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In-situ analysis of lunar regolith with the gas chromatograph-neutral gas mass spectrometer on the Luna-Resurs lander

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Abstract

We developed a time-of-flight neutral gas mass spectrometer (NGMS) that was selected as part of the gas analytic package for the Luna-Resurs mission to investigate lunar regolith and the lunar exosphere in-situ. The recently presented scientific performance measurements of the NGMS prototype [4] are comparable with preliminary calibration data of the flight model. Hence, NGMS will fully comply with the scientific requirements of the Luna-Resurs mission.

1. Introduction

Analysing chemical composition of the volatile species in lunar soil has contributed significantly to our understanding of the origin and evolution of the Moon and solar system bodies but key questions remain unanswered. Volatiles and water are shown to be present on the lunar polar regions [2] but the absence of highly sensitive in-situ chemical composition measurements only allow for speculations about how the Moon evolved. Therefore, chemical analysis of lunar regolith is of considerable interest in the Russian Luna-Resurs mission.

2. NGMS

The NGMS instrument [3, 7] design benefits from heritage from P-BACE/MEAP [1] and RTOF/ROSINA/Rosetta [6] instruments. Analysis capabilities of the instrument include investigation of volatiles and their chemical composition, the fraction of water and organic compounds as well as isotope composition of CHON and noble gases, and its scientific performance depends on the measurement mode and the mission phase respectively.

Figure 1: Mass of the NGMS flight model is < 3.5 kg, size is 18 x 26 x 15 cm^3 and it consumes < 25 W [3].

2.1 GC

The NGMS instrument operates with pyrolysis cells with temperatures of up to 1100°C to release volatiles from the collected regolith sample, a thermal analyser and a gas chromatograph (GC) are used for chemical pre-separation. The continuous analysis of the GC outflow allows for a dynamic range of up to 10^6 within 1 second integration time.

Prototype GC-NGMS measurements show sensitivities of hydrocarbons of about $2 \cdot 10^{-10}$ by mass and of about $2 \cdot 10^{-9}$ by mass for noble gases [4]. Measurements with the NGMS flight model and

prototype GC columns indicate that a similar range as in the NGMS prototype measurements is feasible during the mission. For comparison, for the SAM instrument, the GC-mass spectrometer on the Curiosity rover of NASA, the reported sensitivity for organic compounds is $(1–10)\cdot10^{-9}$ by mass [5].

2.1 Exosphere

During cruise phase and on the surface, NGMS analyses the tenuous exosphere as a stand-alone instrument with an increased signal-to-noise ratio compared to the GC mode due to higher integration times. Calibration measurements with noble gas mixtures show that the instrument is able increase its dynamic range which is mainly limited by the mission scenario (integration time) while the mass resolution is still up to $m/\Delta m = 1200$. Trace gas quantities of species at 10^{-16} mbar partial pressure could therefore be measured when assuming an ambient gas pressure of the lunar atmosphere in the order of 10^{-10} mbar [7].

3. Summary and conclusion

We developed a neutral gas mass spectrometer which operates as a stand-alone device or in combination with a gas chromatograph. In both cases the NGMS instrument is capable to analyse both the structure and composition of molecules, isotopes and elements. The dynamic range of the flight instrument is estimated to be in a similar range as the reported prototype levels which is about 6 decades within 1 second integration time allowing for highly sensitive isotope and chemical composition analysis of the lunar surface and exosphere.

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