

Prototype of the gas chromatograph – mass spectrometer to investigate volatile species in the lunar soil for the Luna-Glob and Luna-Resurs missions.

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Abstract

In preparation for the Russian Luna-Glob and Luna-Resurs missions we combined our compact time-of-flight mass spectrometer (TOF-MS) with a chemical pre-separation of the species by gas chromatography (GC). Combined measurements with both instruments were successfully performed with the laboratory prototype of the mass spectrometer and a flight-like gas chromatograph. Due to its capability to record mass spectra over the full mass range at once with high sensitivity and a dynamic range of up to 10^6 within 1s, the TOF-MS system is a valuable extension of the GC analysis. The combined GC-MS complex is able to detect concentrations of volatile species in the sample of about $2 \cdot 10^{-9}$ by mass.

1. Introduction

Since all lunar soil samples available on Earth originate from a restricted area at the lunar near side, close to the equator, the Russian space agency will launch two spacecraft Luna-Glob and Luna-Resurs landing at the lunar poles. For the detection and analysis of the volatile species in the lunar soil, our Neutral Gas Mass Spectrometer (NGMS) was selected as a part of the GC-MS analytic complex. As an additional feature NGMS will also be operated as a standalone instrument to analyse the composition of the tenuous lunar exosphere.

2. The Neutral Gas Mass Spectrometer

The Neutral Gas Mass Spectrometer (NGMS) is a time-of-flight type mass spectrometer (TOF-MS) [4]. The neutral gas is ionised by electron impact ionisation. To achieve advanced performance a gridless ion mirror (reflectron) is integrated in the ion

path [3]. The ion optical design of NGMS is based on the P-BACE instrument [1].

A TOF mass spectrometer allows the acquisition of complete mass spectra at once without the necessity of scanning over the mass range. These qualities are combined with high sensitivity and a large dynamic range of up to 10^6 within 1s integration time useful for continuous measurements as they are needed for the analysis of the output of a chromatographic column (GC), which provides sample separation in temporal domain.

3. Experimental

3.1 GC-MS Setup

In the laboratory a sample valve with a defined sample volume is used as an injection system to load a sample into the chromatographic column. Due to the chemical properties of the chromatographic column and the kind of species to be analysed, the sample is separated in time at GC output. The species of interest, eluted in the carrier gas, are then detected and analysed with NGMS to their composition and structure (see Figure 1).

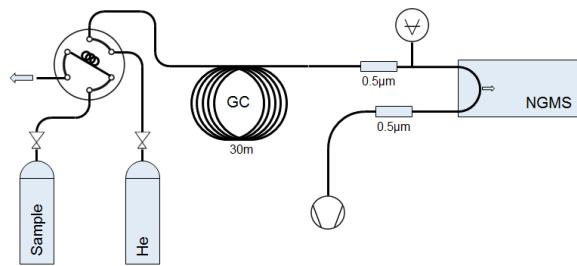


Figure 1: Scheme of the laboratory GC-MS setup with sample valve.

3.2 Measurements

Since the GC module we used provides an integrated Thermal Conductivity Detector (TCD), direct comparison between the data recorded by a TCD and NGMS is possible of the same sample.

For testing purposes a gas mixture of several organic compounds (at 1000 and 100 ppm level) with the helium carrier gas is used. A sample of that mixture is injected with the sampling system described in Figure 1. At the output of the chromatographic column the species are detected by TCD, non-destructively, and after a short transfer line the same sample is fed into NGMS.

Typical GC-MS data are shown in Figure 2, where the top panel shows TCD data over the full retention time span and the bottom panel shows the corresponding mass spectrometric data.

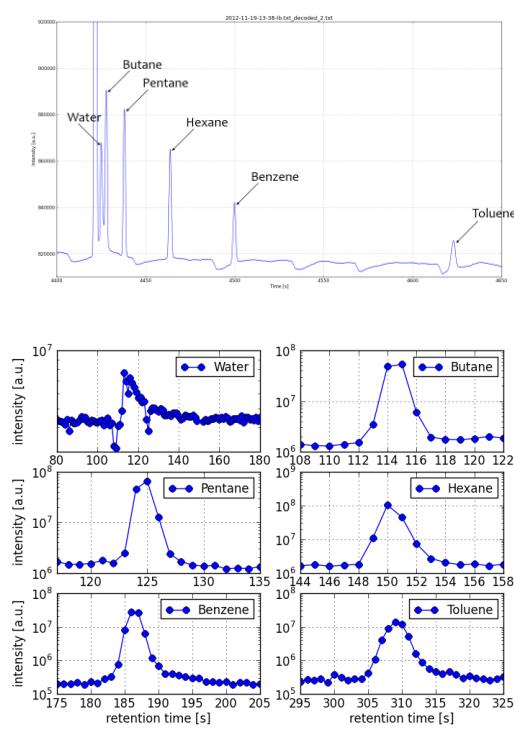


Figure 2: TCD data of a hydrocarbon mix (top) and mass spectrometric analysis of the peaks at GC output by NGMS (bottom).

As an example, the lower panel in Figure 2 shows the temporal evolution in mass spectrometric data of all six labelled peaks in TCD data. Shown is the composite signal of the parent molecule and its main fragments due to electron impact ionisation. By

selecting the most favourable fragments the signal-to-noise ratio can be maximised. Since the fragmentation pattern is characteristic to the molecular structure the fragments can also be used to identify the species.

Typically, mass spectra are recorded at 1s cadence, however, shorter cadences are easily possible (e.g. 0.1 s) when a difference in retention times of consecutive species makes this necessary.

Due to the high sensitivity and the large dynamic range of NGMS, the instrument is able to detect species in very low concentration, below the detection limit of the TCD. With the present system it's possible to detect 1 nmol with GC alone (TCD detection) and 10 – 100 pmol with the NGMS. For a volume of the sample oven of about 52 mm³ volatile species with a concentration as low as 2·10⁻⁹ by mass can be detected.

4. Summary and Conclusions

Combined measurements with chemical pre-separation by gas chromatography and analysis by our time-of-flight neutral gas mass spectrometer NGMS were performed successfully. During a GC-MS measurement NGMS acquires continuously complete mass spectra to record the maximum possible chemical information from the sample. Due to the high sensitivity and the large dynamic range of 10⁶ of NGMS, we can detect volatile species in the sample at a concentration of about 2 ppb by mass. For comparison, for the SAM instrument on the Curiosity rover a sensitivity for organic compounds of 1 – 10 ppb by mass has been quoted [2].

References

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