Development of Laser Post-Ionization Secondary Neutral Mass Spectrometer for in-situ U-Pb chronology

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In space and planetary sciences, Secondary Ion Mass Spectrometers (SIMS) with an ion micro-beam has been widely used for in-situ isotopic analyses of micron scale samples [1]. In the SIMS analysis, the surface of the sample is irradiated by a primary ion beam, and among the sputtered materials, secondary ions are introduced into the mass spectrometer. One of the disadvantage of the SIMS is that the secondary ion yield is low (less than a few %), and a large fraction of the sputtered samples are lost as neutrals without being analyzed, which makes it difficult to carry out trace element analyses with a sub-micron spatial resolution due to the severely low ion counting statistics.

In order to improve this disadvantage, we have carried out the post-ionization of the secondary neutrals with a femtosecond laser [2]. By irradiating the high power laser above 10^{15} W/cm^2, 100% of the sputtered atoms and molecules can be ionized. In addition, in the high electromagnetic fields, all kinds of species are ionized, regardless of ionization potential, through the non-resonant ionization regime and can be analyzed simultaneously by using the time of flight (ToF) mass spectrometer.

The multi-turn time of flight secondary neutral mass spectrometer (MULTUM-SNMS) has been developed in Osaka University [3]. This instrument consists of a focused ion beam with a liquid metal gallium ion source, a femtosecond laser and multi-turn ToF mass spectrometer. The sample is sputtered with a 30 keV Ga^+ ion beam which can be focused to a spot diameter of 40 nm and maximum current density is 30 A/cm^2. The ejected neutrals are irradiated with the femtosecond laser, and the post-ionized ions are introduced into the multi-turn ToF analyzer (MULTUM), the ion optical system of which achieves an ultra high mass resolving power of 250000 [4].

The performance evaluation of MULTUM-SNMS has conducted with a lead plate sample. It was demonstrated that the post-ionization with the femtosecond laser can make the Pb+ secondary yield about 10000 times higher. In addition, a mass resolution greater than 12000 is achieved utilizing MULTUM ion optics. Toward the application to U-Pb chronology, 91500 zircons which contain around 100 ppm uranium and used as a standard specimen of zircon U-Pb chronology was measured using MULTUM-SNMS. From a sputtered area of around 1 um in diameter, U^+, UO^+ and UO_2^+ signal peaks were detected. In this presentation, we will also report the lead isotope ratio of the same specimen and discuss the feasibility of sub-micron scale in-situ U-Pb chronology with MULTUM-SNMS.

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