LIMAS–New horizon of noble gas cosmochemistry

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Noble gases found in natural solids are used as tracers to study natural phenomena. However, the process by which they are incorporated into solids is not well understood. In this context, chemical thermodynamics is not very useful because the amount extracted from solids usually exceeds the amount that can be dissolved. If noble gases were trapped by adsorption, they would be found on the surface of or at the interface between solids. If noble gases were implanted into solids, they would be found just beneath the surface. In either case, microanalysis of noble gases in solids is essential to clarifying their incorporation mechanism. Recently, a novel in situ noble gas analysis technique using the Laser Ionization Mass Nanoscope (LIMAS) was developed [1]. LIMAS can conduct isotope measurements with lateral and depth resolutions of 10 nm and 5 nm, respectively, and down to ~1 atomic ppm (~10^{17} cm^{-3}) for ^{4}He with 1 μm resolution.

LIMAS measurements reveal the following novel astrophysical evidence: Presolar mainstream SiC grains form during the last million years of AGB stars and then migrate outward immediately. During this migration, the grains are irradiated by stellar winds from the central stars of planetary nebulae, at distances ranging from 0.3 to 30 light-years from their formation [2]. Solar wind components in meteorites are found in just below the solid surface, at depths of less than 100 nm, and the irradiated grains form a network structure generated by granular convection in the early solar system [3, 4, 5]. Solar wind components are significantly fractionated isotopically during their implantation, and solar energetic particles have not been observed in natural samples [6]. A large solar event, approximately 40 times larger than the largest solar particle ejection events observed since the space-based measurement of solar activity began, has been identified [7].

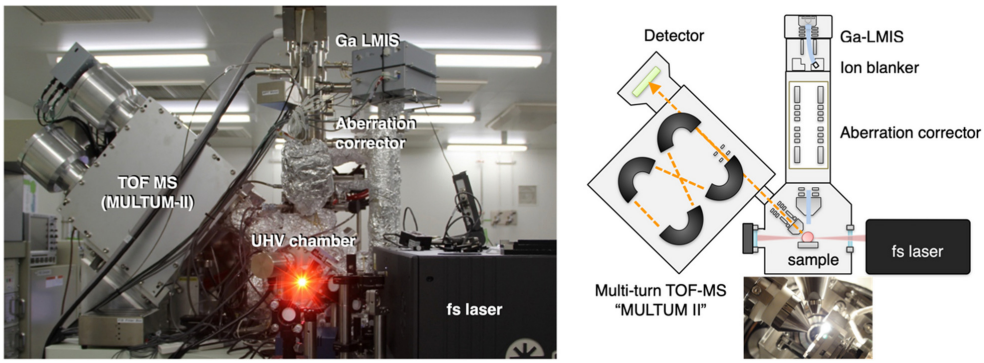

Figure 1. Photograph and schematic image of LIMAS. Configuration of primary and secondary columns and sample holder is inserted.

[1] K. Bajo, H. Yurimoto, *J. Anal. Sci. Tech.* **15**, 2024, 19. [2] K. Bajo et al., *Nat. Commun.* **16**, 2025, 8976. [3] S. Wada et al., *Meteorit. Planet. Sci.* **60**, 2025, 1151–1165. [4] K. Bajo et al. *Anal. Chem.* **96**, 2024, 5143. [5] S. Wada et al., *Meteorit. Planet. Sci.* **61**, 2026, in press. [6] Y. Otsuki et al., *Earth Planet. Sci. Lett.* **683**, 2026, 120000. [7] T. Obase et al., *Astrophys. J.* **978**, 2025, 142.