

A miniature LIMS instrument for in situ chemical analysis of solids with high spatial resolution on planetary surfaces (Poster Flash Talk)

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1. Introduction

The detection of extinct or extant life and the assessment of the habitability on Mars are currently two of the most thriving interests in Astrobiology and Space Research, which drive significantly the development of dedicated instrumentation for in situ exploration on planetary surfaces. To improve the current understanding of processes (chemical and physical) that might have altered the Martian surface accurate and sensitive information of solids with high spatial resolution at micrometre level are required, complementing the chemical information at larger scale (bulk analysis). Instrumentation based on laser ablation/ionisation mass spectrometry is a promising alternative measurement technique for future space exploration missions. In our contribution we demonstrate the measurement performance and capabilities of our miniature LIMS system for sensitive chemical analysis of solids with high spatial resolution (micrometre and nanometre level), on the basis of measurement campaigns conducted on basaltic and mineral samples with some of which containing micrometre sized fossil structures.

2. Instrument Description

The system used for the analysis of the chemical (elements and isotopes) composition of solids is a miniature reflectron-type time-of-flight (R-TOF) mass spectrometer (dimension mass analyser: 160 mm x Ø 60mm) coupled with a femtosecond laser ablation ionisation source ($\tau \sim 190$ fs, $\lambda = 775$ nm, 1 kHz pulse repetition rate, max. 1 mJ/pulse) [2,4,5,7]. A lens system placed on top of the instrument is used to focus laser pulses through the mass analyser towards the sample surface to spot sizes in the range of about 10 – 20 μm in diameter. Only positively charged species can enter the instrument where they are accelerated, focussed and confined into the interior by the ion optical system. After passing the drift path the ions are reflected at the ion mirror towards the multi-channel plate (MCP) detector system passing a second time the drift path. The positively charged species arrive in time sequences at the detector system (TOF principle), according to their mass over charge ratio. TOF spectra are converted subsequently to mass spectra [4].

3. Materials

To demonstrate the measurement capabilities of the miniature LIMS system, *tomographical* measurements of two different sample materials will be presented and discussed in detail. The two samples are i) a basalt sample including mineral filamentous structures (Fig. 1, top row, approximate age of 360–320 Ma), that were collected at Kinghorn, Fife, Scotland [1], and ii) an aragonite host with embedded micrometre-sized fossil veins (Fig 1, bottom row), collected from slow-spreading Mid-Atlantic Ridge at 26.9 m depth below the seafloor [6].

4. Results and Discussion

The spot-wise chemical analysis and the sequenced storage of mass spectra allow for a detailed 3D chemical analysis of the investigated samples. In this way the monitoring of bio-relevant elements allows the identification and localisation of fossil structures embedded within the aragonite host (see Fig. 2) where conventional optical microscope imaging techniques find its limitation. Furthermore, this measurement procedure allows to improve the quantitative nature of the chemical analysis of these micrometre structures as only mass spectra containing chemical information attributed to the fossil can be selected and accumulated to increase the signal-to-noise ratio (SRN) [6]. A similar analysis procedure was applied for the chemical analysis of the basaltic sample material, however, this time by monitoring mineral specific elements, including e.g. the elements of millerite (NiS) or quartz (SiO₂). This analysis procedure allows us to monitor changes of mineral phases within the sample material and hence to chemically “zoom-in” into locations of interest [1]. Both measurement campaigns will be discussed in more detail during the contribution to demonstrate the versatility of our miniature LIMS system.

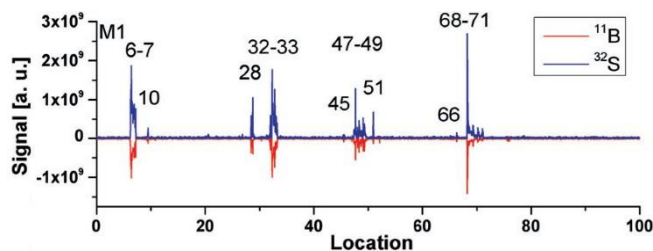


Fig. 1: By monitoring bio-relevant elements during the mass spectrometric acquisition filament structures within the sample material can be identified. Image adopted from [6].

5. Summary

To date, the miniature LIMS system shows various measurement capabilities for the chemical analysis of highly heterogeneous sample materials, ranging from sensitive (10 ppb, atomic fraction) and quantitative element analysis [2,4], high accurate isotope analysis that allows for in situ dating [3], high lateral (at micrometre level) and vertical (at nanometre level) resolution providing 2D and 3D chemical investigations of solids [1,6,7], to the determination of sample mineralogy [1]. Therefore, the miniature LIMS system is a promising alternative measurement technique for future space exploration missions where high detection sensitivity and versatility are requested.

6. References

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Short Summary

The measurement performance and capabilities of our miniature LIMS system for in situ chemical analysis of solids with high spatial resolution will be demonstrated, on the basis of measurement campaigns conducted on basaltic and mineral samples with some of which containing micrometer sized fossil structures.