



Versatile Mars atmosphere simulation chamber used to test a combined Raman-LIBS instrument

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Abstract

The forthcoming ExoMars mission will search for life and characterise the geological environments. All the analytical techniques proposed to be used by the ExoMars rover need to be validated under Martian conditions. This is particularly the case for spectroscopic signal detection that will be dependent upon temperature and atmospheric conditions. Here we report a Mars atmospheric simulation chamber (MASC) fabricated at the Vrije Universiteit Amsterdam that is capable of operating between +40 and -40°C at sub mbar pressures. For calibration under Martian conditions a dominantly CO₂ atmosphere will be used between 0.1–30 mbar. This is followed by a comparison of the performance of the laser Raman under Martian environmental conditions compared to performance under Earth atmospheric conditions.

1. Introduction

Univocal evidence of past or present life on Mars is the principal objective of ESA's first mission of the Aurora programme, ExoMars. Due to its essential role in supporting all types of known life forms there is a huge scientific effort to search for evidence of water on Mars. Detection and quantification of the amount and form of water is therefore a key requirement of instrumentation on ExoMars. A combined Raman-laser induced breakdown spectroscopy (LIBS) was initially chosen to be a fundamental part of the rover Pasteur instrument package of ExoMars. Raman spectrometry would characterize mineralogy and organic compounds and simultaneously the LIBS determine multi-elemental compositions. Descoping of ExoMars means that only a Raman system will now be flown but the innovative RLS instrument is being considered for future missions to Moon and Mars. The principal goal of the work reported here was to set up a versatile Mars atmosphere simulation chamber

(MASC), which can allow comprehensive testing of components and entire instruments under the variable but extreme conditions characteristic of Mars. Our initial focus is to determine how Raman analyses are influenced by parameters such as temperature, $p\text{CO}_2$.

2. MASC System Design and control

MASC was designed to allow large prototype instruments to be tested under Martian conditions. The chamber is optimised to provide stable atmospheric conditions and minimal thermal gradients so that the influence of these parameters on analytical techniques can be rigorously assessed (Table 1). The cylindrical chamber is 1000 mm in length with an internal diameter of 440 mm. Independently cooled mounting plates are attached to the end doors meaning that instruments and samples can be maintained at different temperatures if required. In addition, independent cooling can be applied to detectors if required (e.g., CCD kept at low temperature).

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|--------------------------|---------------------------|
| Operating Pressure | 0.1 – 50 mbar |
| Background vacuum | <10 ⁻⁴ mbar |
| Leak tightness | <10 ⁻⁹ scc/sec |
| Atmospheric composition | Carbon dioxide ~100% |
| Water content | 0.05% |
| Temperature | -40 to +40 °C |
| Cool-down / warm-up time | One night (16 hours) |

Table 1: Operating conditions of MASC

The outer chamber wall has an isolation vacuum over its full length. Freon is used as the cooling fluid via contact with a heat exchanger containing silicon fluid. Internal temperature variation is monitored by 20 sensors. The atmosphere can be operated in static mode or continually flushed with CO₂. Numerous electronic feed throughs as well as optical ports are built into the end doors to provide the versatility required to test different instrumentation. This chamber is available for use to outside users as part of the trans-national access programme (TNA-2) of the Europlanet-RI initiative.

3. Summary and Conclusions

Production and control of various but stable temperatures throughout the chambers is a challenging aspect of any Mars chamber design. We have shown that MASC is able to produce and maintain uniform temperatures throughout the chamber volume and also has the flexibility to temperature for some devices sensitive at low temperature such as CCD detectors.

Initial work examined the behaviour of Raman vibration bonds in hydrated minerals (e.g., jarosite and amphibole) at Martian conditions, (i.e., in a CO₂ atmosphere at pressures between 5 and 12 mbar and temperature of -40 to +40 °C) compared to terrestrial measurements. As shown previously (1) low temperature has a significant influence on some Raman spectroscopic bands. Raman spectra in some samples show better resolved peaks with the appearance of new bands. Work is underway to fully quantify the temperature dependence of shifts in Raman bands, i.e., a simple correlation with temperature of significant shifts due to bond re-configurations. Subsequent work will also characterise variations in LIBS spectra in typical Martian minerals with changing temperature and $p\text{CO}_2$.

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References

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