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In-situ chemical composition measurements with a laser ablation mass spectrometer for space research: Quantitative investigations of meteorites

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Abstract

We present a laser ablation/ionisation mass spectrometer (LMS). With this instrument we measured the quantitative chemical composition of Allende and Sayh al Uhaymir meteorites in-situ and with very high spatial resolution. From the main rock-forming elements, the mineralogy of the samples was inferred. Measurements of trace elements in SaU allowed dating analyses of the material and the calculation of the crystallisation temperature of the Zircon grains that were identified in the KREEP sample. The measurements on Allende made it possible to analyse the meteorite matrix in particular, beside the various chondrules embedded in the matrix. The LMS is suitable for being operated on a planetary lander or rover, where it would allow for high performance in-situ studies of rocks on the planetary surface.

1. Introduction

The knowledge of the chemical composition of moons, comets, asteroids or other planetary bodies is of particular importance for the investigation of the origin and evolution of the Solar System. High resolution in situ studies on planetary surfaces can yield important information on surface heterogeneity, basic grain mineralogy, chemical composition and age of surface and subsurface. In turn, these data are the basis for our understanding of the physical and chemical processes which led to the formation and alteration of planetary material [6].

2. Experiment

We present a highly miniaturised laser ablation/ionisation mass spectrometer (LMS) that was designed and built for space research at the University of Bern [3][4]. The instrument is suitable for its application on a planetary lander or rover.

With the LMS, we investigated samples of the Allende and the Sayh al Uhaymir (SaU) meteorite. Both meteorite samples were investigated with a spatial resolution of about 10µm in lateral direction. The high sensitivity and high dynamic range of the LMS allow for quantitative measurements of the abundances of the rock-forming and minor and trace elements with high accuracy [1],[3].

2.1 Allende meteorite

The chemical composition and mineralogy of a sample of Allende meteorite [2] was investigated with high spatial resolution. Fig. 2 shows an example from the various measurements carried out on the sample. The left panel shows the element map of K, derived from a measurement that covers a part of a CAI as well as the matrix material. A detail of the sampled area, marked by the red in the left panel, is shown in the right panel of Fig. 2. In this detailed picture, the sharp craters from the laser ablation measurements can be seen. The map in the left panel complements the optical image, showing that the Allende matrix material contains considerably more K than the CAI.

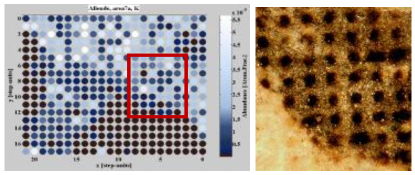

Fig.2: **Measurements on Allende meteorite** *Border of a CAI and the meteorite matrix and the according map of K.*

We measured the composition of various chondrules in Allende, offering valuable clues about the condensation sequence of the different components of the meteorite. We explicitly investigated the chemical composition and heterogeneity of the Allende matrix with an accuracy that cannot be reached by the mechanical analysis methods that were and are widely used in meteoritic research.

2.2 Sayh al Uhaymir

We investigated three samples of the SaU meteorite, which cover the KREEP-rich impact melt breccia as well as the regolith. Mineralogical analyses (see Fig. 3) allowed identifying several Zircon-grains in the sample. The high mass resolution of the LMS, coupled with a high-voltage pulser allowed for measurements of the rare earth elements. We demonstrate the capabilities for dating analyses with the LMS. By applying the U-Th-dating method, the age of the SaU169 sample could be determined.

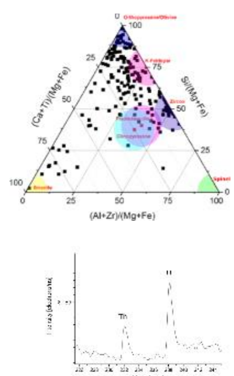

Fig. 3: **SaU 169**

Mineralogical analyses of the sample allowed for identification of several Zircon-grains and other pure mineral grains.
The detection of Th and U allowed for dating analyses.

3. Summary and Conclusions

Our analyses show that the LMS is a high performance instrument, designed for space research. The instrument data allow for in-situ measurements of main, minor and trace elements of rocks and soil. These data are fundamental for detailed analyses of the mineralogy and the age of the material and thus are key information for the reconstruction of the condensation sequence and the analysis of alteration processes. The LMS is a small and light weight instrument, designed for operation on a planetary lander or rover. With our studies of meteorites as an example, we show that the LMS would be a suitable instrument for high-quality quantitative chemical composition measurements on the surface of a celestial body like a planet, moon or asteroid.

Acknowledgements

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