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Present status for in-situ noble gas analysis by Sputtered Neutral Mass Spectrometry with tunneling ionization

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LIMAS (Laser Ionization MAss nanoScope) was installed in 2011. In-situ analysis for trace elements in nanometer-scale is a concept of this apparatus. I have conducted mechanism of solar wind (SW) implantation into extra-terrestrial materials such as Itokawa particles. Because depth profile of SW-He have not been determined by using conventional noble gas mass spectrometer (NG-MS) in a quantitative way, a depth profiling of the SW noble gas contributes to the great progress for understanding implantation and removing processes of the SW noble gases. The processes imply the space-weathering history of the materials on its asteroid surface.

LIMAS is mainly composed Ga focused ion beam (FIB) for primary ion, femtosecond (fs) laser for tunnel ionization of sputtered particles, and time-of-flight mass spectrometer. Depth profiling procedure is as follows. The FIB system is carried out high spatial resolution with large primary current. The smallest beam size was 8 nm at 3 pA, and the largest size was 600 nm at 30 nA. The fs laser can ionize the all element even He because of high energy density. The energy density is 8E15 W/cm^2 because the pulse energy and width was 6.3 W and 30 fs, respectively, and the laser pulse was focused on a volume of 50 x 50 μm^2. This laser pulse induces tunneling ionization (Delone and Krainov, 1998). Helium depth profile method in a few micrometer has been developed with LIMAS and atomic force microscope for crater depth measurement.

LIMAS can detect tens ppma He from sub-micrometer area on solid surface. In presence useful yield of He is 0.02% which should be up to 1% by optimize laser focusing and irradiation position. The yield of 0.02% corresponds to 4000 He atoms for single He ion count. The back ground of He is much less than that of the NG-MS because LIMAS is used by dynamic operation under the ultra-high vacuum.

LIMAS can measure locally concentrated noble gas because the sputter rate of the pulsed FIB is low, which indicates that this measurement is almost non-destructive isotope analysis. This feature can play a role for analysis of tiny and precious samples such as the Itokawa particles. U,Th-He and K-Ar dating for single grain can be applied by the in-situ noble gas analysis. The in-situ dating may obtain a new insight of thermal history of igneous rocks by comparing conventional in-situ dating method such as U-Pb age.

Keywords: noble gas, in-situ analysis, Sputtered Neutral Mass Spectrometry