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Highly accurate isotope measurements of surface material on planetary objects in situ

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Studies of isotope variations in solar system objects are of particular interest and importance. Highly accurate isotope measurements provide insight into geochemical processes, constrain the time of formation of planetary material (crystallization ages) and can be robust tracers of pre-solar events and processes. A detailed understanding of the chronology of the early solar system and dating of planetary materials require precise and accurate measurements of isotope ratios, e.g. lead, and abundance of trace element. However, such measurements are extremely challenging and until now, they never have been attempted in space research.
Our group designed a highly miniaturized and self-optimizing laser ablation time-of-flight mass spectrometer for space flight for sensitive and accurate measurements of the elemental and isotopic composition of extraterrestrial materials in situ. Current studies were performed by using UV radiation for ablation and ionization of sample material. High spatial resolution is achieved by focusing the laser beam to about Ø 20μm onto the sample surface. The instrument supports a dynamic range of at least 8 orders of magnitude and a mass resolution m/Δm of up to 800—900, measured at iron peak. We developed a measurement procedure, which will be discussed in detail, that allows for the first time to measure with the instrument the isotope distribution of elements, e.g. Ti, Pb, etc., with a measurement accuracy and precision in the per mill and sub per mill level, which is comparable to well-known and accepted measurement techniques, such as TIMS, SIMS and LA-ICP-MS. The present instrument performance offers together with the measurement procedure in situ measurements of 207Pb/206Pb ages with the accuracy for age in the range of tens of millions of years. Furthermore, and in contrast to other space instrumentation, our instrument can measure all elements present in the sample above 10 ppb concentration, which offers versatile applications regarding in situ investigations of the chemical composition of extraterrestrial surface material.

References
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