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Venus Elemental and Mineralogical Camera (VEMCam)

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Abstract

The Venus Elemental and Mineralogical Camera (VEMCam) is an integrated remote LIBS and Raman instrument concept designed to operate from within the safety of the lander. The extreme Venus surface conditions requires rapid analyses and VEMCam can collect over 1000 chemical and mineralogical spectra within the first hour. Here, we discuss the VEMCam prototype calibration and analysis in which samples are placed in a 2 m long chamber capable of simulating the Venus surface atmosphere.

1. Introduction

The extreme ~462 **ºC** (735K) surface temperature and 9.2 MPa atmospheric pressure create a challenging environment for investigating the Venus surface. Rapid quantitative chemical and mineralogical investigations are required to understand how surface minerals and rocks interact with the Venus atmosphere. Remote measurements made from within the safety of the lander are ideal and avoid many risks, including use of sampling hardware and the extended time required to deliver samples to instruments inside the lander.

The Venus Elemental and Mineralogical Camera (VEMCam) can make thousands of measurements within the first two hours on the surface, providing an unprecedented description of the Venus surface. VEMCam is based on the ChemCam instrument on the Mars Science Laboratory rover and the SuperCam instrument selected for the Mars 2020 rover. VEMCam includes an integrated Raman and Laser-Induced Breakdown Spectroscopy (LIBS) instrument capable of probing many disparate locations around the lander. VEMCam also includes a color Remote Micro-Imager (RMI) to acquire high-resolution context images of targets analyzed by Raman and LIBS spectroscopy. This paper provides an overview of this highly capable VEMCam Raman and LIBS integrated instrument concept and prototype.

2. Raman and LIBS Spectroscopy

Raman and LIBS are highly synergistic techniques. Raman spectroscopy is fundamentally sensitive to molecular vibrations from which the definitive mineralogy is determined and chemistry is inferred. LIBS provides quantitative chemical analyses from

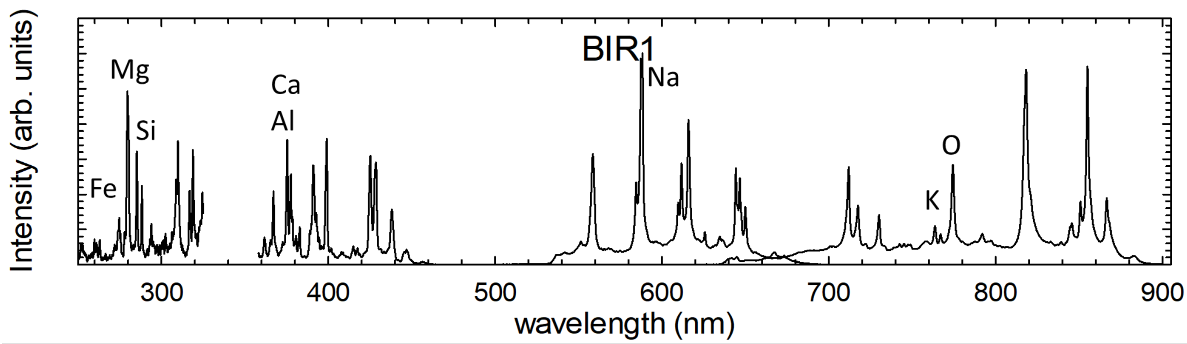

Figure 1: LIBS spectrum of the Icelandic Basalt (BIR-1) under simulated Venus atmospheric temperatures (465ºC) and pressure (92 atm).

which mineralogy can be inferred.

LIBS experiments focus a Nd:YAG laser (1064 nm, 10 Hz, 45 mJ/pulse) laser onto a sample surface. The laser ablates material and generates expanding plasma containing electronically excited atoms, ions and small molecules. These excited species emit light at wavelengths diagnostic of the species present. Some of this emission is collected with an 89 mm telescope and recorded with two reflection (275 – 500nm) and one transmission (535 – 800 nm) spectrometer. Figure 1 contains a LIBS spectrum of BIR-1 under simulated Venus surface conditions.

Figure 2 contains several Raman spectra collected with a pulsed and frequency doubled Nd:YAG laser (532 nm, 10 Hz, 20 mJ/pulse). The laser stimulates Raman-active vibrational modes in the sample producing Raman emission. Some of this emission is collected with an 89 mm telescope and recorded using the transmission spectrometer noted above.

3. Raman and LIBS Analysis

The samples probed by Raman and LIBS analyses are placed in the Venus chamber depicted in Figure 3. The Venus chamber is 2 m long, 110 mm diameter and can simulate the CO_2 supercritical environment.

Qualitative LIBS chemical analysis requires the collection LIBS spectra from a diverse set of standards probed under Venus surface conditions. This collection of chemical standard represents igneous powers including BIR-1 (Figure 1), BCR-2, BHVO2, AGV2, DH4909, DH4911, DH4912, and GBW07105. These raw spectra are processed by methods similar to those developed for ChemCam [1]. A partial least squares model is developed using the processed spectra from which quantitative LIBS analysis is completed [2, 3].

Raman analysis consists of the generation of a spectral library of pure mineral samples. The diagnostic spectral features from each pure mineral are used to interpret the mineralogical signatures from mixed samples. The bottom half of Figure 2 contains pure mineral spectra collected under Venus surface conditions. These spectra are used to identify the minerals present in the mixed sample in the top half of Figure 2. These experiments also demonstrate that the Raman fingerprints of minerals are insensitive to the surface pressure and temperature.

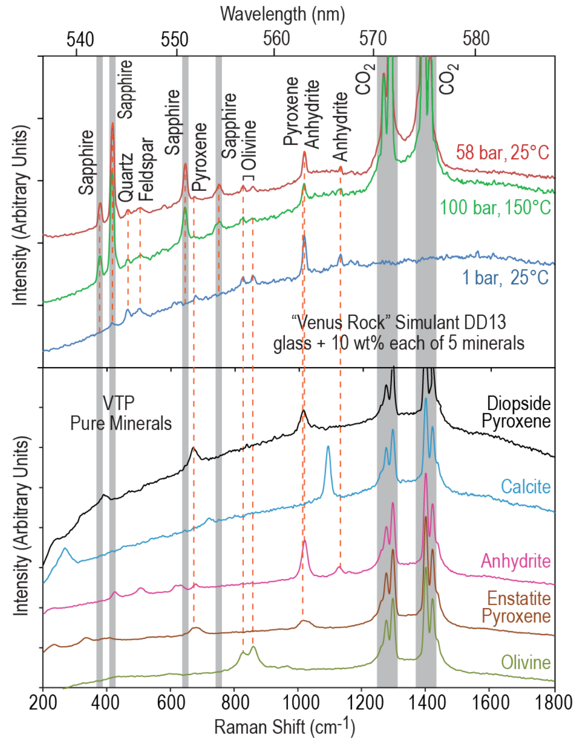

Figure 2: Raman spectra of various mineral mixtures (top) and pure minerals (bottom) [4].

Figure 3. The 2 m long, 110 mm diameter Venus chamber used for sample analysis at >92 atm of CO_2 at >465ºC.

References

[1] Wiens et al. Spectrochimica Acta B, 2013, 82, 1-17. [2] Clegg et al. Spectrochimica Acta B, 129 (2017) 64–85, [3] Anderson et al. Spectrochimica Acta B, 129 (2017), [4] Clegg et al. Applied Spectroscopy, 68 (2014) 925-936.