OBSERVING THERMAL EMISSIONS OF MINERAL MIXTURES ACROSS THE LUNAR TERNARY WITH THE SIMULATED AIRLESS BODY EMISSION LABORATORY.

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Introduction: The uppermost layer of soil on airless bodies is referred to as the “epiregolith,” which represents the boundary between a planetary surface and space. On the Moon, this layer is typically less than 2 mm in thickness, but dominates spectral observations from the far-ultraviolet to the far-infrared. The lack of atmosphere on the Moon compared to Earth (of which the epiregolith is largely isothermal) results in significant thermal gradients (~60K/100µm) due to airless bodies lacking the convective heat transfer provided by a thick atmosphere [1]. This ensures that the spectral emissions of regolith on the Moon appear different than they would on Earth.

To address this issue, we have measured thermal infrared (TIR) emissions of lunar-like mineral mixtures in the Simulated Airless Body Emission Laboratory (SABEL) at Johns Hopkins University Applied Physics Laboratory. SABEL is an environmental chamber that illuminates and heats particulate samples under a cold shroud in vacuum to generate a thermal gradient akin to that found in the epiregolith of the Moon. These measurements provide ground-truth observations to remotely-sensed data collected by the Diviner Radiometer Experiment (Diviner) aboard the Lunar Reconnaissance Orbiter (LRO) [2].

SABEL Measurement Setup: Measurements of minerals under a simulated lunar environment involve: (1) pump the chamber down to a vacuum of <10e^{-4} mbar, a pressure sufficient to simulate lunar heat transport processes within a space [3]; (2) cool the chamber cold shroud to ~130K to simulate the cool space environment above the epiregolith; (3) heat the particulate sample from below using a heating element to simulate the ambient temperature of the moon at 2 mm depth; and (4) illuminate the sample from above using a lamp to simulate solar radiation and heat the sample surface [2]. The interior of SABEL’s chamber includes a liquid-nitrogen-cooled cold shield, a quartz-halogen lamp (with an angle of illumination of 50°), a parabolic mirror to reflect thermal emissions to the spectrometer, as well as a rotating sample carousel with six heated sample cups, a blackbody target, and a calibration target. Vacuum is provided by a Pfeiffer HiCUBE 300 Classic pump system, which includes both a backing and turbomolecular pump. The chamber is connected to a Bruker Vertex 70v FTIR spectrometer via a KBr window, and is kept under a vacuum using a Pfeiffer HiScroll Dry Scroll vacuum pump. The spectrometer is equipped with both Mercury-Cadmium-Telluride (MCT) and Deuterated Triglycene Sulfate (DTGS) detectors.

Samples: SABEL has been used to study a wide range of powdered mineral mixtures featuring similar characteristics to lunar minerals, as well as Apollo samples. One of the largest sample suits studied in SABEL is the “Lunar 3-Mixture” (L3M) collection, which consists of 49 terrestrial mixtures of 3 endmembers of minerals with lunar-like compositions. The endmembers used are Miyake Jima anorthite (~An95), Tanzanian enstatite (~Mg90), and San Carlos olivine (~Fo90) [1]. The minerals were crushed and sieved to a size of <32 µm, and separated into 49 mixtures of varying percentages of each endmember.

Samples are mixed thoroughly and placed into a 28 mm diameter by 2 mm deep sample cup that fits into SABEL’s rotating carousel. A flat edge is used to smooth the surface of the sample cup of any excess sample.

Results and Applications: Spectra produced under a simulated lunar environment have three main characteristics within the 6-25 µm range: (1); a Christiansen feature (CF), the wavelength of the transmission maximum located between 7.5-10 µm for silicates [4], (2) Reststrahlen bands (RB), molecular vibrational bands caused by Si-O stretching and bending in the 8-14 µm region [4]; and (3) a transparency feature (TF), an emissivity minimum in a mineral’s spectra that occurs between 10-15 µm (Figure 1) [4].

While the spectral shape of a mineral stays relatively the same under SLE and ambient conditions, slight variations occur within the TF, CF, and RB regions. It has been determined that under a simulated lunar environment, (1) the CF position shifts to shorter wavelengths; (2), the spectral contrast of the RB and TF decreases; and (3) the overall

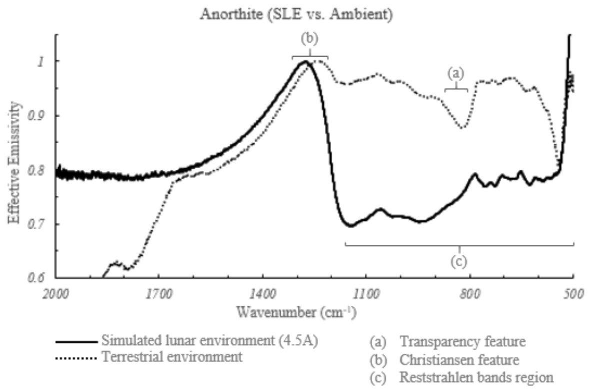

Figure 1: *Comparison of the effective emissivity of anorthite under simulated lunar environment and terrestrial settings. Three main diagnostic features of thermal infrared spectra (transparency features, Christiansen features, and Reststrahlen bands) are shown.*

spectral contrast increases [1]. Figure 1 shows a comparison between pure anorthite (A100) TIR emissions under SLE and Ambient conditions. Under earthlike-conditions, A100 has a CF position at 8.05 µm; while under SLE conditions, the CF position shifts to 7.83 µm, featuring a position change of -0.22. For pure enstatite (E100), the CF position shifts from 8.39 µm to 8.18 µm (ΔCF = -0.21); for pure forsterite (F100), the position shifts from 8.96 µm to 8.85 µm (ΔCF = -0.11). As shown in Figure 2, a generally linear trend in CF position shift was observed in both lamp settings ($R^2 = 0.871$ for 3.2A, and $R^2 = 0.896$ for 4.5A). Mixtures with a higher olivine concentration did not follow these linear trends as closely as mixtures with higher anorthite concentrations.

Additional Measurements and Future Work: In addition to the L3M sample suite, measurements of eleven Apollo samples have also been collected with SABEL (including samples from Apollo 11, 14, 15, 16, and 17). Two of these samples (Apollo 15071 and 61141) have also been measured under a similar vacuum environment chamber located at the University of Central Florida, known as Planetary Analogue Surface Chamber for Asteroid and Lunar Environments (PASCALE). PASCALE and SABEL are very similar in that both chambers utilized the same lamps, spectrometer, surface temperatures, and chamber pressures, with the main difference being the angle of illumination of the solar lamp (50° and 55° for SABEL and PASCALE, respectively) [2].

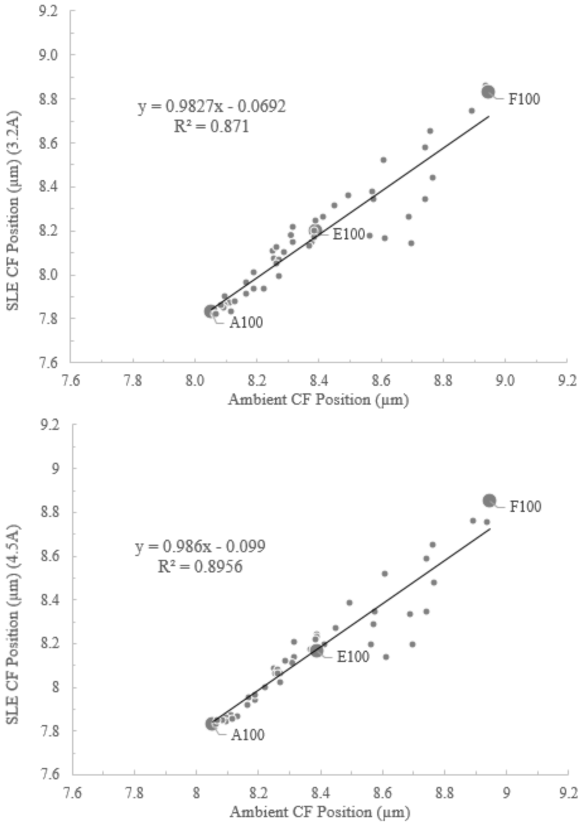

Figure 2: *Comparison in Christiansen feature (CF) position for simulated lunar environment settings (at 3.2A and 4.5A lamp settings) against terrestrial settings. A linear shift in CF position from SLE to Ambient measurements is noticeable in both lamp settings*

The results of this experiment will be explained further in this abstract's corresponding poster.

Future plans for SABEL include running the sample suite on a gold-coated A562 Integrating Sphere, which works as an accessory to SABEL's spectrometer. It is predicted that measurements under an integrating sphere will provide additional insight into the diffuse reflectance spectra of our sample catalogue.

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References: [1] Greenhagen B. T. et al. (2019) *AGU*, Abstract #P32A-04. [2] Greenhagen B. T. et al. (2019) *LPSC 50*, Abstract #2751. [3] Logan L. M. and Hunt G. R. (1970) *JGR*, 75, 6539-6548. [4] Greenhagen B. T. (2009) [Doctoral Dissertation, UCLA].