

CHARACTERIZING THE EFFECTS OF SMALL-SCALE SURFACE TEXTURES ON THERMAL IR SPECTRA OF APOLLO BULK LUNAR SOILS. A. Husic¹, K. L. Donaldson Hanna¹, B. T. Greenhagen², and N. E. Bowles³, ¹University of Central Florida, Orlando, FL (adis@ucf.edu), ²Johns Hopkins Applied Physics Laboratory, Laurel, MD, ³University of Oxford, Oxford, UK.

Introduction: Apollo mare and highland soils [e.g., 1-3] as well as basaltic rocks [4] have been well-characterized across the visible- to near-infrared (VNIR) wavelengths including the effects of mineralogy, mineral chemistries, ilmenite content and space weathering on their spectra. These lab analyses provided ground truth to remote sensing observations from Earth-based telescopic and spacecraft like those from Clementine, Galileo, Kaguya/SELENE, and Chandrayaan-1 as well as providing key insights into the composition and evolution of the lunar surface. Diviner Lunar Radiometer, a thermal infrared (TIR) radiometer onboard the Lunar Reconnaissance Orbiter (LRO), making it necessary to characterize Apollo samples across TIR wavelengths. The near-surface vacuum environment of airless bodies like the Moon creates a thermal gradient in the upper hundred microns of regolith. Lab studies of particulate rocks and minerals (< 100 μm) as well as selected lunar soils under vacuum and lunar-like conditions have identified significant effects of this thermal gradient on TIR spectral measurements [e.g., 5-10]. Such lab studies demonstrate the high sensitivity of TIR emissivity spectra to environmental conditions under which they are measured.

In this work, an initial set of TIR emissivity measurements of bulk lunar soil samples are made in the Planetary Analogue Surface Chamber for Asteroid and Lunar Environments (PASCALE) built by University of Oxford to constrain the ‘best’ practices for simulating the near surface environment of the Moon, including the effects of sample packing. Here we focus on characterizing the spectral changes observed due to small-scale surface textures created by packing the sample into the sample cup using a range of techniques. To best understand the difference between returned samples measured in the lab on Earth and undisturbed lunar soils in their native setting, we will compare our lab measurements to Diviner TIR observations of the Apollo sampling stations. These comparisons are integral for constraining thermally derived compositions and properties of the lunar surface from current and future TIR datasets of the Moon and other airless bodies.

Methodology: This initial study includes Apollo bulk mare soil sample 15071 and highlands soil sample 61141. To characterize a range of small-scale surface

textures, samples were prepared in four different ways and spectra were collected of each to characterize the effects due to sample preparation.

The first method was to fill a sample cup with the soil and then flattening the surface by taking a lab spatula across it, known as the ‘flat edge’ samples. The first method is a common sample preparation technique used in laboratories. The second method was to pour soil into a sample cup and then tapping the cup bottom on a counter until the surface was mostly level, avoiding over-tapping which would cause larger particles to rise to the top, known as the ‘tapped’ samples. The third method was to spoon the sample directly from the vial into the cup (rather than pouring) and does not involve flattening but instead leaves the surface texture intact, known as the ‘spooned’ samples. The fourth method was to pour the soil into a sample cup and using a flat surface to gently press the sample to flatten and compress it, known as the ‘pressed’ samples. Figure 1 includes images of Apollo 61141 prepared using these four methods.



Figure 1. Apollo bulk soil 61141 prepared in the sample cup using four different methods.

Once prepared, these samples were loaded into the PASCALE. Details of sample measurements and calibration procedures with PASCALE have previously been described by [11]. PASCALE allows operation in ambient and simulated lunar environment (SLE) conditions. Under ambient conditions, samples are

heated from below to 353K, with the chamber at room temperature ($\sim 295\text{K}$) and a pressure of ~ 1000 mbar with N_2 gas. Under SLE conditions, the chamber is pumped down to $\sim 1 \times 10^{-4}$ mbar and cooled to temperatures below 125K. The samples are heated from below to 353K and heated from above via a quartz halogen lamp to a brightness temperature of $\sim 390\text{K}$. Once brought to a stable temperature, samples were measured across thermal infrared (TIR) using a Bruker Vertex 70V FTIR spectrometer. Spectra were measured at a resolution of 4 cm^{-1} over the $\sim 2000\text{-}200\text{ cm}^{-1}$ range using a wide-range beamsplitter [11].

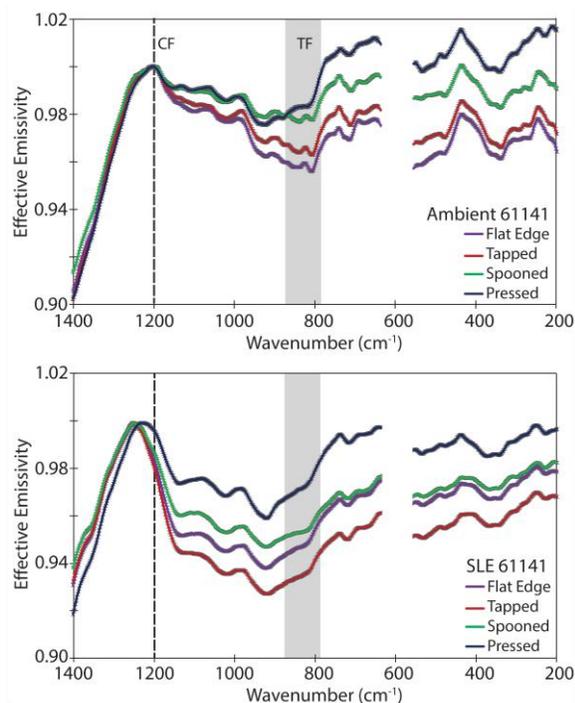


Figure 2. (top) Ambient emissivity spectra of Apollo bulk soil 61141 prepared in the sample in four different ways as shown in Figure 1. **(bottom)** SLE emissivity spectra of the same Apollo 61141 samples. The dashed vertical line near 1200 cm^{-1} highlights the Christiansen feature (CF) identified in the ambient spectra of 61141. The grey vertical box highlights the transparency features (TF) in the ambient spectra. Uncertainties in the spectral measurements are shown as error bars on each spectrum. Low SNR data near 600 cm^{-1} related to the FTIR beamsplitter's low transmission [11] have been removed.

Results: Figure 2 shows the plots of ambient (top) and SLE (bottom) spectra for Apollo bulk soil sample 61141 prepared using the four methods described above. The position and shapes of the Christiansen feature (CF) and vibration bands in the ambient spectral measurements are quite similar. Two main differences are observed: 1) the depth of the transparency feature

(TF) varies in depth across the different sample preparation methods with the pressed sample having the shallowest TF and 2) the general slope of each spectrum is different across the $1200 - 800\text{ cm}^{-1}$ and $700 - 200\text{ cm}^{-1}$ spectral ranges. The observed differences in TF depth is most likely related to the porosity of the sample as different sample preparation methods creates different textures and porosity. As the surface of sample is compressed, the pore size between regolith grains decreases and the sample begins to spectrally behave more like coarse particulates and whole rocks and the TF becomes less pronounced [e.g., 6,12]. The pressed and spooned sample spectra have reduced TF depth suggesting the porosity of those samples have decreased. This behavior is not surprising for the pressed sample as the surface of the sample was compressed as part of the sample preparation. However, it is unexpected that the slight compaction from the spoon used in the sample preparation is enough to alter the porosity and thus the spectrum.

In the SLE spectra, the position and shape of the CF and vibration bands are similar for the tapped, spooned, and flat edge spectra. The only observed difference between those spectra is the spectral contrast between the CF and the vibration bands. In the pressed sample spectrum, the CF position is identified at a lower wavenumber than the CF positions identified in the other SLE spectra. Also, the pressed sample spectrum has a CF that is more rounded and the contrast between CF and vibration bands is reduced. These observed differences in the pressed sample spectrum are due to the decreased porosity in the sample.

Discussion: Future work will focus on quantifying the observed spectral differences due to sample packing and comparing these lab measurements of Apollo 61141 and 15071 to Diviner observations of the Apollo sampling stations where each sample was collected. These comparisons will allow us to better understand the 'best' practices for measuring lunar soils in labs in order to best simulate near surface conditions on the Moon.

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