INVESTIGATION OF THE EVOLUTION OF HYDRATION IN CARBONACEOUS ASTEROID REGOLITH SIMULANT.

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Introduction: Water has been found to be prevalent throughout the solar system from as far out as distant KBOs [1] to the inner solar system in the permanently shadowed craters on Mercury [2 find citation]. The role of water in a geologic context has been intensely studied and it is suggested that aqueous alteration due to the presence of water may be one of the most widespread mechanisms that affects primitive solar system materials [3]. Of particular interest is the discovery of water in various forms as found on primitive asteroids [4]. More recently, NASA's OSIRIS REx spacecraft discovered spectral evidence suggestive of the presence of hydrated minerals on the near-Earth asteroid (101955) Bennu [5].

Water and hydroxyl both have strong absorptions in the 3 μm spectral region, making that region particularly diagnostic. The 2.7 – 2.8 μm band minimum associated with the presence of hydroxyl [6] has been shown to be diagnostic of phyllosilicates and the degree of aqueous alteration in carbonaceous chondrites [7-10]. Understanding the hydration state of primitive bodies in the solar system via the study of the 3 μm spectral feature may help us understand the degree of aqueous alteration, thermal evolution, and potential of bodies for future resource utilization.

Table 1: Mineralogical composition of the CI-2 asteroid regolith simulant.

Mineral	Wt.%
Mg-serpentine	48.0
Magnetite	13.5
Vermiculite	9.0
Olivine	7.5
Pyrite	6.5
Epsomite	6.0
Sub-bituminous coal	5.0
Attapulgite	5.0

The Exolith Lab at the Center for Lunar and Asteroid Surface Science at the University of Central Florida (UCF) has developed and produced a series of high-fidelity asteroid regolith simulants [11,12]. Among the types developed is a carbonaceous asteroid-like regolith simulant named CI-2 based on the compositional analysis of the Orgueil meteorite [13]. The composition of the CI-2 simulant is shown in Table 1. Having a high-fidelity material analog with a finely controlled mineral composition has provided us the unique opportunity to explore the evolution of the 3 μm spectral feature as we exposed the sample to a variety of asteroidal conditions via infrared spectroscopy.

We also performed thermogravimetric analysis (TGA) on the sample to measure the temperatures at which the volatile loss and mineral phase transitions might occur.

Experiment: The CI carbonaceous asteroid regolith simulant (CI-2) was prepared for us at the Exolith Lab at UCF. Infrared spectra was taken at the Laboratory for Spectroscopy under Planetary Environmental Conditions (LabSPEC) at the Johns Hopkins University Applied Physics Lab (JHU APL) with a Bruker 70 FTIR spectrometer. Once secured the CI-2 regolith simulant within the sample holder, the apparatus was placed within the Ultra-High-Vacuum (UHV) Chamber, which was pumped down to 10^{-6} – 10^{-7} Torr. The sample was then gradually heated to 474 Kelvin over the course of several hours. After allowing the sample to cool overnight, it was then cooled to approximately 147 Kelvin. IR spectral measurements were taken throughout both the heating and cooling process at 25 Kelvin intervals.

To measure band parameters, we fit a linear continuum across the 3 μm absorption feature from ~ 2670 nm to ~ 3260 nm. After dividing by the continuum we then measured the band center, band depth, and band area.

TGA was performed at the Advanced Materials Processing and Analysis Center at UCF using an SDT Q600 from TA Instruments. The samples mass was constantly measured while being heated via nitrogen flow at a rate of 20º C/min to 1200º C.

IR Spectra: Shown in Figure 1 is the IR spectra (shifted for comparison) of the CI-2 simulant at various stages in the heating and cooling cycled.

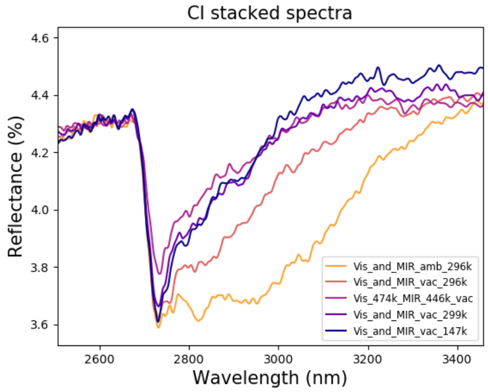

Figure 1: Evolution of the 3 µm absorption feature as captured at various staged in heating and cooling.

TGA: Shown in Figure 3 are the results from the TGA experiment showing the change in mass and heat flow as the CI-2 sample is slowly heated to 1200º C.

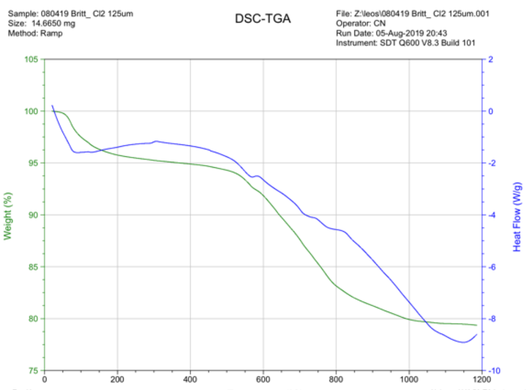

Figure 2: TGA data shows two key episodes of mass loss were observed between 20º and 200º C and between ~500º and ~1000º C.

Discussion: Throughout the heating profile we observed a slight longward shift in the band center of the 3 µm absorption feature along with a gradual shallowing and decrease in band depth and band area. This can be attributed to the desiccation of the sample and the loss of absorbed molecular water. Cooling the sample to cryogenic temperature resulted in no significant shift or change in either band parameters. We measured the band shape of the feature following the procedure by Takir and Emery [14] and ascribe a "sharp" classification, consistent with their interpretation of the feature due to hydrated minerals and phyllosilicates.

In the TGA data we observed two episodes of mass loss between ambient and 200º C, consistent with the release of absorbed water, and between 500º C and 1000º C. This suggests that we should expect no significant change to the band feature due to mineral evolution of Mg-rich serpentines at the temperatures in which we took spectral measurements.

References:

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