EPSC Abstracts
Vol. 6, EPSC-DPS2011-1065, 2011
EPSC-DPS Joint Meeting 2011

Study of the Main Geochemical Characteristics of Phobos' Regolith Using Laser Time of Flight Mass Spectrometry

G. G. Managadze (1), P. Wurz (2), R. Z. Sagdeev (1), A. E. Chumikov (1), M. Tulej (2), M. Iakovleva (2), N. G. Managadze (1), and A. L. Bondarenko (1)
(1) Space Research Institute, Russian Academy of Sciences, Moscow, Russia, (2) Physics Institute, University of Bern, Switzerland (managa@iki.rssi.ru / Fax: +7 495 333 12 48)

Abstract

We present the laser ablation mass spectrometer, LASMA, that is part of the scientific payload of the Phobos Sample Return Mission (also known as Phobos-Grunt mission of Roskosmos, Russia). LASMA will measure the elemental composition of soil samples collected from Phobos' soil.

1. Introduction

Knowing the elemental composition of planetary objects allows the study of their origin and evolution within the context of our Solar System. Landed probes are critical to such an investigation. Instruments on a landed platform can answer a different set of scientific questions than can instruments in orbit or on Earth [1]. Such studies are best performed with dedicated mass spectrometer systems.

Direct analysis of soil samples with laser-based mass spectrometric (LMS) systems has been proposed as spacecraft instrumentation previously [2, 3, 4], and one such instrument, LIMA-D [5], was included in the previous Phobos missions [6]. LIMA-D was a time-of-flight mass spectrometer designed to study the surface composition of Phobos from a hovering distance of 30–80 m. However, these instruments were rather heavy, mainly due to the mass of the laser system. Modern laser systems are much smaller and allow for compact instruments.

In recent years highly miniaturised laser mass spectrometers for direct compositional investigation of planetary surfaces have been developed by several groups for various planetary missions [7, 8, 9, 10]. These instruments are based on high intensity pulsed lasers removing material from a rock (or other solid), atomising and ionising the material and identification of the ions by time-of-flight analysis.

2. The LASMA Instrument on Phobos-Grunt

The LASMA instrument is a laser ablation mass spectrometer [11] for the Phobos-Grunt mission, which is scheduled for launch in November 2011 [12]. LASMA is a typical lander LMS and is based on an earlier development [7]. In this instrument a 7 ns laser pulse with 16 mJ power from a flash-lamp pumped Nd:YAG laser (wavelength 1064 nm) is used, which is focussed to a spot of Ø 50 µm on the sample surface. Since the laser repetition rate has to be kept very low (maximum repetition rate of 0.1 Hz) to stay within the power limits of the Phobos-Grunt spacecraft, spectra are recorded with a high-dynamic range detector and matching signal acquisition system. For each individual laser shot the recorded spectrum is transmitted to Earth. The flight instrument has overall dimensions of 220 x 110 x 260 mm^3, weighs about 2.6 kg, and is mounted on the outside wall of the lander. Figure 1 shows a picture of the integrated LASMA instrument. An articulated arm will collect surface soil samples from the vicinity of the landing site and deliver these to the sample carousel of LASMA, which can accommodate up to 14

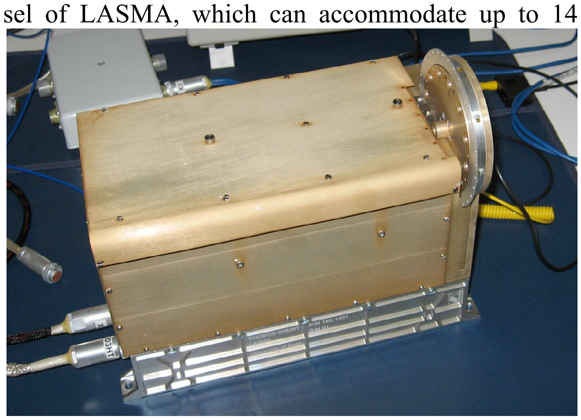

Figure 1: Integrated LASMA instrument. The analyser is the yellowish structure on top, with the sample carousel on the right; the electronic box is the silvery structure on the bottom [12].

samples.

LASMA can record mass spectra in the mass range from 1 to 250 amu, with mass resolutions of $m/\Delta m \approx 380$ (FWHM). Figure 2 shows two mass spectra from the calibration of the LASMA instrument. One mass spectrum is from a Ti-W alloy sample, which is the calibration sample of the LASMA instrument; the other mass spectrum is from a lunar simulant material, which is powder sample resembling the samples we expect to measure on Phobos' surface. The calibration sample also serves as in-flight calibration of the LASMA instrument. It is a mechanically robust sample with elements covering most of LASMA mass range, which does not degrade upon prolonged laser irradiation. These mass spectra are recorded for a single laser shot, and in both cases a dynamic range of four decades is achieved. Individual elements are identified in the spectra, and isotope patterns are resolved for the major elements. The detection efficiency for the elements is reasonably constant allowing for quantitative elemental analysis of solid surfaces. The accuracy of elemental composition measurement is about 10%, and for the isotope measurement it is about 1% [11].

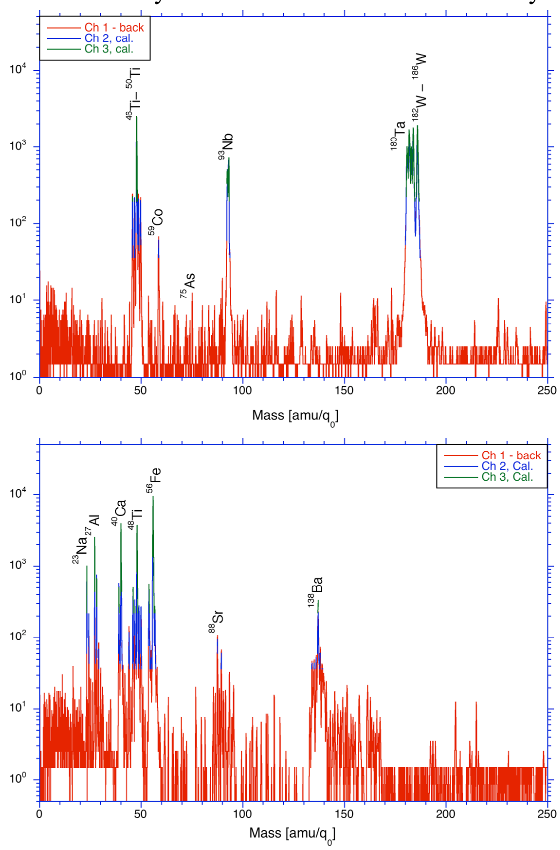

Figure 2: Top panel: Mass spectrum from a Ti-W alloy used as in-flight calibration sample; Bottom panel: Mass spectrum of a lunar simulant material.

References

[1] P. Wurz, D. Abplanalp, M. Tulej, M. Iakovleva, V.A. Fernandes, A. Chumikov, and G. Managadze, In Situ Mass Spectrometric Analysis in Planetary Science, Sol. Sys. Res. submitted, 2011.

[2] R.Z. Sagdeev, G.G. Managadze, I.Yu. Shutyaev, K. Szego, and P.P. Timofeev, *Methods of remote surface chemical analysis for asteroid mission,* Adv. Sp. Res. 5, 111–120, 1985.

[3] R.Z. Sagdeev, J. Kissel, G.G. Managadze, R. Pellinen, F. and Vollmer, E., *Remote surface chemical analysis techniques for small bodies of the Solar System without atmosphere,* in Remote Geochem. Analysis: Element and Mineralogical Composition. Eds.: C.M. Pieters and P.A. Englert. Cambridge Univ. Press. 569–577, 1993.

[4] R.J. DeYoung, and W. Situ, Laser elemental mass analysis at large distances, Appl. Phys. Lett. 64(22), 2943–2945, 1994.

[5] G.G. Managadze, R.Z. Sagdeev, and I.Y. Shutyaev (1987), Device for mass-spectrometric analysis of the surfaces of space objects. Soviet Patent No. 1218852. Priority of invention 23.07.1984, registered 15.11.1985. Soviet Inventions Bulletin No. 17, 273.

[6] R.Z. Sagdeev, and A.V. Zakharov, A brief-history of the expedition to Phobos, *Sov. Astron. Lett.* 16, 125–128, 1990.

[7] G.G. Managadze, and I. Yu. Shutyaev, Chapter 5 in *Laser Ionization Mass Analysis*, Chemical, Analysis Series Vol. 124, Wiley, New York, 1993.

[8] W.B. Brinckerhoff, G.G. Managadze, R.W. McEntire, A.F. Cheng and W.J. Green, Laser time-of-flight mass spectrometry for space, Rev. Sci. Instr. 71, 536–545, 2000.

[9] U. Rohner, J. Whitby, and P. Wurz, A miniature laser ablation time-of-flight mass spectrometer for in situ planetary exploration, *Meas. Sci. Technol., 14,* 2159–2164, 2003.

[10] U. Rohner, J. Whitby, P. Wurz, and S. Barabash, A highly miniaturised laser ablation time-of-flight mass spectrometer for planetary rover, *Rev. Sci. Instr.,* 75, 1314–1322, 2004.

[11] G.G. Managadze, P. Wurz, R.Z. Sagdeev, A.E. Chumikov, M. Tuley, M. Yakovleva, N.G. Managadze, A.L. Bondarenko, Solar System Research, 44, 376–384, 2010.

[12] L.M. Zelenyi, A.V. Zakharov, G.M. Polischuk, and M.B. Martynov, Project of the Mission to Phobos, Solar System Research, Vol. 44, 15–25, 2010.