High sensitive noble gas mass spectrometer equipped with a Giese-type ion source

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Although noble gas isotopes are powerful tracers in geosciences, their extremely low abundances in mineral and rock samples make their analysis quite difficult. For example, concentration of $^3\text{He}$, which is a good indicator of mantle-derived component because of its primordial origin, is as high as 0.01 parts-per-trillion in volcanic rocks and mantle-derived materials. Such scarce noble gas isotopes are detected with a special mass spectrometer operated in static mode. We have made it possible to detect $10^3$ to $10^4$ atoms of noble gas isotopes by modifying a commercial sector-type single focusing noble gas mass spectrometer (VG5400), which is equipped with a double collector system to detect $^3\text{He}$ and $^4\text{He}$ simultaneously with a secondary electron multiplier and Faraday cup, respectively [1]. Here we report an attempt of further improvement of sensitivity of the mass spectrometer by installation of a new ion source (Giese-type source).

The Giese-type electron ionization (EI) ion source is equipped with two electrostatic quadrupole lenses [2]. This source has been reported to have up to two orders of magnitude higher sensitivity than conventional Nier-type EI source because of the absence of a beam defining slit to collimate the ion beam and thus high transmission [3]. We designed a Giese-type source to have an adequate resolution to separate $^3\text{He}^+$ from HD$^+$ and H$_3^+$, to have the source housing volume as small as possible, and to be bankable at up to 300 °C to reduce outgas from the source materials. The ion and electron optics were based on a calculation by Lu and Carr [4] and refined using SIMION-3D software [5]. Prior to the installation on the mass spectrometer, the ion beam profile emitted from the source was monitored by a microchannel plate and phosphor screen to optimize the configuration of the quadrupole lens.

A sufficient mass resolution over 500 essential for $^3\text{He}/^4\text{He}$ analysis has been achieved with an improved sensitivity approximately three times higher than the previous condition. The amount of helium required to obtain a precision with $^3\text{He}/^4\text{He}$ ratio is two orders of magnitude smaller than that with the condition installed by the manufacture. However, total ion transmission is estimated to be about 30%, suggesting further refinement of the source condition is required to obtain the maximum sensitivity.


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