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The evaluation for ion trajectory and transmittance of Laser Ionization MAss nanoScope (LIMAS)

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In analyses of interstellar materials in meteorites, target material sizes are generally smaller than 100 nm. Therefore, analytical method with high sensitivity and a high mass resolution is required for sub-microscale in-situ analysis.

We have developed a tunnel ionization time of flight sputtered neutral mass spectrometer: LIMAS. This apparatus mainly consists of a focused ion beam system (Ga-FIB), a femtosecond (fs) laser system and a MULti-TUrn time-of-flight Mass spectrometer II (MULTUM II) (Ebata et al., 2012).

The fs laser is used for tunnel ionization of neutral particles that are sputtered by the Ga-FIB beam. Because the energy density of the fs laser is more than 2 x 10^{15} W/cm^2, all of elements can be ionized.

Based on the ion optics of MULTUM II, time of flight of the ion can be infinitely extended to get high mass resolution.

In this study, we operated voltages of einzel lenses and deflectors in an ion injection optics based on the result of an ion optics simulation using SIMION. A parameter setting of MULTUM II was based on (Okumura., 2005). As a result, we evaluated mass resolving power and the transmittance of fs laser induced ions in the MULTUM II.

Sample surface was kept on ground state, and the acceleration voltage was fixed at -4 kV. The voltages of the ion injection optics and MULTUM II were floated on -4 kV. Then, post-ionized positive ions were injected into MULTUM II. The ion injection optics consists of three stage injection and acceleration lens, two einzel lenses, and two sets of two direction deflectors. The ˜30% of ions were injected into MULTUM II from the result of the ion simulation. We operated parameters in the ion injection optics for an ion was focused on a cycle starting focal point in MULTUM II. Focal point in ion injection optics of ion trajectory moves to sample position side to become a large aperture angle by the high electrode voltage of injection lenses. The focal point in MULTUM II was determined by the aperture angle and voltage of the einzel lenses.

The above eight parameters were changed and adjusted based on the result of the ion simulation. Toroidal fields in MULTUM II were optimized by operating electrical potential valance among the fields.

After the optimize of the electrode voltages, we obtained the mass resolving power of more than 27,000 ($^{24}Mg^+$, number of cycle: 100 cycles in MULTUM II) without laser (SIMS mode), and of more than 40000 ($^{24}Mg^+$, number of cycle: 100 cycles) with laser (SNMS mode). The ion transmittance in MULTUM II was evaluated. Relationships of the ion transmittance of MULTUM II with the number of cycles are as follows. Assuming that the ion intensity of linear mode (from sample surface to the detector) is 100%, the ion transmittances at 20 cycles are 28% and 5% for SIMS and SNMS modes, respectively. The transmittances of 100 cycles are 26% and 2% for SIMS and SNMS modes, respectively. The decreasing of the intensity can be explained by two factors. One is that the half of the injected ions cannot meet a condition of the ion trajectory of MULTUM II. Another is ion collision with residual gas molecules in MULTUM II.

Keywords: TOF-MS, SNMS, fs-laser