LIMAS: TUNNEL-IONIZATION TIME-OF-FLIGHT SPUTTERED NEUTRAL MASS SPECTROMETER. Hisayoshi Yurimoto[1], Ken-ichi Bajo[1], Satoru Itose[2], Miyuki Matsuya[2], Morio Ishihara[3], Kiichiro Uchino[4] and Masato Kudo[2], [1]Department of Natural History Sciences, Hokkaido University, IIL, Sapporo 001-0021, Japan (yuri@ep.sci.hokudai.ac.jp), [2]JEOL Ltd., Musashino, Akishima, Tokyo 196-8558, Japan, [3]Department of Physics, Osaka University, Toyonaka 560-0043, Japan, [4]Graduate School of Engineering Sciences, Kyushu University, Kasuga 816-8580, Japan.

Introduction: Secondary ion mass spectrometry (SIMS) is considered to be an extremely sensitive, micro-area analytical technique of solid surfaces. Quantification of He is often difficult, however, because of the extremely low secondary-ionization yields for He due to its high ionization energy [1-3]. Recently, sputtered neutral mass spectrometry (SMNS) successfully measured the depth-profile distribution of solar wind helium from a NASA Genesis target [3]. They used a unique SMNS instrument called LIMAS (laser ionization mass nanoscope) applied strong-field tunnel ionization to detect He neutrals sputtered from a ~1 μm^2 area of the surface.

Instrumental setup and performances: LIMAS consists of a liquid metal ion source and an aberration corrector for sputtering of nanometer scale area on samples, a femtosecond laser for tunneling-ionization of the sputtered neutrals, and a multi-turn time-of-flight (TOF) mass spectrometer for isotope analysis [5].

A fine Ga primary ion beam down to 8 nm is carried out by an aberration corrector installed in the primary ion optics column. The aberration corrector corrects chromatic and spherical aberrations. The femtosecond laser beam was focused to a diameter of ~50 μm above the sample surface achieving a power density of ~10^{20} Wm^{-2}. Ionization efficiency for sputtered neutrals by the laser are achieved to about 10% for He and about 100% for other all elements due to tunneling effect by the strong field.

A multi-turn time-of-flight mass spectrometer, MULTUM II [6], is equipped with LIMAS. MULTUM II is designed to achieve perfect space and time focusing ion optics for a multi-turn TOF mass spectrometer. Flight path lengths of ion species are expanded by using multi-turning on the same trajectory in MULTUM II under the constant temporal width of the ion packet. Mass-resolving power of 620,000 is achieved at TOF of 5 ms corresponding to flight path length of 1.3 km. The measured useful yields for Si are 2×10^{-3} at the high mass-resolving power.

Ion detection system consists of microchannel plates, preamplifier and 3 GHz 8 bit digitizer. The pulse width of single ion signal is 1.3 ns for the TOF mass spectrum. The system can quantifies up to 10 ions in an ion packet with time resolution of 0.2 ns. The performances are enough to acquire mass spectrum and can process data in real-time.

We conclude that LIMAS is an instrument with satisfactory high mass-resolving power and a high useful yield for microanalysis.

References: [1] Gnaser. H. and Oechsner, H. 1991. *Surface and Interface Analysis* 17: 646–649. [2] Tyagi, A. K. 1993, *Bulletin of Materials Science* 16: 45-49. [3] Lefaix-Jeuland, H. et al. 2013. *Nuclear Instruments and Methods in Physics Research* B295: 69-71. [4] Bajo, K. et al. 2015, *Geochemical Journal* 49: 559-566. [5] Ebata, S. et al. 2012, *Surface and Interface Analysis* 44: 635-640. [6] Okumura, D. et al. 2004 *Nuclear Instruments and Methods in Physics Research* A519: 331-337.

EVALUATION FOR MULTI-TURN TIME OF FLIGHT MASS SPECTRUM OF LASER IONIZATION MASS NANOSCOPE. A. Tonotani[1], K. Bajo[1], S. Itose[2], M. Ishihara[3], K. Uchino[4], and H. Yurimoto[1]. [1]Natural History Sciences, Isotope Imaging Laboratory, Hokkaido University, Sapporo, Japan. E-mail: azusat@ep.sci.hokudai.ac.jp, [2]JEOL Ltd., Musashino, Akishima, Tokyo, Japan, [3]Department of Physics, Osaka University, Toyonaka, Osaka, Japan, [4]Graduate School of Engineering Sciences, Kyushu University, Kasuga, Fukuoka, Japan.

Introduction: A sputtered neutral mass spectrometer (SNMS) called LIMAS [1] was developed for measuring solar wind particles from extraterrestrial materials collected by planetary exploration missions, such as JAXA Hayabusa and NASA Genesis [2]. LIMAS consists of a Ga liquid metal ion source and an aberration corrector for sputtering of nanometer scale area on samples, a femtosecond laser for tunneling-ionization of the sputtered particles, and a multi-turn time-of-flight mass spectrometer (MULTUM II) for isotope analysis. We have evaluated the performance of MULTUM II equipped with the ion injection optics of LIMAS.

Experimental procedure: We carried out numerical simulations of ion trajectories in the ion injection optics from a sample surface for calculating load voltages for the lenses. The ion trajectories were simulated by using SIMION 8.1 (Scientific Instrument Service, Inc.). We investigated the relationship between the loading voltages of L1 and L2 of extraction lenses for obtaining optimal parameter in LIMAS. Finally, we evaluated mass resolving power and transmittance of LIMAS using the optimal parameters.

Results and Discussion: Ion intensities as a function of L1 and L2 voltages are similar to the simulation results, indicating that the characteristics of the ion injection optics are basically designed by the simulation. From both results, we determined voltages -700 V for L1 and -3300 V for L2 as optimal parameter for extraction lenses of LIMAS.

Mass-resolving power increased up to the TOF of 1000 μs (200 multi-turn cycles). After 1000 μs, mass-resolving power became saturated. Saturation of the mass-resolving power (R = ~10^5) indicates that the averaged peak width increases linearly with increasing the number of cycles. Averaged peak-width consists of single spectra with different TOF in each cycle, which depends on modulations of the acceleration voltage, the injection timing for the ion injection optics, and the electric field for the electric sectors in MULTUM II. Therefore, we developed mass calibration methods for correcting those modulations. The mass calibration introduce that the mass-resolving power of LIMAS increased linearly with increasing the flight path length, and reached 620,000 (FWHM) at 1,000 multi-turn cycles of MULTUM II (flight path length: 1,312 m).

The transmittance of LIMAS decreased to 60–70% after 20 multi-turn cycles of MULTUM II, compared with the linear mode transmittance. The transmittance per multi-turn cycle became constant (99.96%) after 20 multi-turn cycles. A useful yield of 3×10^{-3} for Si ions was obtained for LIMAS at 30 multi-turn cycles of MULTUM II. The calculated useful yields for LIMAS are comparable to those for Cameca ims 6f of 7×10^{-3} [3].

References: [1] S Ebata. et al. (2012) SIA 44, 635-640. [2] K Bajo. et al. (2015) Geochem. J. 49, 559-566. [3] R. L. Hervig,. et al. (2006) Chem. Geol. *227*, 83–99.