IR Spectroscopy of ammoniated phyllosilicates and mixtures with relevance for dwarf planet (1) Ceres

S. De Angelis (1), M. Ferrari (1), S. Stefani (1), A. Raponi (1), M.C. De Sanctis (1), G. Piccioni (1), E. Ammannito (2)

(1) Institute for Space Astrophysics and Planetology, IAPS-INAF, Rome Italy, (simone.deangelis@iaps.inaf.it) (2) Italian Space Agency – ASI, Rome, Italy

Introduction

The surface composition of (1) Ceres has been revealed with great detail by VIR spectrometer high resolution observations [1] on board Dawn spacecraft [2]. Spectroscopic observations in the infrared range 1-5 μm have shown an average surface composition consisting of a mixture of Mg-phyllosilicate, (Mg,Ca)-(carbonate, a dark absorbing phase and NH₄-phyllosilicates [3], and bright areas locally composed of mixtures of Na-carbonates, phyllosilicates, a dark phase and ammonium compounds [4]. The reproduction in laboratory of such mineral mixtures is thus of interest in order to better constraint and interpret remote-sensing observations. In this work we focus on the preparation and IR spectroscopic measurements in laboratory of NH₄-phyllosilicates and mineral mixtures.

1. Sample preparation and experimental setup

A set of 8 phyllosilicates were chosen from Clay Minerals Society, grinded and dry sieved to a fine grain size (d<36 μm). Ammonium phyllosilicates were then prepared following a procedure similar to what described in Bishop et al. 2002 [5]. All powders were immersed in excess (10:1 vol/mass) solutions of ammonium hydroxide (30% NH₄ in H₂O) for several days, centrifuged and decanted. This cycle was repeated more times, and finally samples were dried. Splits of these samples were separated and treated with a leaching procedure. Other endmembers, concerning the average mixture, were prepared in the form of d<36 μm-powders, specifically antigorite, (Ca,Mg)-(carbonate and magnetite. A set of 8 different mixtures has been then prepared, keeping fixed antigorite, dolomite and magnetite, and varying the NH₄-clay mineral constituent.

All end-members have been spectrally characterized by means of visible/infrared spectroscopy. Spectra in the VNIR have been acquired with a FieldSpec Pro in the 0.35-2.5 μm range, with 6 mm spatial resolution and spectral resolution 3-8 nm. Fourier Transform Infrared Spectrometer (FTIR-PLAB) Vertex-80 was used in reflectance mode to acquire spectra of powders, with spectral resolution 2 cm⁻¹, spatial aperture of about 6 mm, in the spectral range 1.3-14 μm, using an MCT detector. Each acquisition was performed by summing 256 scans in order to increase S/N ratio. Reflectance spectra were acquired from all endmembers, and separately from phyllosilicates, NH₄-phyllosilicates and “leached” NH₄-phyllosilicates, and finally from mixtures.

<table>
<thead>
<tr>
<th>Clay minerals endmembers</th>
<th>Selpilite</th>
<th>SEPSPl</th>
</tr>
</thead>
<tbody>
<tr>
<td>( (K_0.10)[Mg_{5.14}Al_{0.81}Mn_{0.02}Fe^{3+}<em>{0.04}Fe^{2+}</em>{0.14}][Si_{1.90}Al_{0.1}O_{26}(OH)_4] )</td>
<td>Rectorite</td>
<td>RAR1</td>
</tr>
<tr>
<td>Nontronite-1</td>
<td>NAU1</td>
<td>(Na,Ca)[Al_{2}(Si_{3.55}Al_{0.45})Fe^{3+}<em>{0.01}]O</em>{26}(OH)_4</td>
</tr>
<tr>
<td>Nontronite-2</td>
<td>NAU2</td>
<td>(Mg_{0.52})[Si_{2.55}Al_{0.45}]Fe^{3+}<em>{0.01}O</em>{26}(OH)_4</td>
</tr>
<tr>
<td>Illite-1</td>
<td>IMT2</td>
<td>K_{0.58}Al_{2.0} [(Al_{0.66}Si_{3.34}O_{10})(OH)_{4}]</td>
</tr>
<tr>
<td>Illite-2</td>
<td>ISCZ1</td>
<td></td>
</tr>
<tr>
<td>Montmorillonite</td>
<td>SCA3</td>
<td>(Mg_{0.96}Al_{0.04}|Na_{0.28}K_{0.05})(Al_{2.75}Fe^{3+}<em>{0.12}Mn</em>{0.06}Mg_{1.03}Ti_{0.02})[Si_{1.48}Al_{1.0}O_{26}(OH)_4]</td>
</tr>
<tr>
<td>Hectorite</td>
<td>SHCA1</td>
<td>(Mg_{0.56}Na_{0.44}K_{0.05})[Mg_{1.81}Li_{0.19}Mn_{0.14}Ti_{0.02}]Si_{1.78}Al_{1.0}Fe^{3+}<em>{0.05}O</em>{26}(OH)_4</td>
</tr>
</tbody>
</table>

Tab. 1. Clay minerals endmembers.

2. IR Spectral measurements: results

In fig.1 an example of spectra acquired on nontronite endmember (NAU-1) is shown, in which the non-
treated sample (blue line) is compared with the NH₄-
treated sample (green). The full spectral coverage has 
been subdivided in five ranges for clarity, 
specifically 0.35-2.5 μm (FieldSpec) and then 1.3-2.5 
μm, 2.5-4.1 μm, 4-6 and 6-14 μm for FTIR data. The 
ammoniated sample is characterized by the 
ocurrence of several new features in four of the five 
displayed ranges, although a global change in the 
overall spectrum is visible in the full range; namely a 
substantial decrease in reflectance level is observed, 
together with a reduction of spectral contrast. New 
absorption bands putatively attributable to NH₄⁺ ions 
appear near 2 and 2.1 μm, near 3.1 μm and at 7 μm.

In fig.2 the VIR average spectrum of Ceres (purple 
line) [3] is compared with mixture spectra measured 
with FTIR. Here the mixture is composed by 
serpentine-antigorite, dolomite, magnetite and NH₄-
NAU1 (nontronite). Laboratory spectra show a good 
matching with VIR spectrum; the agreement is better 
for what concerns the OH 2.7 μm-band of serpentine 
and the 4 μm-band of carbonate. The feature near 3.1 
μm due to NH₄⁺ in laboratory spectra is evident, 
although additional adsorbed water is present in the 
sample and influences the band.

3. Summary and Conclusions

Treatment of phyllosilicates with ammonia shows 
that different minerals behave in different ways: 
NH₄⁺ ions are easily accepted by several crystal 
structures (nontronite, montmorillonite), while other 
structures accept these ions with difficulty. 
Laboratory spectra of the mixture show a good 
agreement with VIR spectrum. Further work is 
ongoing to remove adsorbed water from 
phyllosilicates, in order to facilitate NH₄⁺ inclusion 
in mineral structures, and to separate NH₄⁺ and OH⁻ 
absorption features in the 3-μm spectral region.

Acknowledgements

The experiment is funded by ASI.

References