

LABORATORY STUDIES ON THE 3 μm SPECTRAL FEATURES OF Mg-RICH PHYLLOSILICATES AND INSIGHTS FOR THE INTERPRETATION OF ASTEROID RYUGU SURFACE SPECTRA.

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Introduction: The Near Infrared Spectrometer (NIRS3) on Hayabusa 2 mission detected a weak and narrow absorption feature centered at 2.72 μm across the entire observed surface of the asteroid 162173 Ryugu [1]. The presence of an absorption feature at 2.72 μm is indicative of the presence of (OH)-bearing minerals. Furthermore the position of the observed peak can be likely associated to that of the Mg-OH features, as in Mg-rich phyllosilicates. [1] However, the collected spectra from the Ryugu surface show no other absorption features in the 3 μm region. It has been suggested that thermal alteration processes, can darken the surfaces of carbonaceous chondrites, thus decreasing the reflectance values around 3 μm . In addition, thermal alteration processes, have been taken into account to explain the formation of Ryugu asteroid [2]. To investigate on this point and to check the behavior of the spectral features around 3 μm with thermal alteration, we performed laboratory experiments on two Mg-rich phyllosilicates (serpentine and saponite). In particular, we studied two different situations: 1) *thermal alteration at increasing T* - the samples were heated at different steps of 100°C, starting from 100°C up to 700°C, for 4 hours each; 2) *long time heating at constant T* - samples were heated at constant T~250°C for 1 month (1th step) and then for 2 months (2nd step).

Experimental setup and procedure: we selected four samples of serpentine and saponite in two different grain sizes: 25-63 μm and 125-250 μm .

Samples preparation, heating processes and measurements were performed in the Planetary Spectroscopy Laboratory (PSL) of the German Aerospace Center (Deutschen Zentrums für Luft- und Raumfahrt, DLR) in Berlin [3] (**Figure 1**). Three identical FTIR (Fourier Transform Infrared Spectrometers) instruments are operated at PSL, in an air-conditioned laboratory room. The 3 spectrometers are all the same identical model, Bruker Vertex 80V that can be evacuated to ~.1 mbar. Two spectrometers are equipped with aluminum mirrors optimized for the UV, visible and near-IR, the third features gold-coated mirrors for the near to far IR spectral range. Using three instruments that are identical (apart from the different internal mirrors) has some major benefits. Most importantly it facilitates the cross-calibration between the three instruments. The instruments can also share the collection of detectors,

beamsplitters, and optical accessories that are available in our equipment to cover a very wide spectral range

In the first part of our experiment, samples were heated in vacuum (~ 0.1 mbar) using the induction system in the external emissivity chamber of the PSL. The temperature of the sample was increased slowly and gradually up to the desired value. T was controlled by means of temperatures sensors located inside the chamber, in contact with the sample cup (stainless steel) rim and bottom part. After reaching the targeted T, the samples were kept stable at these temperature and pressure conditions for ~ 4 hours. After each step, the heated samples were cooled down in vacuum and then measured in the whole spectral range (from UV to IR) in bidirectional reflectance.

In parallel, two of the selected samples (serpentine 125-250 μm and saponite 125-250 μm) were stored in two autoclaves in an oven at 250°C for 1 month (first set of samples), and then once again at the same temperature for two months (second set of samples). The 1-month and 2-months heated samples, after cooling down in the autoclaves, were measured in reflectance, with the same experimental setup used for the samples heated at different T steps.

Bidirectional reflectance measurements were recorded in vacuum by using two of the Bruker Vertex80V FTIR spectrometers at PSL in two different angles configurations: 1) $i=0^\circ e=26^\circ$; 2) $i=0^\circ e=40^\circ$.

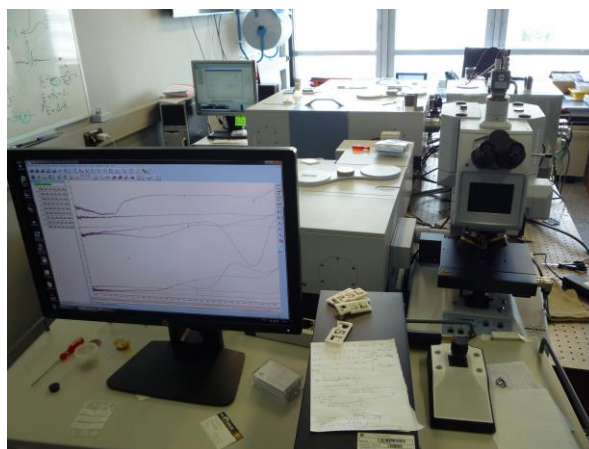


Figure 1. Picture of the laboratory set-up at PSL https://www.dlr.de/pf/desktopdefault.aspx/tabid-10866/19013_read-44359/

Results and discussion:

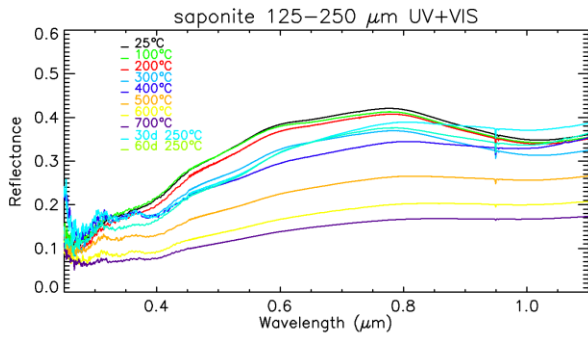


Figure 2. Saponite 125-250 μm in UV+VIS range.

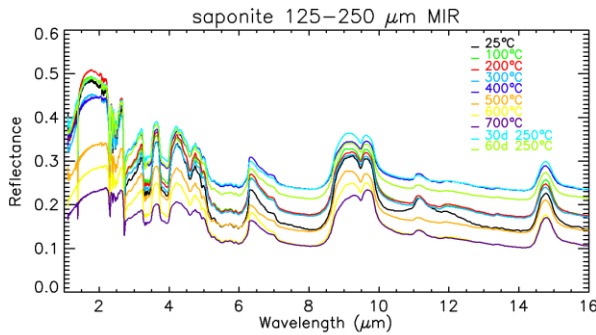


Figure 3. Saponite 125-250 μm in MIR range.

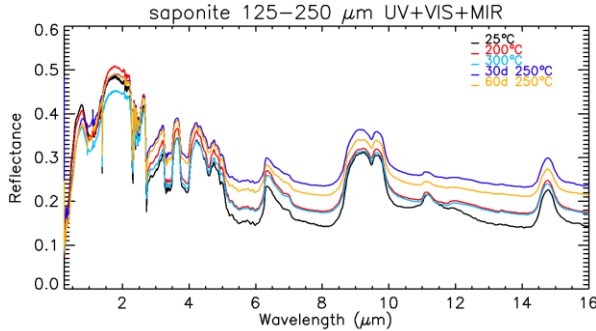


Figure 4. Saponite 125-250 μm in full range range.

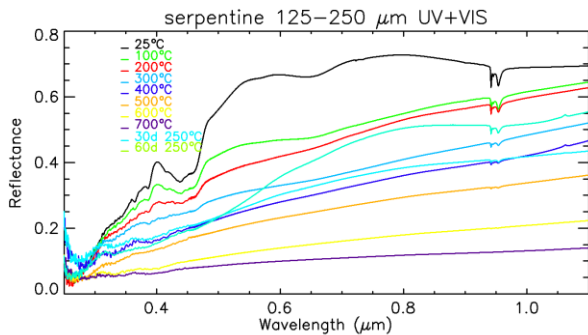


Figure 5. Serpentine 125-250 μm in UV+VIS range.

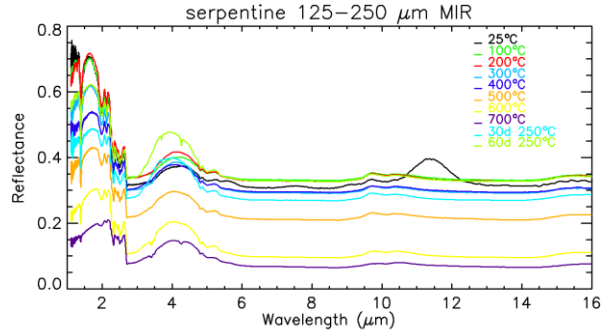


Figure 6. Serpentine 125-250 μm in MIR range.

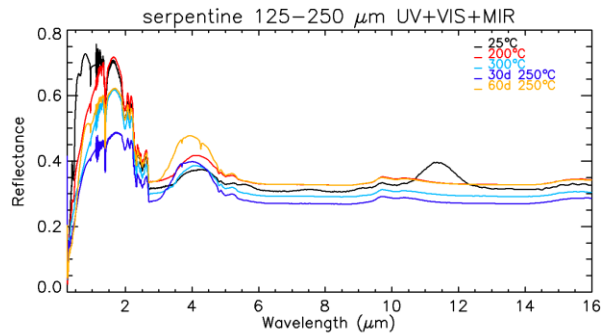


Figure 7. Serpentine 125-250 μm in full range.

Figure 2 to 4 show the saponite sample in the UV+VIS, MIR, and the full spectral range (only for $T_{\text{ambient}}=T_{\text{sample}}=200^\circ, 300^\circ\text{C}$, and the 1-month and 2-months at 250°C heated samples). Figure 5 to 7 show the same for the serpentine sample. Figure 2 and 5 show a darkening (lower measured reflectance) occurring at increasing temperature for the 2 samples in the UV+VIS spectral range. The same effect is not recorded in the MIR spectral range, as can be seen in figure 3 and 6. Hi-T and longtime heated samples show a prominent feature around $0.38 \mu\text{m}$ only for the saponite sample. In the serpentine sample the numerous features in the $0.35\text{-}0.7 \mu\text{m}$ region tend to disappear, the spectra look flat (or flatter) already for temperatures from 200°C . The $2.7 \mu\text{m}$ feature decreases with Hi-T, but is still present in saponite, The peak around $11.4 \mu\text{m}$ in serpentine disappear as heating begins. The feature around $0.95 \mu\text{m}$ (present in both sample) is decreasing with increasing T. Similar but narrower feature in saponite is more resistant to increasing T.

References: [1] Kitazato K. et al. (2019) *Science*, 364, 272–275. [2] Sugita S. et al. (2019) *Science*, 364, doi:10.1126/science.aaw0422. [3] Maturilli A., et al. (2018), *Infrared Remote Sensing and Instrumentation XXVI, Proceedings Volume 107650A*, <https://doi.org/10.1117/12.2319944>.