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Spectral Characterization of a Suite of Well-Characterized Bulk Lunar Soils from the Ultraviolet to the Far Infrared at the Planetary Emissivity Laboratory, DLR Berlin.

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Abstract

Here we present a comprehensive set of laboratory measurements from the ultraviolet (UV) to the far infrared (FIR; 0.2 – 75 µm) on a suite of well-characterized lunar analogues. The objectives of the study included (a) characterize the reflectance of a suite of well-characterized samples across the UV to FIR under a controlled geometry and (b) comparing orbital UV, visible to near infrared (VNIR), thermal infrared (TIR), and FIR measurements of the Apollo landing sites with our laboratory reflectance and emissivity measurements to gain a better understanding of the difference between returned samples and undisturbed soils in their native setting.

1. Introduction

We utilized the facilities within the Planetary Spectroscopy Laboratory (PEL) at DLR, Berlin to characterize the reflectance from the UV through the FIR of a suite of lunar analogues in February 2018. These reflectance measurements, covering the entire spectral range, are the first of their kind. In addition, emissivity measurements were made across thermal infrared wavelengths to characterize differences between reflectance and emissivity across the TIR spectral range.

Our laboratory measurements will enable the analyses of past, current, and future remote sensing observations to constrain the surface compositions of airless bodies including the Moon, Mercury, and asteroids. These remote sensing observations included Mariner 10, Clementine, Smart-1, Chandrayaan-1, SELENE/Kaguya, MESSENGER, Diviner Lunar Radiometer, the Lunar Reconnaissance Orbiter Camera, Spitzer Space Telescope, BepiColombo, and James Webb Space Telescope.

2. Sample Suite

The analogue sample suite included well-characterized Apollo bulk soil samples and terrestrial minerals. Apollo bulk soils included samples from 5 of the 6 landing sites and with a range of compositions and maturities. The specific Apollo soils measured were 10084, 14259, 15071, 15201, 15411, 15601, 66031, 67701, 70181, 72501, and 79221. These soils have previously been characterized in reflectance by the Lunar Soil Characterization Consortium (LSCC) [e.g. 1-3] and in emissivity by Donaldson Hanna et al., [4].

Terrestrial mineral samples included a lunar-like anorthite (Miyake-jima anorthite with similar Ca- and Fe-contents as lunar anorthites), the same lunar-like anorthite that had been laser irradiated to simulate the effects of space weathering, San Carlos olivine (a well-characterized sample across most spectral ranges), a Mg-rich spinel, and a Mg-rich enstatite. All terrestrial mineral samples were fine particulates (< 75 µm). Several of these samples have been previously characterized in reflectance in RELAB and in emissivity by Donaldson Hanna et al., [4].

While most of these samples have been previously measured across specific spectral ranges, the new measurements made during this campaign filled necessary wavelength gaps (e.g. 0.2 – 0.4 µm, 2.6 – 7.0 µm, and 25-50 µm) and provide spectra across the entire UV to FIR spectral range from a single reflectance set-up and FTIR spectrometer.

3. Laboratory Measurements

Each of the samples was measured in the bi-directional reflectance set-up that sits in the sample compartment of the Bruker Vertex80V Fourier Transform Infrared (FTIR) spectrometer at the PEL. Samples were measured under vacuum conditions (pressures < 1hPa) across the 0.2 – 75 µm spectral range at a spectral resolution of 4 cm^{-1}. Each sample was measured with a fixed geometry of 30° phase angle (incidence 17° and emergence 13°).

As an inter-comparison check with other laboratories, San Carlos olivine was measured across all wavelengths. This olivine has been measured and characterized by most laboratory spectroscopy facilities in reflectance, emission, and transmission, thus its spectra are well known. Our initial analyses suggest that the reflectance measurements are comparable to previously measured San Carlos olivine reflectance spectra and that the signal to noise is sufficient to uniquely distinguish all spectral features from the noise.

In addition to the UV through FIR reflectance measurements of the lunar analogues, emissivity measurements were made of a select group of samples (e.g. samples where there was sufficient material to fill the emissivity sample cups). These samples included Apollo soil 10084, San Carlos olivine, Miyake-jima anorthite, Mg-rich spinel, and the Mg-rich enstatite. These measurements were made in an environment chamber that was backfilled with dry air, was cooled to 4C using a water chilling unit, and were heated from below to 80C. These calibrated emissivity spectra will be directly comparable to those that we make in the Planetary Spectroscopy Facility at the University of Oxford [e.g. 5].

4. Summary

Using the extensive spectroscopic facilities at the Planetary Emissivity Laboratory at DLR, Berlin, over 50 science quality spectra across a very wide (UV to FIR) spectral range were recorded for a suite of lunar samples, representing five out of the 6 landing sites. In addition, analogue samples including a San Carlos olivine, a Mg-rich enstatite, and a laser irradiated Miyake anorthite sample were measured across the same wide spectral range.

Analysis of the new laboratory data is ongoing and the spectra will provide a new measurements for the analysis of multispectral and hyperspectral lunar and other Solar System airless bodies remote sensing data for past, present, and future missions.

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