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A miniature laser ablation mass spectrometer for quantitative in situ chemical composition investigation of lunar surface

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The chemical composition of planetary bodies, moons, comets and asteroids is a key to understand their origin and evolution [Wurz,2009]. Measurements of the elemental and isotopic composition of rocks yield information about the formation of the planetary body, its evolution and following processes shaping the planetary surface. From the elemental composition, conclusions about modal mineralogy and petrology can be drawn. Isotope ratios are a sensitive indicator for past events on the planetary body and yield information about origin and transformation of the matter, back to events that occurred in the early solar system. Finally, measurements of radiogenic isotopes make it possible to carry out dating analyses. All these topics, particularly in situ dating analyses, quantitative elemental and highly accurate isotopic composition measurements, are top priority scientific questions for future lunar missions. An instrument for precise measurements of chemical composition will be a key element in scientific payloads of future landers or rovers on lunar surface.

We present a miniature laser ablation mass spectrometer (LMS) designed for in situ research in planetary and space science and optimised for measurements of the chemical composition of rocks and soils on a planetary surface. By means of measurements of standard reference materials we demonstrate that LMS is a suitable instrument for in situ measurements of elemental and isotopic composition with high precision and accuracy. Measurements of soil standards are used to confirm known sensitivity coefficients of the instrument and to prove the power of LMS for quantitative elemental analyses [Neuland,2016]. For demonstration of the capability of LMS to measure the chemical composition of extraterrestrial material we use a sample of Allende meteorite [Neuland,2014]. Investigations of layered samples confirm the high spatial resolution in vertical direction of LMS [Grimaudo,2015], which allows in situ studying of past surface processes on a planetary surface. Analyses of Pb isotopes show that the statistical uncertainty for the age determination by LMS is about $\pm$100 Myrs, if abundance of 206Pb and 207Pb is 20ppm and 2ppm respectively [Riedo,2013]. These Pb isotopes have abundances of tens to hundreds of ppm in lunar KREEP [Nemchin,2008].

We demonstrate the measurement capabilities of LMS for petrographic and mineralogical analyses, for isotopic studies and dating analyses, which are key topics for future missions to the Moon. Having the LMS instrument installed on a lunar rover would allow measuring the chemical composition of many rock and soil samples, distributed over a certain area, inside the South Pole Aitken Basin for example. LMS measurements would yield valuable conclusions about age and mineralogy.

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