SYNTHETIC SPACE WEATHERING EFFECTS IN THE NEAR- AND MID-INFRARED.

K. A. Shirley[1], T. D. Glotch[1], Y. Yang[2], T. Jiang[2] and H. Zhang[2], [1]Geoscience Department, Stony Brook University (katherine.shirley@stonybrook.edu), [2]Planetary Science Institute, School of Earth Sciences, China University of Geosciences.

Introduction: Space weathering is an important process for regolith development on airless bodies within our solar system. It includes micrometeoroid impacts and solar wind irradiation. Space weathering complicates analysis of visible and near-infrared (VNIR) reflectance spectra by reducing overall albedo and band strength and introducing red spectral slopes [1-4]. The effects of space weathering on mid-infrared (MIR) spectra are less well understood. In this work, we systematically investigate the effects of space weathering on MIR emission spectra acquired in a simulated lunar environment.

In a recent work, [5] performed irradiation of olivine samples using a pulsed laser to simulate the space weathering effects of micrometeoroid bombardments. This experiment was able to replicate the darkening and reddening effects of space weathering observed in the VNIR and [5] concluded that the MIR spectra remained relatively unchanged. To further analyze the effects of space wathering on MIR spectra, we measured these samples in the Planetary and Asteroid Spectroscopy Environmental Chamber (PARSEC) at Stony Brook University, which is capable of measuring MIR emissivity spectra under a simulated lunar environment.

Environmental conditions on airless bodies have been known to cause changes in MIR spectral features [6&7]. For the Moon, the strongest effect is due to the thermal gradient within the upper 100s of microns of regolith [7]. Because space weathering is a process that darkens the regolith, it is reasonable to hypothesize that the thermal properties of the regolith would change accordingly, resulting in changes to the measured spectra. PARSEC can simulate the environmental conditions on the surface of the Moon so that we can measure the extent to which space weathering affects MIR spectra from airless bodies.

For comparison, we also created our own “weathered” olivine samples, which were darkened by adding small amounts of nanophase amorphous black carbon to the samples. The purpose of these samples is to isolate the darkening effect of space weathering and its influence on the thermal gradient within our samples.

Here, we examine the changes in MIR emissivity spectra due to these two synthetic space weathering techniques, as well as the importance of environmental conditions in our ability to properly evaluate remote sensing data from space weathered airless bodies.

Methods: Olivine samples from [5] were irradiated using a pulsed laser to simulate space weathering from micrometeorite bombardment (see [5] for further details). To compare the effects of this method to pure darkening of an olivine sample, we used carbon black to darken San Carlos olivine samples to varying degrees. We collected VNIR reflectance spectra for all samples using an ASD Fieldspec 3Max spectrometer, and MIR emissivity spectra using PARSEC under both terrestrial (AMB) and simulated lunar environment (SLE) conditions. AMB conditions are defined as having PARSEC at 1000 mbar and 23 °C, and SLE as $< 10^{-6}$ mbar and $<$-120 °C, and illuminated with a solar lamp in accordance with previous work [8-10].

Results: The VNIR reflectance spectra for the irradiated samples of [5] show the darkening and redding effects of space weathering as irradiation is increased, as well as a loss in spectral contrast of the main olivine feature at 1 μm. Our carbon darkened samples show darkening and loss of the 1 μm feature, but lack the reddening effect (Fig. 1). As reported in [5] the MIR reflectance spectra show minimal change under AMB conditions with only small variations in spectral contrast apparent.

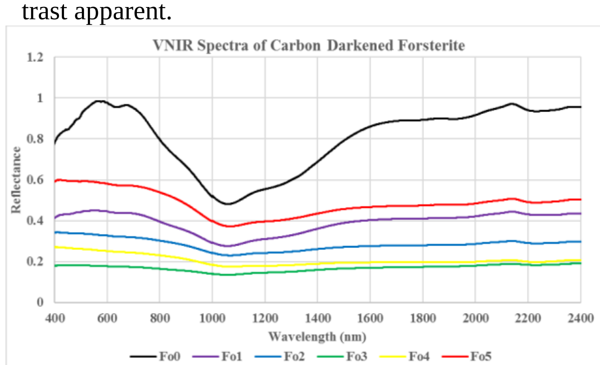

Fig. 1 VNIR reflectance spectra of carbon-darkened olivine samples show decrease in reflectance and loss of spectral contrast in the 1 μm feature as more carbon is added. No reddening effect is observed.

Under SLE conditions, substantial variation in MIR spectra is apparent. The Christiansen Feature (CF) position (emissivity maximum) shifts to longer wavelengths for the olivine samples that have experienced greater weathering. This shift is sudden in the irradiated samples, and more gradual in our carbon darkened samples (Figs. 2&3). The variation in strength of features between the two data sets is due to particle size difference of olivine grains with the irradiated olivine being smaller overall. To compare the two datasets, we have plotted the reflectance at 750 nm and the position of the CF in cm^{-1} in Fig. 4.

Discussion: The MIR spectra for the two data sets exhibit similar behavior when compared in Fig. 4. They both show that the darkest samples have CF positions at the lowest wavenumber; however, the difference from the AMB measured CF position is of note. In the irradiated olivine, we see the almost no difference between samples, except for the two darkest samples which have the lowest frequency CF position in the entire dataset. For the carbon-darkened olivine, the darkest samples have a CF position which most closely matches that measured under AMB. The most likely explanation for this has to do with particle size variation between the two datasets. The irradiated olivine has smaller particles than our carbon-darkened olivine, and previous work has shown that the SLE CF for the smallest particle size will match most closely with AMB CF [11].

While space weathering does not appear to have drastic effects on MIR spectra under AMB conditions, it does appear to affect the position of the CF and spectral contrast when samples are measured under SLE. The artificially darkened olivine samples show a similar trend of almost no change in spectra under AMB but a trend of decreasing albedo corresponding to decreasing frequency of the CF position under SLE. This highlights the importance of the environment and the thermal properties of these samples, and points to darkening as the main cause of changes in MIR spectral features.

Conclusions: As [5] concluded, the MIR is less susceptible to space weathering using the irradiation technique as the formation of nano-phase iron particles within the sample does not change the bulk silicate structure that is responsible for MIR spectral features. However, on an airless body, the albedo of the sample will affect the thermal properties of the material, which can cause variation in the position of the CF and spectral contrast of other MIR features.

Future Work: We will continue to investigate spectroscopic differences between space weathering through irradiation and simple darkening using PARSEC to simulate an airless body with other minerals, and with variation in particle size.

References: [1] Hapke B. et al. (1973) *The Moon, 7*, 342-355. [2] Hapke B. (2001) *JGR*, *106*, 10039. [3] Hapke B. (2012). [4] Pieters, C. M. et al. (2000) *Meteoritics & Planet. Sci.*, *35*, 1101. [5] Yang Y. et al. (2017) *A&A.*, *597*, A50. [6] Conel J. E. (1969) *JGR*, *74*. [7] Henderson B. G. & Jakosky B. M. (1997) *JGR*, *102*, 6567-6580. [8] Ruff S. W. et al. (1997) *JGR*, 102. [9] Thomas I. R. et al. (2012) *Rev. Sci. Intrum.*, 83(12), 124502. [10] Donaldson Hanna K. L. et al. (2012) *JGR*, 117. [11] Shirley K. A. & Glotch T. D. (2016) *LPSC XLVII*, Abstract #2552.

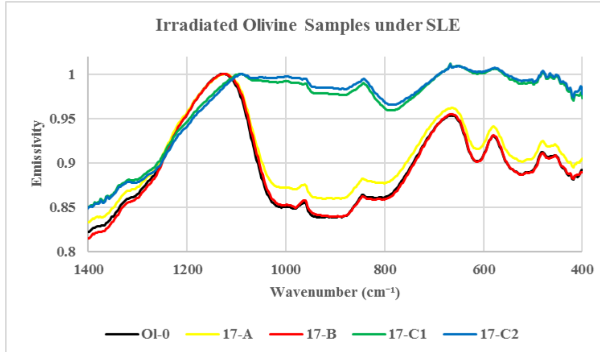

Fig. 2 MIR emissivity spectra for the [5] irradiated samples measured under simulated lunar environment conditions. Note the jump in CF and loss of spectral contrast in the most irradiated samples 17-C1 and 17-C2.

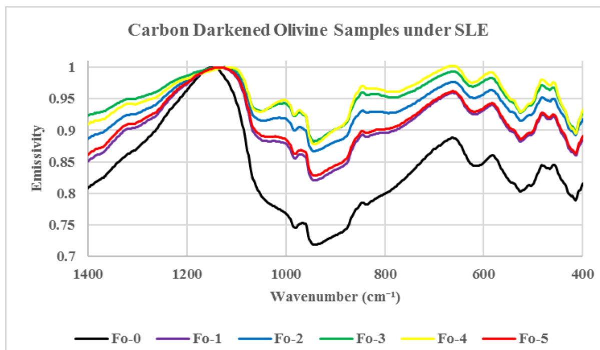

Fig. 3 MIR emissivity spectra for the carbon-darkened olivine measured under simulated lunar environment. Note the shifting of the CF position and loss of spectral contrast as the samples darken.

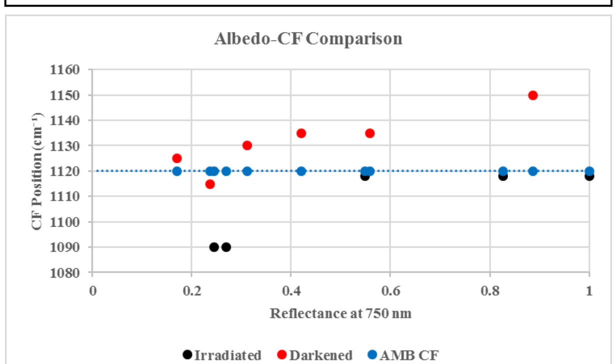

Fig. 4 Comparison of the irradiated olivine from [5,black] and the carbon-darkened olivine (red) showing the trend between SLE CF position and albedo of the sample. Both data sets show lower albedo corresponding to shorter wavenumber CF positions under SLE. Unaffected olivine is the brightest data point in each data set. Each sample's corresponding AMB CF position is shown in blue.