DUST COATING DEPOSITION CHAMBER FOR THERMAL INFRARED SPECTRAL ANALYSIS UNDER SIMULATED AIRLESS BODY CONDITIONS. C. R. Tinker[1] and T. D. Glotch[1], [1]Stony Brook University Center for Planetary Exploration (Connor.Tinker@Stonybrook.edu)

Introduction: Airless bodies in the solar system are commonly dominated by complex regolith mixtures consisting of coarse and fine particulates. These materials often manifest as continuous or heterogeneous coatings with the potential to mask underlying substrates from remote analysis. This can make accurate spectral analysis of surface materials challenging, especially for thermal infrared (TIR) techniques where properties concurrently depend on grain size and albedo [1-4]. This is especially true under simulated asteroid environment (SAE) conditions under which radiation dominates the near-surface temperature gradient, and layers of mixed particulates can create complex thermal effects that are inconsistent with typical models relating a uniform characteristic particle size to thermal inertia.

Further intricacy is presented when these coatings occur as discontinuous patterns where some substrate is exposed, and some is masked. Particularly thin coatings (10 – 100 μm) can provoke thermal effects that are inconsistent with spectral results, even working to change spectral properties without significantly effecting diurnal temperature curves [5-6]. These inconsistencies are hypothesized through modeling as there is no fully relevant laboratory study that has characterized these effects across a variety of coating thicknesses and patterns. This is especially true for Bennu as inconsistencies in NASA's Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer (OSIRIS-REx) TIR spectroscopy and thermal inertia results are hypothesized to be caused by very thin and heterogeneous dust coatings [6-8].

Effects of Dust Coatings on TIR Spectra: Dust coating experiments have been carried out before, but none performed spectroscopic analysis of coatings under SAE conditions or used materials that are reasonable analogs for carbonaceous chondrite compositions. [9-12] used biconical reflectance or thermal emission spectroscopy to study the effects of dust coatings on TIR spectra under ambient conditions. These studies showed that Reststrahlen bands become shallower and emissivity decreases shortward of the Christiansen feature (CF) with increasing dust coating thickness. On airless bodies there is a complex near surface thermal gradient and a strong dependence of spectral properties on albedo and grain size, therefore it is not clear these relationships will hold true under SAE conditions [1-4, 13-16].

These observations motivate further work to understand the spectral and thermophysical effects of thin and/or discontinuous dust coatings. This study provides a foundation for quantitative TIR spectral and thermophysical analyses of complex dust coatings by acquiring TIR spectra of continuous and discontinuous dust-coated surfaces under SAE conditions. We have designed and fabricated a low-cost dust deposition chamber to enable the controlled deposition of fine dust (<10 μm) on chip and coarse particulate (180-250 μm) samples. This will provide the foundation for more complex thermal models of airless body surfaces that can account for the diverse regolith mixtures found on the surfaces of Bennu and Ryugu.

Dust Deposition Chamber Characteristics: Design and construction of the prototype dust deposition chamber was previously reported in [17], and shown in Figure 1. To facilitate more consistent and reproducible dust deposit thicknesses, the chamber has undergone a redesign to accept smaller packets of dust and require reload after every layer cycle. The prototype chamber was intended to be run for long periods of time after loading several cycles worth of dust, however, testing showed cycles could be completed in minutes. While more technician interaction is required to operate the improved chamber, it now produces consistent layers more reliably.

Deposition Calibration and Testing: Experimental range and viability of the deposition chamber was assessed through calibration and testing. The chamber allows variability in dust layer thickness, porosity, particle size, mass, and pattern. Each calibration cycle utilized a set mass of input dust over a 120 second period. This calibrated cycle was then repeated twice to deposit a set thickness of dust, and two more times for each additional layer iteration. The agitation fan speed was adjusted so dust was distributed from the center of the enclosure but not ejected into the walls of the chamber. The lofting fan speed was calibrated similarly, ensuring the dust was picked up by the flow of the fans but not ejected into the chamber edges. The agitation time of 30 seconds was set to ensure minimal dust is left inside the agitation basket after the end of each cycle. The lofting time for each cycle was 90 seconds, or the minimal time required to achieve consistent dust flow.

The calibration procedure was used to determine how many cycle iterations were required to produce dust layers ranging from 10 – 1000 μm. In the first stage of calibration the amount of dust placed into the agitation basket was varied to determine the mass that produces close to a 10 μm layer. Coating thicknesses were measured relative to the sample holder mask at 50

locations using a WiTEC confocal microscope with a Z stage offering sub-micron focus precision. The resulting dust layer thickness for a single cycle was tested 5 times to assess the chambers repeatability.

The second stage of calibration used the input mass derived from stage one to test what layer thickness repeated cycles can achieve. The first 20 iterations in the calibration were measured after every final cycle. The number of repeated cycles between each calibration point was increased to match the growth of the curve, but did not exceed 10 cycles. The resulting calibration curve was used to estimate the number of iterations required to achieve a desired layer thickness. The accuracy of this calibration was assessed by measuring three estimated dust layers that were between calibration points on the curve. Repeatability was again tested for larger layers with higher iterations five times. Both heterogeneous and homogeneous calibration curves were used to account for shifting of the dust that may occur during removal of the deposition mask.

Sample Preparation: For this work both the substrate and dust were sourced from antigorite, the dominant mineral component of complex CI and CM analog mixtures used to simulate Bennu's spectra [18]. While it would be ideal to use a direct spectral analog to Bennu, the amount of material required imposes challenges. A match to the OTES spectra is not necessary to observe changes due to dust coatings in an SAE. To generate the dust, antigorite is hand ground in a mortar and pestle to roughly 300 µm so it can be loaded into a McCrone micronizing mill. After 10 minutes of wet grinding in ethanol the ≤10 µm size fraction was separated in ethanol using Stokes' settling method [19]. The size distribution was confirmed using a Malvern Instrument's Mastersizer 2000 laser diffractometer over three successive laser diffraction runs totaling 36,000 measurements, as demonstrated by [20]. The dust was then baked at 500°C for 24 hours to remove hydration features according to the methods described in [21]. Based on [18], nanophase carbon lamp black was mixed with the dust to achieve a visible albedo like that of Bennu (~.04). The amount of nanophase carbon lamp black added was adjusted according to preliminary measurements of the mixture's albedo using an ASD FieldSpec3 Max spectrophotometer to measure the reflectance at 550 and 750 nm referenced to a calibrated Spectralon standard. SAE TIR emission measurements were acquired with the sample at 80°C and PARSEC chamber at -120°C ± 10. The resulting SAE spectra for 10 µm antigorite dust with 15 volume % lamp black are shown in Figure 2. Coarse particulate substrates (180-250 µm) were created by wet and dry sieving hand ground antigorite then washing with ethanol to remove clinging fines. Chip substrates were sanded and polished to fit the sample cup and provide a smooth reference surface. Nanophase carbon was only added to the coarse particulate substrate and dust, as it does not stick to the chip substrate.

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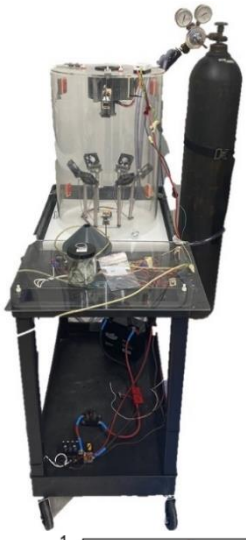

Figure 1: Image of the deposition chamber, masking cone, and mask. Entire system is mobile to reduce sample transport.

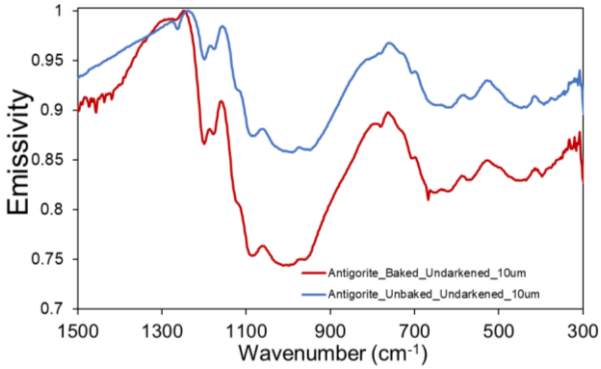

Figure 2: SAE spectra of undarkened baked and unbaked ≤10 µm Antigorite dust with 15 vol % lamp black, acquired using PARSEC.