Mass spectrometric analysis of sublimation products from silicate dust

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Molecules containing refractory elements have been detected along various lines of sight in star-forming regions. SiO is among the most important species, whose detection in molecular outflows has been commonly interpreted by sputtering of silicate dust in shock waves. Recently, SiO was also detected in the innermost disk of a massive protostar in the high-resolution observation using ALMA [1]. The possible production mechanisms of SiO in the inner disk include both non-thermal and thermal pathways: sputtering under shocks or radiation and sublimation under high temperatures ($\gtrsim$1500 K). The latter is of particular interest because this might be related to sublimation of planetary materials of the solar system recorded in primitive meteorites. However, it has been controversial whether the sublimation of silicate materials produces SiO [2,3]. In this study, we aimed to experimentally identify the sublimation products of forsterite (Mg_2SiO_4), which is a representative silicate mineral likely constituting dust.

We developed a new ultra-high vacuum apparatus consisting of a resistive heating system made of refractory metals and a quadrupole mass spectrometer with an electron-impact ionization source. Using this apparatus, we heated powdered forsterite at controlled temperatures (<2300 K) and detected the sublimated gas species under collision-free conditions. We identified Mg, SiO, and O as major products and MgO as a minor product (MgO/Mg~10^{-2}-10^{-1}) of sublimation of forsterite (Fig. 1). The Mg:SiO ratio was ~2:1, suggesting that the major sublimation reaction is Mg_2SiO_4 (s) → 2Mg (g) + SiO (g) + 3O (g). The identified products are different from the theoretical predictions based either on thermochemical calculations or kinetic experiments. The present detection of SiO as a major product indicates that SiO observed in the inner disk possibly traces dust sublimation, and thus, may be related to the sublimation of solar system materials studied through meteorites.

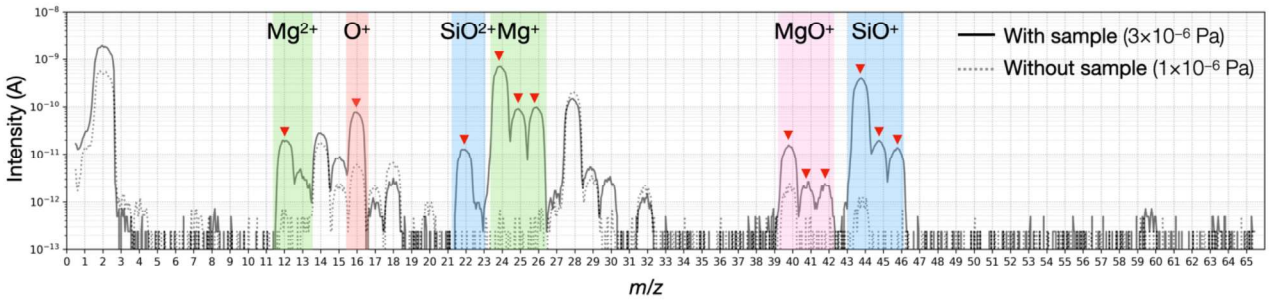

Figure 1: Mass spectrum of sublimation products of forsterite heated at 1900 K. The solid and dotted lines show the mass spectrum with and without the sample, respectively. The detected ions are indicated in the figure.

References

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