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Thermal InfraRed (TIR) laboratory experiments in support of the interpretation of new Martian orbital data

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Abstract

In this work, we show the main results of a laboratory program aimed to collect emissivity spectral data of particulates samples of Martian analogue materials and their mixtures in the Thermal InfraRed (TIR) spectral range. The results of these measurements will support the analysis and interpretation of new orbital TIR spectral datasets. The emissivity of the selected materials is measured, at low (20°C) to medium temperatures (150°C) within an external home-designed emissivity chamber attached to a Bruker Vertex80V FTIR spectrometer, with liquid nitrogen cooled HgCdTe (MCT) detector and KBr beamsplitter. Spectral parameters are retrieved to study their behavior in relation with compositional changes, percentage, grain size and temperature gradients. Emissivity spectra of thermally processed samples are compared with hemispherical reflectance spectra acquired before and after the thermal process.

1. Introduction

Much knowledge of Mars mineralogy relies on data collected remotely, using infrared spectroscopic tools [1,2,3]. Nearly every mission to Mars has onboard an instrument devoted to spectroscopy. This includes the imaging spectrometer Observatoire pour la Mineralogie, l'Eau, le Glace e l'Activite (OMEGA) [4] and the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [5], that provide remote measurements of mineralogy in the Near-InfraRed (NIR) spectral range. The information supplied by OMEGA and CRISM in the NIR has been completed by TES [6] and PFS [7] in the Thermal-InfraRed (TIR) and it will be improved thanks to the higher spectral resolution of the new TIRVIM spectrometer of the ExoMars2016 mission [8]. The analysis of orbital TIR spectral data has a huge potential: it provides a large amount and wide variety of information on the composition, temperature and state of the surface and the atmosphere as well as their interaction.

The goal of this study to contribute to the laboratory information needed to correctly interpret remote sensing thermal orbital spectra from the Martian surface, by more thoroughly analyzing the effects of temperatures, mineral proportions, and particles size on the spectral properties of Martian analogue material in the TIR spectral range.

2. Samples choice

The suite of samples selected for this work includes pure end-member minerals that most closely represent class of minerals detected on the Mars' surface using OMEGA and CRISM data [e.g. 4, 9, 10]. Martian analogues including clays, silicates, carbonates, oxides and sulfates are measured in two different configurations: emissivity at different T and hemispherical reflectance.

3. Experimental set-up

Measurements are performed in the Planetary Spectroscopy Laboratory (PSL) of the German Aerospace Center (Deutschen Zentrums für Luft- und Raumfahrt, DLR) in Berlin [11].
Emissivity measurements are recorded by using an external emissivity chamber home-designed to work from 1 to 150 µm, with a high SNR for sample temperatures from ~ 300 to ~ 1000 K. The external chamber is attached to a Bruker Vertex80V FTIR spectrometers by means of KBr or CsI windows allowing the evacuation of the instrument [11].
Hemispherical measurements are recorded by using a gold-coated lab-sphere adapted for vacuum measurements that fits into the same spectrometer.

4. Laboratory measurements

The main steps of our study are:

- Emissivity and reflectance characterization of particulate samples (including pure materials and mixtures);

- Comparison between emissivity and hemispherical reflectance spectra of particulate samples at different temperatures;
- Systematic study of parameters influencing the spectral behavior of laboratory particulate pure samples and mixtures, conducted during and after the measurements, to establish detection limits and behavior of mineral mixtures of fine particulates in the thermal infrared portion of the spectrum.

Hemispherical reflectance is measured for all the selected samples before and after the thermal process. The emissivity spectra obtained are calibrated against an appropriately chosen blackbody. To derive the sample emissivity, the sample are measured at a certain temperature T, and then the radiance obtained (I) is divided for the blackbody radiance (BB) measured at the same temperature T. To obtain the same temperatures, sample and blackbody temperatures are monitored by using thermocouples inside the emissivity chamber.

5. Summary and discussion

In the present work we have developed and applied to Martian analogue samples a laboratory procedure for the analysis of particulate mixtures and their pure components. The main point of this work is the study of the variation of their key spectral features in the TIR spectral region in relation with increasing temperature, grain size and mixing of two different components.

The experiments performed in this work represent a first step of a systematic laboratory study program aimed at a better interpretation of planetary orbital data for a careful detection of the materials present on the Martian surface. Measurements are used to build an improved spectral library, which is then applied to the interpretation of orbital data.

This work has been thought in the framework of the ExoMars 2016 mission, and in preparation for the up-coming in-situ measurements of the ExoMars 2020 rover, but it gives also useful insight for the investigation of other planetary surfaces.

Examples of emissivity spectra obtained for two of our samples are shown in **Figure 1**. The spectra are shown in comparison with emissivity spectra retrieved from hemispherical reflectance measurements. Pictures of the two samples taken during the measurements, are also shown.

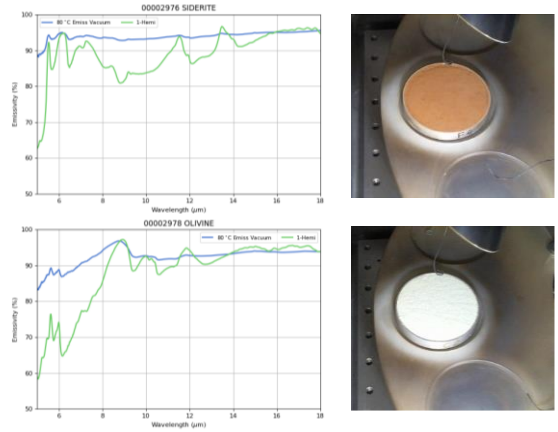

Figure 1. Left: Comparison between emissivity measured in the vacuum chamber at T=80°C and emissivity retrieved from hemispherical reflectance measurements performed at T ambient for siderite (up) and olivine (bottom) samples. **Right:** Pictures of two samples in the emissivity chamber taken during the measurements.

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