ASTEROID AND LUNAR ENVIRONMENT CHAMBER (ALEC): SIMULATED ASTEROID AND LUNAR ENVIRONMENTS FOR MEASURING ANALOG MATERIALS.
K. L. Donaldson Hanna[1], C. M. Pieters[1], W. R. Patterson III[1], T. Hiroi[1], D. Moriarty[1], M. B. Wyatt[1], and C. Thompson[2], [1]Department of Geological Sciences, Brown University, Providence, RI 02912, (Kerri_Donaldson_Hanna@Brown.edu), [2]ATK Mission Research, Logan, UT 84341.

Introduction: Thermal infrared (TIR) emissivity spectral measurements of planetary surfaces have diagnostic features indicative of rock and mineral compositions. These include: (1) the Christiansen feature (CF), an emissivity maximum resulting from a rapid change in the refractive index at wavelengths just short of the fundamental molecular vibration bands, (2) the reststrahlen bands (RB), the fundamental molecular vibration bands due to Si-O stretching and bending motions, and (3) transparency features (TF), emissivity minima caused by volume scattering in a spectral region of relative transparency between the principal RB.

Conel [1] found that the CF position in silicates is diagnostic of mineralogy and average composition and changes with the change in bond strength and molecular geometry associated with changing mineralogy. Previous laboratory emissivity measurements of particulate rocks and minerals under vacuum and lunar-like conditions [2,3,4,5,6,7] observed a shift in CF position to shorter wavelengths (higher wavenumbers), an enhancement in the spectral contrast of the CF maximum, and a decrease in the spectral contrast of the RB. The RB absorption positions, shapes and intensities, and number of absorptions are dependent on the masses, geometry, and bond strengths between anions and cations within a crystal lattice. Thus, each mineral has a diagnostic set of RB absorptions owing to each mineral's unique composition and/or crystal structure [1,3,8]. TF, like the CF, are indicators of mineral compositions and there is a higher-probability of determining specific rock type compositions if both the CF and TF are used for interpretations [3,9]. As particles decrease in size, the spectral contrast of the TF increases. Donaldson Hanna et al. [7] showed that under a simulated lunar environment the TF of some silicate minerals disappeared. These lab studies demonstrate the high sensitivity of TIR emissivity spectra to environmental conditions under which they are measured and provide important constraints for interpreting new thermal infrared datasets of the Moon, including the Diviner Lunar Radiometer Experiment onboard NASA's Lunar Reconnaissance Orbiter, as well as telescopic observations and future missions like OSIRIS-REx to asteroids.

Laboratory emissivity measurements of minerals, rocks, meteorites, and lunar soils made under lunar- and asteroid-like conditions at TIR wavelengths are necessary for the analysis of TIR data sets. However, a complete database of laboratory emissivity spectra measured from the visible-to-near infrared (VNIR) to TIR wavelengths of minerals, rocks, meteorites, and lunar soils of varying compositions and particle sizes has not previously existed. The new Asteroid and Lunar Environment Chamber (ALEC) at Brown University will provide the capabilities to start building those necessary spectral libraries.

Instrument Design and Experimental Setup: ALEC is the newest addition to Brown University's Reflectance Experiment Laboratory (RELAB) [10]. The new environment chamber was built to simulate the temperatures and pressures experienced on lunar and asteroid surfaces. ALEC is a vacuum chamber that can reach pressures of $<10^{-4}$ torr. An internal rotate stage enables the measurement of six samples and two blackbodies without breaking vacuum. The rotation stage is covered by a radiation shield that cools it conductively. Each sample cup is covered by a cooled radiation shroud that is painted with high emissivity paint, emulating the coldness of space. Sample cups can be heated from below using temperature controllers [Lakeshore Cryotronics Inc., model 340] with a cup temperature accuracy of 0.1K and/or heated from above using a halogen light source that replicates solar style heating. Both sample cups and blackbodies are monitored by temperature controllers allowing accurate temperature control and monitoring.

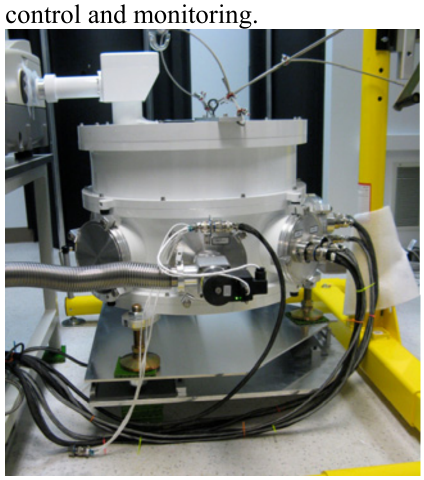

Fig 1. ALEC's optical axis aligned with RELAB's Nexus 870 FTIR spectrometer as seen in the upper left of the image.

The environment chamber is attached to RELAB's Thermo Nicolet Nexus 870 Fourier Transform Infrared (FTIR) spectrometer through a potassium bromide (KBr) emission port window. A KBr beam splitter and a deuterated triglycine sulfate and thermoelectrically cooled (DTGS-TEC) detector allow laboratory emissivity spectra to be collected at a resolution of 2 cm^{-1} over the 400 - 7400 cm^{-1} (1.4 – 25 μm) spectral range.

The spectrometer is purged with dry air to remove particulates, water vapor, and CO_2. The same dry air line can be used to backfill the environment chamber to any desired pressure using a Pfeiffer wide range gauge and Pirani measurement system for spectral measurements.

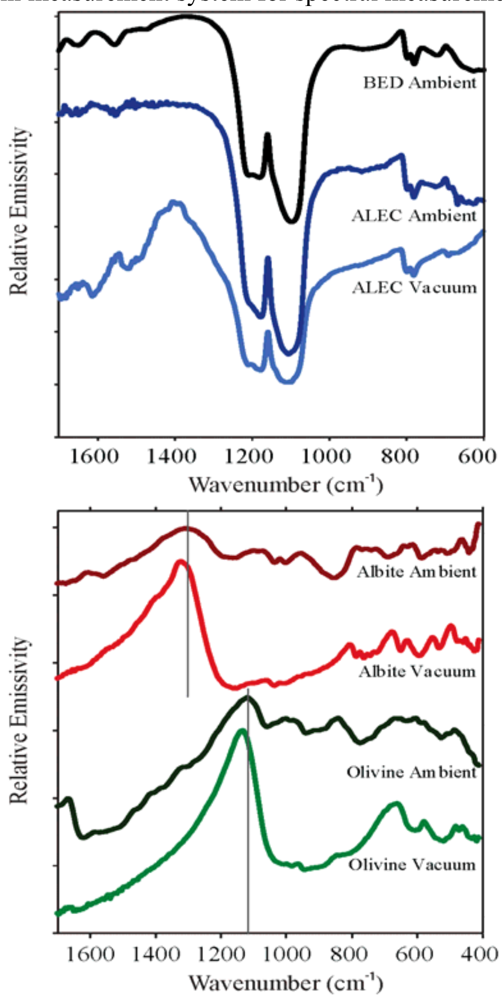

Fig 2. (Top) Quartz measured in ALEC under ambient and vacuum conditions compared to quartz measured under ambient conditions from BED [15] **(Bottom)** San Carlos olivine and albite measured in ALEC under ambient and vacuum conditions. Grey lines indicate CF positions for ambient measurements of albite and olivine.

Stainless steel sample cups are filled with particulate material and heated to the desired temperature for several hours to bring the sample to achieve thermal equilibrium and remove adsorbed water. In our initial spectral measurements of the particulate samples, 500 multiple interferograms were collected and averaged by the instrument to increase the signal-to-noise ratio. The calibration of spectral measurements for the particulate samples is achieved by making regular measurements of a highly accurate blackbody at two temperatures also with 500 multiple interferograms. This calibration method has previously been established by [6, 11, 12].

First Light Results: Fine particulate samples of quartz (45-75 μm), San Carlos olivine (Fo_{90}) (0-25 μm), and albite (An_{01}) (0-25 μm) have been measured under ambient (sample heated from below to 405K and pressure ~1000 torr) and vacuum conditions (sampled heated from below to 405K and pressure <10^{-4} torr). In Figure 2, a comparison of quartz spectra measured in ALEC with those of a quartz sample (25-63 μm) from the Berlin Emissivity Database (BED) [15]. We note the spectral similarities in the position of the CF and RB as well as the shape of the RB. We also observe a small shift in CF position to higher wavenumbers and an enhancement in the CF when samples are measured under vacuum conditions as seen in quartz, albite, and San Carlos olivine. These results corroborate previous lab studies [2,3,4,5,6,7].

Future Work: We will begin with the characterization of pure minerals, as they are the easiest to characterize under varying environmental conditions. However it is understood that most planetary surfaces are covered in regolith that is a complex mixture of minerals, glasses, and agglutinates. Future spectral measurements will focus on building a spectral library of well-characterized Apollo lunar soils and rocks as well as meteorites as they are the most relevant to current and future TIR datasets. In the tradition of other spectral databases [10, 13, 14, 15], we will also measure various compositions of minerals known to be on the lunar and asteroidal surfaces for use as spectral end members and in mixture analysis. Creating a comprehensive spectral library of analogue materials measured under simulated environmental conditions will allow us to better understand how to interpret current and future TIR data.

Acknowledgement: Support from the NASA Lunar Science Institute is much appreciated and many thanks to Neil Bowles, Ian Thomas, Joern Helbert, and Alessandro Maturilli for all of their very helpful discussions.

References: [1] Conel J. E. (1969) *JGR., 74*, 1614-1634. [2] Logan L. M. et al. (1973) *JGR, 78*, 4983-5003. [3] Salisbury J. W. and Walter L. S. (1989) *JGR, 94,* 9192-9202. [4] Henderson B. G. et al. (1996) *JGR, 101*, 14969-14975. [5] Logan L. M. and Hunt G. R. (1970) *JGR, 75*, 6539-6548. [6] Thomas I. R. et al. (2010) *LPS XLI,* Abstract #1364. [7] Donaldson Hanna K. L. (2011) *JGR, In Press.* [8] Lyon R. J. P. (1964) *NASA Rep. CR-100*, 264pp. [9] Cooper B. L. et al. (2002) *JGR, 107*, doi:10.1029/2000JE001462. [10] Pieters C. M. and Hiroi T. (2004) *LPS XXXV,* Abstract #1720. [11] Ruff S. W. et al. (1997) *JGR, 102,* 14899-14913. [12] Maturilli A. et al. (2006) *Planet. Space Sci., 54*, 1057-1064. [13] Christensen P. R. et al. (2000) *JGR, 105*, 8735-9739. [14] Clark R. N. et al. (2007) *Digital Data Series 231.* [15] Maturilli A. et al. (2008) *Planet. Space Sci., 56,* 420-425.