EPSC Abstracts
Vol. 8, EPSC2013-8, 2013
European Planetary Science Congress 2013

In situ chemical composition measurements with a miniature laser ablation mass spectrometer for planetary exploration

M.B. Neuland(1), S. Meyer (1), K. Mezger (2), A. Riedo (1), M. Tulej (1) and P. Wurz (1)
(1)Physics Institute, Space Research and Planetary Sciences, University of Bern, Sidlerstrasse 5, CH - 3012 Bern, Switzerland,
(2) Institute of Geological Sciences, University of Bern, Baltzerstrasse 1+3, CH - 3012 Bern, Switzerland,
Contact: neuland@space.unibe.ch , Tel.: +41 (0)31 631 44 24, Fax: +41 (0)31 631 44 05

Abstract

We present a miniature laser ablation mass spectrometer (LMS) for planetary and space research. For demonstrating the performance of the instrument, a sample of Allende meteorite is investigated as an analogue to a planetary surface. Investigation of a very inhomogeneous structure like the surface of a chondritic meteorite requires high spatially resolved data of chemical content, elemental and isotopic. We measure the composition of the Allende meteorite and show that by using a ns-laser for ablation, elemental analysis is accomplished with high quality allowing to study the mineralogy. The results will be compared to measurements using a fs-laser system to show improvements of the technique.

1. Introduction

The chemical composition of planetary bodies, moons, comets and asteroids is a key to understand their origin and evolution [1]. From measurement of the elemental content of a rock, conclusions about formation of the body and following surface alteration can be drawn [2]. Detection of elements that are relevant bio-markers can yield information about past or present life on the celestial body. Additionally, the precise determination of the abundances, particularly of radiogenic isotopes, allows dating the object. During the last decade, several methods to perform chemical composition measurements have been adopted for space research. Laser ionisation mass spectrometry (LIMS) is a method that has several advantages, most importantly the speed of analysis and the sensitivity to almost all elements. LIMS instruments can be built in a very miniaturized and light weight way to make them suitable for space missions [1].

2. Instrumental

The LMS instrument combines a laser ablation/ionisation ion source with a time-of-flight mass analyser. A focused laser beam is pointed on the sample of interest, surface atoms are ablated and ionised in a hot plasma plume that is formed. Electric fields guide the produced ions through a drift tube on the micro channel plate detector [6]. Measurements in multiple channels with different gain levels assure a high dynamic range allowing the detection of all elements even down to ppm level. Each laser shot results in a full mass spectrum from 0 to 250 amu/q, where signals from almost all elements (metallic as well as non-metallic) are recorded. In an earlier setup of LMS, a ns-laser was used for the ablation process. Now the laser system was replaced by a fs-laser, providing several advantages for chemical composition measurements. On the basis of NIST samples, we found that fs-laser ablation shows a clear improvement in detection efficiency and quantitative performance [3].

3. Measurements on Allende

Meteorites offer an excellent opportunity for evaluating the performance of a mass spectrometer for space research in the laboratory [2]. In this study, a sample of Allende meteorite serves as an analogue for investigations on a planetary surface. The highly inhomogeneous carbonaceous chondrite of class CV3 contains different chondrules and inclusions as well as pure mineralogical phases and meteorite matrix (see Figure 1). Many pure minerals in inclusions and chondrules are known to be of cm size, but single CAIs or olivine or nickel-iron grains in CV3 chondrites can occur in grain sizes of less than 1 µm [7]. This demands for an instrument providing chemical composition measurements with high spatial resolution. In a first measurement campaign 138 measurements of the elemental composition of the Allende surface have been carried out (see Figure 2).

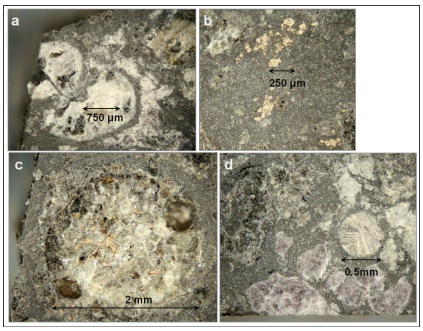

Figure 1: The Allende sample that was used in this study shows a large variety of inclusions and chondrules ranging from mm to µm size.

4. Mineralogical Analysis

From certain element ratios, basic mineralogical classes can be defined. Figure 2 shows the ratios of Ca and Al to (Mg+Fe) for each of the 138 measurements on the Allende surface. Regions of mineral classifications are indicated in different colours. From the graphic it can be seen that barely pure mineral grains were hit in this measurement campaign. As the laser spot on the surface is of approximately 20 µm diameter it can be understood that one measurement represents a mixture of different minerals. The LMS results on the Allende surface also

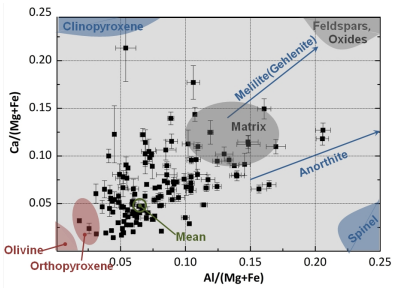

Figure 2: Ratios of Ca, Al, Mg and Fe for the 138 measurements carried out with LMS on the surface of an Allende sample.

reproduced the known depletion in volatile elements of carbonaceous chondrites [9]. The results were compared to published data [8] showing good agreement for major, refractory and volatile elements contained in Allende in the %-range down to the low ppm levels. In a following campaign, measurements will be performed with the fs-laser. We expect that data evaluation of even more elements down to ppb level will be possible as well as the more detailed analysis of regions of special interest, like CAIs, lead-isotopes and others.

5. Summary and Conclusions

The elemental content of a sample of Allende meteorite is investigated using a laser ablation mass spectrometer. The technique allows measurements of the elemental content of the sample with high spatial resolution for almost all elements. From the results, conclusions about the mineralogy and volatility of the sample can be drawn, which makes LMS a powerful instrument for high quality investigation of planetary surfaces and alike.

Acknowledgments

This work is supported by the Swiss National Science Foundation (SNF).

References

[1] Wurz, P. et al.: Laser Mass Spectrometry in Planetary Science, AIP Conf.Proc., CP1144:70-75.

[2] McSween, H., Huss, G.: Cosmochemistry, Camebridge University Press, 2010.

[3] Riedo, A. et al.: Coupling of LMS with fs-laser ablation ion source: elemental and isotope composition measurements, J.Anal.Atom.Spectrom.,2013,submitted.

[4] Neuland, M.B. et al.: Probing the Allende meteorite with a miniature Laser-Ablation Mass Analyser for space application, Planet.Space Sci.,2013,submitted.

[5] Riedo, A. et al.: Performance evaluation of a miniature laser ablation time-of-flight mass spectrometer designed for in situ investigations in planetary research, J.Mass Spectrom., 2013, 48:1-15.

[6] Tulej, M. et al.: On applicability of a miniaturised laser ablation time of flight mass spectrometer for trace elements measurements, Int.J.Spec., 2012, Article ID 234949.

[7] Grossman, L.: Petrography and mineral chemistry of Ca-rich inclusions in the Allende meteorite,Geochim.Cosmochim.Acta 39(4), 433-434, IN1-IN2, 435-454.

[8] Stracke, A. et al.: Refractory element fractionation in the Allende meteorite: Implications for solar nebula condensation and the chondritic composition of planetary bodies, Geochim.Cosmochim.Acta 85: 114-141.

[9] Scott, E.R.D., Krot, A.N.: Chondritic Meteorites and the High-Temperature Nebular Origins of Their Components, Chondrites and the Protoplanetary Disk, ASP Conf.Proc.341:15-53.