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A miniaturized laser-ablation mass spectrometer for in-situ measurements of isotope composition on solar body surfaces

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The in-situ analysis of extraterrestrial material onboard planetary rovers and landers is of considerable interest for future planetary space missions. Due to the low detection sensitivity of spectroscopic instruments, e.g. α-particle X-ray, γ-ray or neutron spectrometers, it is frequently possible to measure only major/minor elements in extraterrestrial materials. Nevertheless, the knowledge of minor/trace elements is of considerable interest to cosmochemistry. Chemistry puts constraints on the origin of solar system and its evolution enabling also a deeper inside to planetary transformation processes (e.g. volcanic surface alteration, space weathering). The isotopes play special role in analysis of the origin and transformation of planetary matter. They are robust tracers of the early events because their abundances are less disturbed as the elemental once. Nevertheless, if the isotope abundance ratios are fractionated, the underlying chemical and physical processes can be then encoded from the variations of abundance ratios. A detailed analysis of isotopic patterns of radiogenic elements can allow age dating of minerals and temporal evolution of planetary matter. High accuracy and sensitive measurements of isotopic pattern of bio-relevant elements, i.e. sulfur, found on planetary surfaces can be helpful for the identification of possible past and present extraterrestrial life in terms of biomarker identification.
Our group has designed a self-optimizing miniaturized laser ablation time-of-flight mass spectrometer (LMS) for in situ planetary measurements (Wurz et al., 2012; Rohner et al., 2003). Initial studies utilizing IR laser radiation for ablation, atomization and ionization of solid materials indicated a high instrumental performance in terms of sensitivity and mass resolution (Tulej et al., 2011). Current studies are conducted with a UV radiation and a high spatial resolution is achieved by focussing the laser beam to 20μm spots onto the sample. The space instrument would have a cylindrical shape with a length of 120 mm, and a diameter of 60 mm, and a weight of about 1.5 kg (all electronics included). The mass analyzer supports high dynamic range of about 107 and a typical mass resolution of m/Δm$\sim$700. A computer-controlled optimizer controls the reproducibility of the performance of the mass analyzer, the laser fluence and the positioning of the sample. The system supports highly sensitive studies of elemental composition with sub-ppm detection limits. Our studies show that high accuracy and precision measurements can also be achieved in the investigations of isotopic patterns. Our initial studies of lead isotopic pattern indicated an accuracy and precision in the per mile range, which are comparable to that achieved by other - well known in isotopic analysis - mass spectrometric techniques, i.e. TIMS, SIMS, LA-ICP-MS used in the laboratory. The initial studies were conducted with Galena minerals and NIST standards. Hence, the miniaturized laser ablation time-of-flight mass spectrometer is a powerful instrument for in-situ measurements for the further investigation in surface characterization.

References

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