REFLECTANCE AND EMISSION MEASUREMENTS OF LUNAR ANALOGUES FOR INTERPRETATION OF RETURNING DATA FROM THE DIVINER LUNAR RADIOMETER ON NASA'S LUNAR RECONNAISSANCE ORBITER (LRO). I. R. Thomas[1], N. E. Bowles[1] and B. T. Greenhagen[2], [1]Atmospheric, Oceanic and Planetary Physics Dept., University of Oxford, UK (*thomas@atm.ox.ac.uk*), [2]Dept. of Earth and Space Sciences, University of California, Los Angeles, CA.

Introduction: Diviner is a nine-channel infrared mapping radiometer designed for high resolution observations of the lunar surface, scheduled to launch in 2009. The instrument consists of two solar channels (0.35 – 2.8 microns), three '8 micron' channels (7.55 – 8.05, 8.1 – 8.4 and 8.4 – 8.7 microns) and four thermal channels (13 – 23, 25 – 41, 50 – 100, and 100 – 300 microns).

The 8 micron channels are specifically designed to be located around a spectral feature known as the Christiansen Feature (CF) [1]. Due to enhancement by the lunar environment, the CF is the main spectral feature seen in the mid-infrared (MIR), and is observed as an emissivity maximum (and hence reflection minimum) in the spectra of lunar minerals [2,3,4].

The shape and spectral location of the CF is dependent on several factors. The CF is tied to the fundamental vibrational bands and shifts to shorter wavelengths with increasing polymerization of the SiO_4 tetrahedra. Therefore the CF of a feldspathic mineral is located at a shorter wavelength than a mafic mineral, hence the CF can be used as a compositional indicator [5,6]. Soil maturity (for example, the effects of different grain sizes and mixing ratios), surface temperature, and the lack of a lunar atmosphere also affect the shape and location of the CF [2,3,5,6].

Data from the solar channels and thermal channels will also be used to further constrain the surface composition, as spectral variations between differing minerals have been observed across the entire spectrum measured by the DLRE, from UV/VIS right through to far-infrared (FIR) [7]. Currently, there is insufficient data available across such a wide spectral range, with regard to each of the factors described above, so new measurements were required.

Measuring Mineral Spectra: The factors that affect the location and shape of the CF were investigated. Representative lunar analogue minerals were chosen which exhibited CF's across the full spectral range expected to be observed on the Moon, which were then crushed and separated into different grain sizes by dry sieving. Mixtures of varying ratios were also made by combining powdered samples of equal grain sizes. The lunar analogue minerals investigated were: forsterite, fayalite, ilmenite, quartz, anorthite, enstatite, augite, diopside, and several mixtures consisting of these minerals in varying amounts. Each mineral was then separated into all or some of the following grain sizes distributions: 0 – 30, 30 – 64, 0 – 64, 64 – 120, and 120 – 450 microns, depending on quantity and structure of sample [8]. All samples were prepared by being loaded into sample cups and baked out in a vacuum oven at 60ºC for at least 3 hours prior to being measured.

The measurements were made using a Bruker IFS66/v Fourier Transform Spectrometer in the Atmospheric, Oceanic and Planetary Physics Department at the University of Oxford. The large spectral range meant that several configurations had to be used to acquire the data, utilizing a Si diode detector, quartz beamsplitter and tungsten source for NIR; a DTGS detector, KBr beamsplitter and Globar source for MIR; and a FIR-DTGS detector, Mylar beamsplitter and Hg-arc source for FIR measurements.

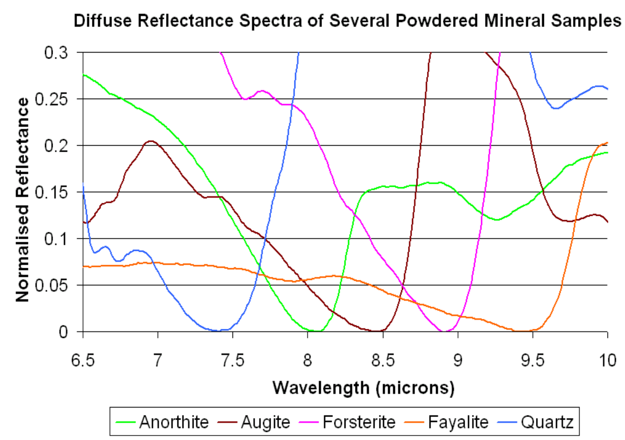

Figure 1: Diffuse reflectances of a selection of the minerals measured.

Diffuse reflectance: A diffuse reflectance jig was placed inside a custom-built vacuum chamber inside the spectrometer's sample compartment, so that the mineral samples could be measured while under a pressure much lower than could be achieved using only the spectrometer vacuum pump. Diffuse reflectance spectra were taken in: a) an overpressure of dry Nitrogen gas, b) a moderate vacuum of approximately 8 mbar of low CO_2, water vapour and hydrocarbon purge gas, and c) a low pressure vacuum of approximately 10^{-3} mbar. A remotely-controlled sample changer was built, allowing three samples and a diffuse reflectance standard to be measured without breaking vacuum. The spectra of the diffuse reflectance standard, a grit-blasted aluminium disc, were taken before and after every mineral spectrum, to ensure that all readings were reliable.

As expected, significant differences in the shape and spectral location of the Christiansen Feature were observed when measuring different minerals (figure 1), and smaller variations were observed in shape and location for differing grain sizes and sample chamber pressures.

Specular Reflectance: These measurements were performed in the same vacuum chamber using the same sample cups as for diffuse reflectance, but by using a specular reflectance jig which had been modified for use with powders. The reference standard used for these measurements was a highly reflective gold mirror.

Total Reflectance: A total reflectance setup is also available, so samples can be measured using this if required.

Emission: The emission measurements required new apparatus to be designed and built in order to simulate the lunar environment (figure 2) [4]. The outer chamber was pumped out to a pressure of at least 10^{-3} mbar, to simulate the low pressure lunar atmosphere, whilst the samples were spread on a grit-blasted aluminium disc which had been painted with Nextel™ Black Paint to make a blackbody. An inner black box and off-axis paraboloid (OAP) were placed above the sample, in direct line of sight of the top layers of the sample, which were cooled to below -50ºC. The blackbody on which the sample was spread, was heated using heater wire connected to a Eurotherm™ temperature controller. This heating mimics the effect of the sun's radiation heating the regolith throughout the lunar day, while the cooled box imitates the view of cold space that the lunar surface radiates out to.

This simultaneous heating and cooling creates a large thermal gradient through the samples, which causes a large reduction in the amplitude of the vibrational and Restrahlen bands whilst greatly enhancing the CF in amplitude (figure 3) [4].

Data Analysis: The reflectance and emission data will be reduced into a form which will allow it to be incorporated into a thermophysical model of the lunar surface, in order to calculate to what extent this new knowledge has on the results of such a model. The spectral data will be fit to the Diviner dataset, and has significant potential to enhance our understanding of lunar surface composition.

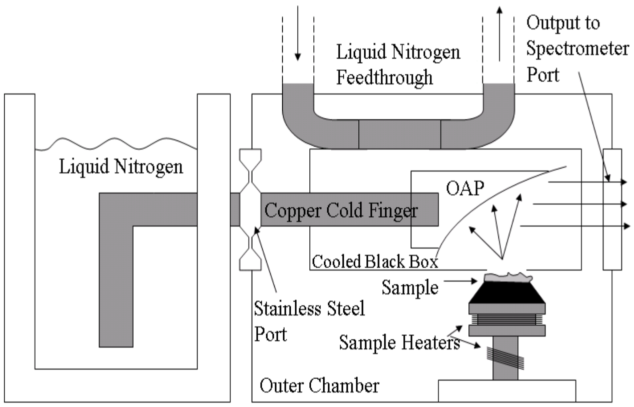

Figure 2: A diagram of the emission chamber apparatus. The copper cold finger, liquid nitrogen feed-through, and sample heaters were thermally isolated from the outer chamber as much as possible.

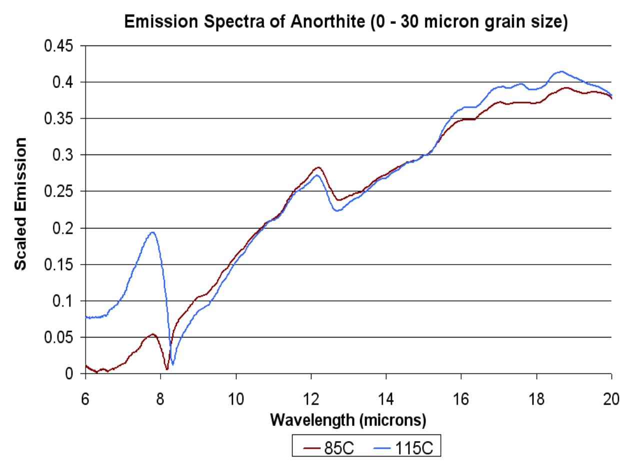

Figure 3: As the thermal gradient through the sample is increased, the Christiansen Feature is greatly enhanced compared to other vibrational and Restrahlen bands.

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