

4-7 Rapid and Reliable Analysis of Impurities in Uranium Ore

— Mass Spectrometric Characterization of Impurities Based on Solid Sample Introduction —

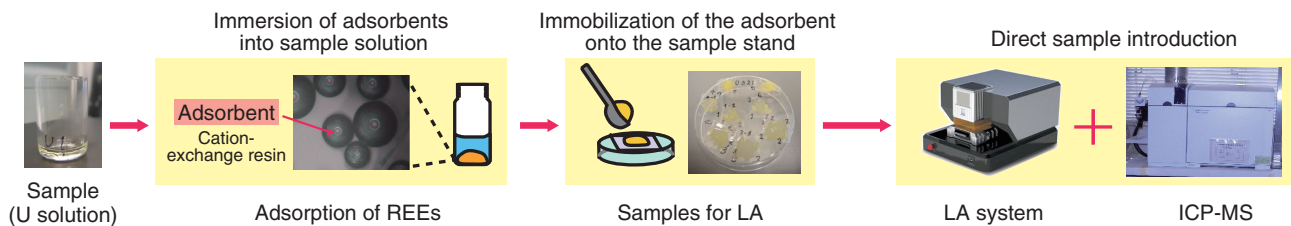


Fig.4-18 Simplified sample preparation achieved by laser ablation technology for ultratrace analysis of rare earth elements

ICP-MS is commonly used for the determination of trace amounts of REEs. Liquid sample introduction, which is typical in ICP-MS analysis, involves a cumbersome dissolving process before measurement. In the proposed method, direct introduction of samples via an LA system achieves the rapid analysis of REEs.

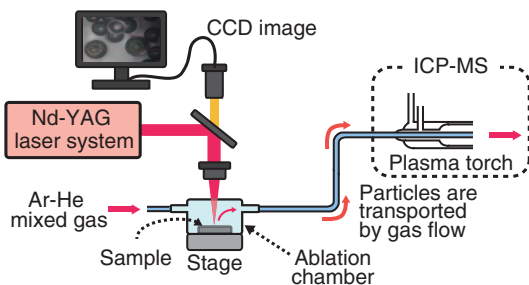


Fig.4-19 Basic principle of the LA system

Particles generated by ablating the sample surface are effectively transported to a plasma torch by an Ar-He mixed gas flow, which leads to the direct measurement of solid samples.

Rare earth elements (REEs) comprising Sc, Y, and 15 lanthanides behave as a coherent group over geological and industrial processes, showing a distinctive pattern unique to their origin. The REE patterns found in uranium (U) ores and their refined products can be a reliable indicator of the origin attribution of U. This is a remarkable property in terms of the regulation of nuclear materials. In this study, a rapid and reliable analytical technique based on inductively coupled plasma mass spectrometry (ICP-MS) combined with a solid sample introduction system was developed for obtaining REE patterns.

ICP-MS has been a promising technique for determination of ultratrace amounts of REEs. However, interferences caused by isobars and molecular ions that have the same mass-to-charge ratio as a target isotope can be a definite factor in misleading measured values. In the determination of REEs, barium (Ba) may cause interferences by forming several barium oxides (e.g., $^{135}\text{Ba}^{16}\text{O}$ to ^{151}Eu) within the plasma. The formation of such oxides is effectively attenuated by the direct introduction of a solid sample using laser ablation (LA) technology. Liquid sample introduction, which is typical in

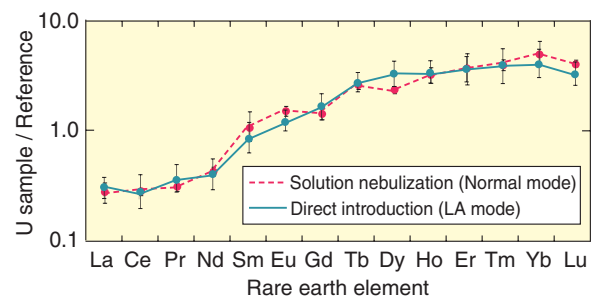


Fig.4-20 REE pattern obtained by laser ablation ICP-MS

The REE pattern obtained through LA-ICP-MS analysis of the U sample exhibited close agreement with that obtained through the nebulization ICP-MS of the REE-purified solution.

ICP-MS analysis, may induce the formation of oxides in the plasma. Ba in the sample solution can be combined with ^{16}O of H_2O molecules in an aqueous solution. In the developed method, ultratrace levels of the REE in a U-bearing sample solution (U standard solution) were adsorbed into cation-exchange resin particles to concentrate the REE into a solid phase and to remove U along with other coexisting elements. Then, the REEs adsorbed in the resin particles were directly measured with LA-ICP-MS, resulting in an efficient and interference-free measurement (Fig.4-18). In the LA mode, fine particles generated by evaporating the sample surface were efficiently transported by an Argon (Ar)-Helium (He) mixed gas flow (Fig.4-19). The REE pattern obtained through LA-ICP-MS analysis of the U-bearing sample agreed within uncertainty with that obtained through the conventional technique based on the nebulization of the REE-purified solution (Fig.4-20).

The developed method is applicable to the fingerprinting of nuclear materials, or nuclear forensic analysis, providing practical information for specifying interdicted nuclear materials.

Reference

Asai, S. et al., LA-ICP-MS of Rare Earth Elements Concentrated in Cation-Exchange Resin Particles for Origin Attribution of Uranium Ore Concentrate, *Talanta*, vol.135, 2015, p.41-49.