A THERMAL EMISSION AND REFLECTION SPECTRAL LIBRARY OF ROCKS FOR THE INTERPRETATION OF CHANG'E 4 AND PLANETARY MISSION DATA. A. Maturilli[1], J. Helbert[1], G, Alemanno[1], S. Schwinger[1], A. Neumaier[1], Y. Wu[2] [1]Institute for Planetary Research, German Aerospace Center DLR, Rutherfordstr. 2, 12489 Berlin, Germany (alessandro.maturilli@dlr.de), [2]Purple Mountain Observatory, Nanching, China.

Introduction: In the last decades orbital spectroscopic observations of the lunar surface have greatly advanced our understanding of the global distribution of different rock types and their chemical compositions. This vast dataset is now complemented by the first in situ reflectance spectra from the lunar surface obtained by the recent Chang'E 3 and current Chang'E 4 missions, which provide more detailed information about the mineralogy of local surface materials and the geological context of the landing sites.

The material analyzed by Yutu-2 at the Chang'E 4 landing site includes not only regolith but also a fragment of rock with a small- to medium grained plutonic texture, that has most likely been excavated by a nearby impact crater [1]. Due to its deep-seated origin, the composition of such a rock fragment is of particular importance for understanding the underlying stratigraphy of the landing site.

A reliable quantification of mineral modal abundances from measured reflectance spectra requires the availability of laboratory spectra of comparable samples. However, current spectral databases primarily contain spectra measured on powder samples, while spectra of coarse grained rock samples are rare. Since reflectance spectra are sensitive to grain size and surface roughness [2], the available powder spectra might not be sufficient for a quantitative interpretation of measured rock spectra.

Rock samples obtained during the Apollo missions indicate that lunar anorthosites are typically coarse grained and can reach grain sizes of more than 1 cm. Hence, the global abundance of anorthosite as the dominant rock type of the lunar surface suggests that such coarse grained rocks are ubiquitous.

Therefore the extension of the current spectral databases by new spectral data of whole rock samples is crucial for the interpretation of current in situ measurements and similar analyses made during lunar and other planetary missions, as Hayabusa2 and OSIRIS-REx.

Set-up description: The Planetary Spectroscopy Laboratory (PSL) of DLR in Berlin is a well established spectroscopy facility providing spectral measurements of planetary analogues from the visible to the far-infrared range for comparison with remote sensing spacecraft/telescopic measurements of extraterrestrial surfaces [3-7]. Three identical FTIR instruments are operating at PSL, in an air-conditioned room (Figure 1). The spectrometers are Bruker Vertex 80V (high-end model) that can be evacuated to ~.1 mbar. One spectrometer is equipped with aluminum mirrors optimized for the UV, visible and near-IR, the second features gold-coated mirrors for the near to far IR spectral range.

Using identical instruments has two major benefits. The instruments can share the detectors and beamsplitters in our collection to cover a very wide spectral range, and this facilitates the cross-calibration between the three instruments. The spectrometers and the accessory units used are fully automatized and the data calibration and reduction are made with quality controlled DLR developed software. High power (24V, water cooled) external sources feature the PSL set-up to cover the UV (0.2 to 0.5 µm) to the VNIR+TIR (1 to 16 µm) spectral range. Two internal sources from VIS to FIR complete the available offer for illumination sources.

Figure 1. Laboratory set-up at the PSL.

Spectral measurements: External simulation chambers are attached to the FTIR spectrometer to measure the emissivity of solid samples. One chamber features a high efficiency induction system to heat the samples under vacuum to temperatures from 320K up to above 900K, while keeping the chamber at almost ambient temperature. A shutter allows separating the spectrometer from the external chamber. Sample cups are made of stainless steel and have elevated rims enclosing the samples heating it from all sides, effectively supressing thermal gradients within. A sample carousel driven by a highly precise stepper motor allows measuring several consecutive samples without breaking the vacuum. A large number of temperature sensors in the emissivity chamber are allocated to measure the sample temperature as well as monitoring the range of equipment and chamber temperatures. A webcam is mounted in the emissivity chamber to monitor the heated sample and its vicinity.

With the Bruker A513 accessory we measure bi-directional reflectance of samples, with variable incidence and emission angles between 0° and 85° (minimum phase angle is 26°). Samples can be measured at room temperature and currently down to 170K using a test setup cooled by liquid nitrogren inside the spectrometer sample chamber. Recently added integrating spheres (one with gold mirror, the other with PTFE mirror) allow for hemispherical reflectance measurements (MIR soon under vacuum).

We can measure bi-directional and hemispherical reflectance under purging or vacuum conditions, covering the 0.2 to above 200 µm spectral range.

Sample preparation and measurements: The initial suite of samples selected for this work includes: - slabs and stone chunks of plagioclases such as anorthosite, diorite, monzodiorite, gabbro and diabas; - salts such as hexahydrite; - iron meteorite samples, among them ataxites and octahedrites.

Samples are placed in the emissivity chamber at PSL and heated in vacuum slowly and gradually up to 400° C. Measurements were taken at 100° C, 200° C, 300° C and 400° C in the MIR and FIR spectral ranges. For the measurements in the MIR, a MCT nitrogen cooled detector and KBr beamsplitter have been used. Spectra in the FIR have been acquired using a room temperature DGTS detector and a Multilayer beamsplitter.

Each sample has been cooled in vacuum down to T_{room}. Thermally processed samples are measured in hemispherical and bi-directional reflectance in the full spectral range from UV to FIR.

A sample of graphite has been measured in emissivity at increasing T, adopting the same configuration and procedure used for the measurements on our samples. The graphite spectra obtained were used to calibrate the emissivity for sample measurements. Figure 2 shows the calibrated emissivity spectra for an anorthosite sample measured at 4 temperatures.

Effect of increasing temperature can be seen on the emissivity spectra: we notice a shift toward longer wavelengths on increasing temperature for the adsorption bands centered around 9.5, 10.2, and 10.6 µm, so like for the peaks located around 9.8, 10.3, and 11.7 µm. The small adsorption band centered around 12 µm seems to be independent from the sample surface temperature. We notice a trend in the peak located around 13 µm: the feature is linearly increasing with the sample temperature, and the peak position is shifting as well toward longer wavelengths. The emissivity maxima around 9 µm shows a trend with increasing temperature too: we do not notice a band shift but the value of the emissivity peak is decreasing with the temperature, as already noticed in [8] for a coarse olivine sample measured in emissivity at similar temperatures.

Conclusion: The PSL is constantly improving to provide the planetary community with reflectance, transmission and emissivity measurements highly complementary to existing spectral databases, under vacuum, that cover the whole spectral range from UV (0.2 µm) to the FIR (200 µm and above), and for sample temperature from 70K to 1000K. In this work we present the first spectral database for reflectance and emissivity of rocks, especially selected for the interpretation of the China National Space Administration (CNSA) mission Chang'e 4 to the Moon. We foreseen to continue adding measurements of new rocks to make the database as much complete as possible for planetary interest.

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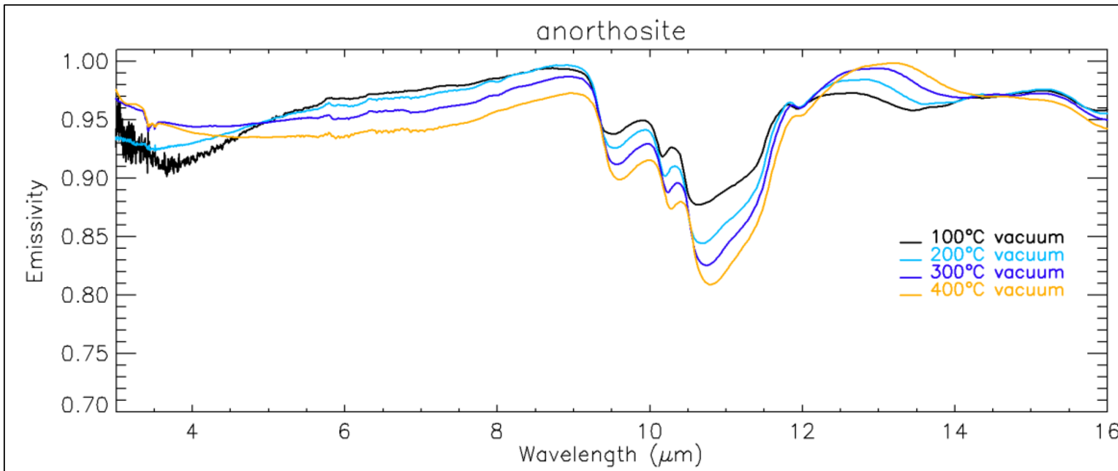

Figure 2. Calibrated emissivity at 4 temperatures for an anorthosite sample.