixing line in μ^{142}Nd versus μ^{148}Nd and μ^{142}Nd versus μ^{150}Nd diagrams. This shift likely results from the incorporation of calcium- and aluminum-rich inclusions (CAIs), indicating that the Nd isotopic variability in the ordinary and CAI-subtracted carbonaceous chondrites was caused solely by the heterogeneous distribution of *s*-process nuclides. The Nd isotope dichotomy between bulk aliquots of ordinary and carbonaceous chondrites can be related to the presence of Jupiter, which may have separated two isotopically distinct reservoirs that were present in the solar nebula. After correcting for *s*-process anomalies and CAI contributions to the Nd isotopes observed in the chondrites, we obtained a μ^{142}Nd value (−2.4 ± 4.8 ppm) that was indistinguishable from the terrestrial value. Our results corroborate the interpretation that a missing reservoir (e.g., a hidden enriched mantle reservoir, erosional loss of crust) is not required to explain the observed differences in ^{142}Nd/^{144}Nd ratios between chondrites and terrestrial materials.

In Chapter 5, we conducted high-precision Sr and Nd isotopic measurements for bulk aliquots of chondrites by applying a complete sample digestion technique. Our new high-precision data indicate that enstatite and ordinary chondrites possess uniform and small, but resolvable, Sr and Nd isotopic deviations from terrestrial rocks. In contrast, we found Sr isotopic variations across different classes of carbonaceous chondrites (CM, CO, and CV), of which the data points deviate from the *s*-process mixing line in the Sr–Nd isotopic space. This shift likely resulted from the incorporation of CAIs into carbonaceous chondrite parent bodies. The planetary-scale Sr and Nd isotopic heterogeneities among terrestrial rocks, enstatite, ordinary, and CAI-subtracted carbonaceous chondrites point to the heterogeneous distribution of *s*-process enriched materials in the early Solar System, which was most likely caused by the global nebular thermal processing. On the other hand, the Sr and Nd isotopic variation observed across CAI-subtracted carbonaceous chondrites cannot be explained solely by the nebular thermal processing. Rather, this isotopic variation was caused by the involvement of *s*-process-depleted silicate grains that repeatedly circulated in the early Solar System, which were transferred and incorporated at varying degrees into the region where parent bodies of individual carbonaceous chondrites have formed. On the other hand, Sr and Nd isotopic compositions for CI chondrites were not explained by this disk evolutionary model, most likely due to the injection of supernovae materials and/or input of materials from the molecular cloud.

In Chapter 6, we introduce the future perspective on the issues that have been discussed in the previous chapters of this thesis.