EPSC Abstracts
Vol. 13, EPSC-DPS2019-1864-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Reflectance spectroscopy of ammonium-bearing phyllosilicates

M. Ferrari (1), S. De Angelis (1), M.C. De Sanctis (1), E. Ammannito (2), S. Stefani (1) G. Piccioni (1)
(1) Institute for Space Astrophysics and Planetology-INAF, Rome, Italy (marco.ferrari@inaf.it)
(2) Italian Space Agency, ASI, Italy

Abstract

In this study, we describe the laboratory production and IR spectroscopic measurements of a suite of ten NH_4-phyllosilicates, starting from the corresponding ammonium-free minerals. The obtained results are compared with spectroscopic data of Ceres' surface.

1. Introduction

Ammonium-bearing minerals on the surface of (1)Ceres have been suggested by [1], using ground-based observations and successively detected by the VIR spectrometer [2], on-board the Dawn spacecraft [3]. In this case, spectroscopic observations in the range of 1-5 µm have shown an average composition consisting of a mixture of Mg-phyllosilicate, (Mg, Ca)-carbonate, a dark absorbing phase, and NH4-phyllosilicates [4], identified by a clear signature at about 3.07 µm. Nevertheless, the specific phyllosilicates bearing ammonium were not fully constrained by the observations, also due to the limited availability of NH_4-phyllosilicates spectra in the literature. IR reflectance studies of ammonium-bearing minerals and rocks (e.g. [5, 6, 7, 8, 9]) show spectral features related to ammonium and other nitrogen complexes at 1.56 µm, 2.05 µm, 2.12 µm, 3.06 µm, 3.25 µm, 3.55 µm, 4.2 µm, 5.7 µm and 7 µm.

2. Experimental procedure

In this work, we focus our attention on the phyllosilicates that are considered putative components of the Ceres surface. For each selected mineral, we prepared three types of powder samples: raw (R), ammoniated (A), and leached (L). All samples have been spectrally characterized by means of visible/infrared spectroscopy in the INAF-IAPS laboratories with the FieldSpec Pro in the 0.35-2.5 µm range, and with the FT-IR, using a Vertex 80 spectrometer operating in the range of 2 to 14 µm. The samples were also measured with the Spectral IMager, an imaging spectrometer operating in the spectral range 0.2 – 5.1 µm, which is a replica of the VIR spectrometer onboard Dawn spacecraft.

3. Measurements results

Figure 1 shows an example of the spectra acquired on the two different clay samples (IMt-2 and SCa3).

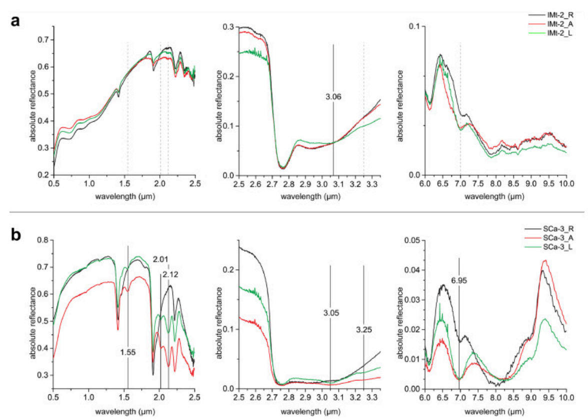

Fig.1. Laboratory reflectance spectra of (a) illite IMt-2_R (black), IMt-2_A (red) and IMt-2_L (blue); (b) montmorillonite SCa-3_R (black), SCa-3_A (red) and SCa-3_L (green). The black solid lines indicate the spectral features linked to the presence of ammonium. The dashed grey lines indicate the expected NH_4-related band positions. The spectral coverage has been divided into three ranges: 0.5–2.5 µm (FieldSpec Pro data); 2.5–4 µm and 6–10 µm (FT-IR data).

The spectra of the three samples of illite (IMt-2_R, IMt-2_A, IMt-2_L) are shown in Fig. 1a. In the range of 0.5–2.5 µm, there are no new absorption bands due to the presence of ammonium. In the 3 µm region, a weak absorption band near 3.06 µm is visible in the ammoniated and leached samples. This clay (IMt-2_R) before the ammonium treatment shows an absorption band at 7 µm probably linked to the presence of some ammonium ions already present in the sample, in the ammoniated and leached versions (IMt-2_A, IMt-2_L) this absorption does not show significant changes, thus no evidence of additional NH_4^+ can be gathered from this sample. Reflectance spectra of the three montmorillonite samples (SCa-3_R, SCa-3_A, SCa-3_L) are shown in Fig. 1b. The ammoniated and leached samples (SCa-3_A, SCa-3_L) are characterized by the occurrence of new bands near 1.55 µm, 2.01 µm and 2.12 µm. The 3 µm region shows a wide absorption band due to the presence of water especially in the two treated samples (SCa-3_A, SCa-3_L), but the presence of the two new NH_4-related features (3.05 µm and 3.25 µm) is still appreciable. The 6.95 µm band appears stronger in the A- and L-samples with respect to that of R-sample; this can be interpreted as the addition of NH_4^+ to clay that already contained carbonate impurities.

4. Comparison with Ceres' data

All the samples were also measured with the visible-infrared spectrometer SPIM. Figure 2, reports only the SPIM spectra of the clays that show NH_4-related bands (e.g. 3.06) in the data previously obtained with FieldSpec Pro and with FT-IR.

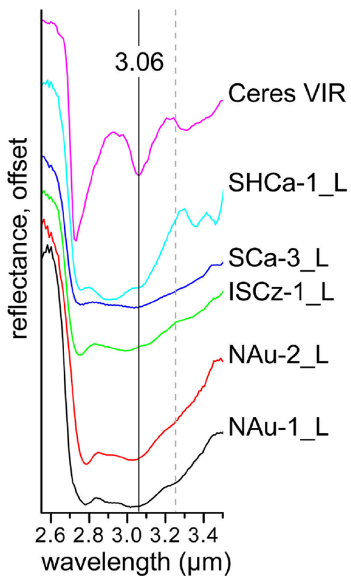

Fig. 2. SPIM reflectance spectra of nontronite NAu-1_L (black), nontronite NAu-2_L (red), illite/smectite ISCz-1_L (green), montmorillonite SCa-3_L (blue) and hectorite SHCa-1_L (light blue), compared with the average spectra of Ceres' surface [4]. The black solid line at 3.06 µm indicates the ammonium related absorption features. The grey dashed line indicate the expected NH4-related band at 3.26 µm.

We show also the average spectrum of Ceres' surface, collected by VIR, for comparison. The Ceres spectrum shows the 3.06 µm absorption linked to the presence of NH_4-bearing phyllosilicates. The reflectance spectra of the two nontronites (NAu-1_L and NAu-2_L) show the absorption band at 3.06 µm, and the same absorption is present in the montmorillonite (SCa-3_L) and in the hectorite (SHCa-1_L) spectra. Even if the 3.06 µm band in the samples is in good agreement in terms of position to the band seen on Ceres (Fig. 2), the overall shape of the 3 µm region is very different if compared to the Ceres VIR spectrum. This is due to the presence of water in the samples that generates a strong absorption throughout the 3 µm region affecting the shape of the collected spectra.

5. Conclusions

This work demonstrates that different phyllosilicates respond differently to the treatment with ammonia. Only the expandable phyllosilicates can incorporate the ammonium ion within their structure by contact with ammonium-rich fluids at low temperature and pressure [10]. Phyllosilicates of magmatic or metamorphic origin, such as biotite and serpentine, do not show spectral variations due to the presence of ammonium. The presence in nature of micas (e.g. biotite and muscovite) with ammonium does not exclude that these can be enriched with ammonium under conditions of temperature and pressure higher than those used in this experiment [11, 12, 13]. The obtained results can be used to better constrain the ammonium carrying species present on Ceres and allow to speculate on a scenario for its thermal evolution.

Acknowledgements

This research is supported by the Italian Space Agency

References

[1] King et al., 1992, Science 255, 1551–1553; [2] De Sanctis et al., 2011, Space Sci Rev 163: 329; [3] Russell et al., 2007, Earth Moon Planet 101: 65; [4] De Sanctis et al. 2015, Nature, 528, 241–244; [5] Farmer and Russell, 1967, Clays Clay Miner. 15:121-142; [6] Krohn and Altaner, 1987, Geophysics 52, 924–930; [7] Bishop et al., 2002, Planet. Space Sci. 50, 11-19; [8] Berg, et al., 2016, Icarus, 265, 218-237; [9] Ehlmann et al., 2018, Meteorit. Planet. Sci. 1-18; [10] Ferrari et al, 2019, Icarus, 321, 522-530; [11] Honma, 1996, Geochim. Cosmochim. Acta, 60, 12, 2173-2178; [12] Busigny, 2003, Chemical Geology. 198,21-31; [13] Papineau, 2005, Chemical Geology. 216, 37-58.