MID-INFRARED SPECTRAL EFFECTS OF THERMALLY ISOLATED DUST COATED SURFACES. F. Rivera-Hernández[1] , J. L. Bandfield[1] and S. W. Ruff[2], [1]Earth and Space Sciences, University of Washington, Seattle, WA 98195-1310; riveraf@uw.edu, [2]School of Earth and Space Exploration, Arizona State University

Introduction: On planetary surfaces, dust coatings can obscure the spectral signature of the underlying soil or rock [1-6]. In addition, it can be difficult to differentiate between the spectral features caused by the dust and those from the underlying surface. Numerous dust coating investigations using thermal infrared (TIR ~ 200 to 2000 cm^{-1}) spectra have shown that a decrease in spectral contrast occurs as thicker dust coatings are applied on a rock surface. These studies indicated that the dust and substrate spectral signatures mixed in a simple "checkerboard" fashion [2,3]. Although this effect makes remote compositional characterization more difficult, it is also relatively well understood and simple to identify in TIR datasets. Thick mantles of dust (>~5 μm) can be easily modeled as a linear combination of uniformly clean and dusty surfaces.

A second dust coating effect has been recognized in many of the in situ measurements taken by the Miniature Thermal Emission Spectrometer (Mini-TES) on the Mars Exploration Rovers (MER) [4-6]. This dust coating effect is thought to be caused by thin mantles of dust (<~5 μm) and unlike the previous dust coating effect, it is highly non-linear (Fig. 1) [5,6]. This dust coating effect has not been recognized in previous laboratory investigations.

Thin dust coatings: Thin mantles of dust contribute spectral features to Mini-TES spectra that are similar to those caused by downwelling radiance from atmospheric dust and were initially attributed as such by [4] (Fig. 1). However, the magnitude of the spectral features can not be accounted for solely by atmospheric dust and more importantly they do not display the features of atmospheric CO_2, which should also be present if atmospheric radiance is responsible for the observed spectral features. Instead the spectral contributions are caused by dust coatings on the surface. The dust acts both as an absorber or emitter, modifying the spectral features of the substrate [5,6]. If the dust is mantling a high conductivity surface, such as a rock, then in theory it would be relatively easy to maintain a large temperature difference between the dust and the underlying rock.

If not corrected, the additional contribution to the spectra caused by thin mantles of dust greatly hinders mineralogical interpretation of rock surfaces [4-6] (Fig. 1). Although these effects have only been identified in Mini-TES data, they are likely to be present in TIR spectroscopic measurements of other Solar System bodies.

Methodology: Our goal is to combine both laboratory measurements and modeling to better understand the behavior and underlying physics of how thin dust coatings can affect TIR spectral measurements. The laboratory measurements will be used to reproduce and quantify these effects, whereas, radiative transfer and thermophysical modeling will be used to understand the underlying physics and the spectral effects observed in spacecraft and laboratory measurements.

Laboratory Measurements. Although dust coating studies have been performed previously, the spectral effects of thin dust coatings present in Mini-TES data have yet to be observed in the laboratory. It is likely that there are two primary factors: 1) previous investigations did not control for dust particle size such that large clumps (>>5 μm in diameter) were deposited on surfaces (Fig. 2) [2,3]. This likely led to a greater influence of linear mixing effects on measured spectra because the large effective particle sizes are opaque. This would result in spectral features similar to that caused by thick mantles of dust. 2) The dust and substrate were not thermally isolated, so that the dust and the substrate had the same temperature. The spectral features (absorptive and emissive) of the dust in this case would cancel and have no net effect on the measured radiance.

We have updated the laboratory set-up of [2] to account for these observations and better simulate natural dust coated surfaces in the martian environment. The simple set-up uses a hand pump and a plastic box. The pump is used to disperse dust into the air within the box. A rock (or other) surface is then mantled by the dust that settles out. The quantity of dust deposited on the surface is controlled by the number of times the pump is used. Our setup includes a cover above the surface. By adjusting the time at which the cover is removed, we are able to limit the size of particles deposited on the surfaces. This allows for the particle size distribution (PSD) to be controlled in order to mimic materials such as lunar regolith or Martian atmospheric dust. Assuming laminar fluid flow and spherical particles, Stoke's law of settling can be used to predict the settling velocities for a particle of a given diameter. The time at which it is necessary to remove the cover to limit the deposition of particles of a given size can then calculated from these velocities. By observing dust mantles of variable thicknesses and PSDs we will better understand the relative roles of the two effects and their magnitudes. Laboratory measurements will be acquired of basalt and a black surface with dust deposited directly on the surfaces as well as a thermally isolated mirror surface. These measurements will provide a means of comparison to both Mini-TES data and a direct comparison to previous laboratory work. Initial measurements of surfaces observed through dust coated mirrors show that the spectral effects seen in Mini-TES data can be reproduced in the laboratory.

Modeling. We start with a simple model of a thermally isolated monolayer of spherical particles above a blackbody substrate at a given temperature. The dust is absorbing, scattering and emitting energy at a separate temperature. The dust particles are assumed to be isolated spheres so that Mie theory can be used to calculate scattering parameters that are necessary to solve the radiative transfer equation [7,8] (e.g., single scattering albedo, asymmetry parameter).

Modeled radiances are calculated using a four stream approximation to the azimuthally averaged radiative transfer equation for a plane parallel medium as outlined by [8]. Apparent emissivities are then calculated from these radiances using a methodology similar to the processing of Mini-TES data. This allows for a direct comparison between the simulated, laboratory, and spacecraft measurements.

The synthetic spectra show spectral behavior similar to that seen in Mini-TES data. We intend to revise this model to include near field scattering effects between the particle and the substrate.

Conclusions: Dust coatings can have dramatic and complex effects on TIR spectra. There is much that is still not understood about how thin mantles of dust effect TIR measurements and our initial investigation is a just a starting point into understanding these effects. More robust modeling combined with a systematic series of laboratory measurements will allow for a more complete understanding of these effects.

A detail that is still perplexing is how the dust and the rocks become thermally isolated, which doesn't appear to occur on Earth. Additional thermophysical modeling will need to be done in order to understand the conditions required for thermal isolation to occur on the Martian surface.

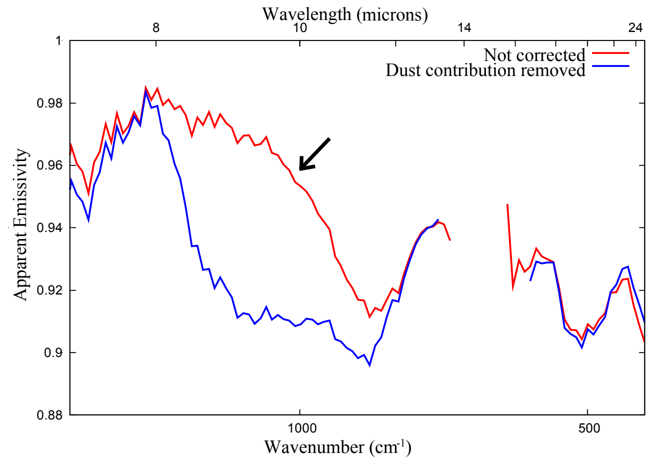

Fig. 1: Mini-TES spectra of Adirondack Class olivine-rich basalts. The emission feature at 8-12 microns coincides with an absorption feature of Olivine and without a correction the absorption feature would not be identifiable.

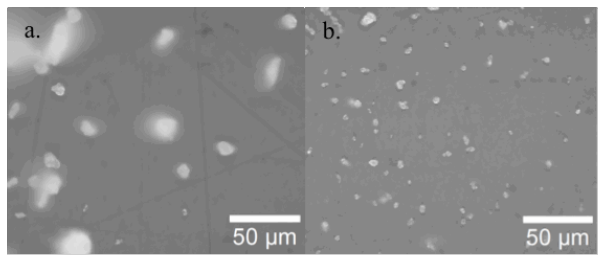

Fig. 2: (a) Without controlling for particle size, dust coating experiments include surfaces dominated by dust particles of different sizes and particle clumping is present. (b) Dust coated surfaces in the experiments presented here restrict the maximum particle size and clumping is minimal.

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