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Carbon dioxide clathrate hydrates at the surface of icy satellites Phoebe and Europa suggested by VIMS and NIMS reflectance spectra

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Abstract

Near IR spectra of carbon dioxide clathrate hydrates have been obtained in the laboratory and are used to study the surfaces of Phoebe and Europa using Cassini and Galileo mission data, respectively. Spectral features of CO_2 clathrates hydrates may be found on icy moons surfaces and we are exploring for their presents and determining their detectivity.

1. Introduction

Clathrate hydrates are composed of water ice cages that trap gas molecules within them. Carbon dioxide clathrate hydrates are found widely on Earth and in the outer solar system, [1], [2], [3]. These molecules are stable over a wide range of conditions (typically from the terrestrial atmospheric pressure to several hundreds of MPa and below ~300 K [4]). However, if they were exposed at the icy satellites surface, they could be metastable with unknown timescale. Our objective first is to determine if remote detection of clathrates at the surfaces of icy moons of Jupiter and Saturn is possible with Galileo/Near-Infrared Mapping Spectrometer (NIMS) and Cassini/Visual and Infrared Mapping Spectrometer (VIMS) reflectance spectra, respectively. Two previous studies produced CO_2 clathrate hydrates IR spectra, but one study is in transmission [5] and the other is in reflectance [6] but with lower resolution and only for mixtures with water ice. We developed an experimental facility to obtain these spectra using a Fourier Transform-Infrared (FT-IR) spectrometer. We first present experimental results in detail, and then we discuss the possibility of CO_2-clathrate hydrate detection at planetary surface from NIMS and VIMS data, especially on Europa and Phoebe.

2. Experimental study

2.1 Experimental facility

CO_2-clathrate hydrates are synthesized in a 50-cm^3 autoclave. The resulting icy blocks are crushed and sieved [7] into samples of different particle sizes. Analysis is performed on a group of several grains and on one single grain. When the icy blocks are crushed, water ice and CO_2-clathrate hydrate mixtures may result. We have not measured the ratio ice/clathrate in the mixtures, which are introduced into an Oxford cryostat and analyzed in primary vacuum (10^{-4} bar) and at low temperatures (85 K-180 K). For single grain analysis, a few pure CO_2-clathrate hydrate grains are placed on a copper plate in a vacuum chamber (30 – 100 mbar) installed in the Oxford cryostat and the temperature is varied over the ranges from 85 to 280 K. In this case, we distinguish clathrate from ice by obtaining a spectrum for each grain through the microscope and using the 2.7-µm band to identify clathrate.

2.2 Experimental result

Nine separate sets of measurements (192 spectra) were conducted for CO_2-clathrate hydrate and water ice mixtures for grain sizes ranging from 270 to 640 µm. Five additional sets of measurements (112 spectra) were obtained for pure CO_2-clathrate hydrates in the grain size range 120-350 µm.

Figure 1 displays spectra for pure water ice, pure CO_2-clathrate hydrates, and mixture of the two. Only a few differences exist between the spectra of CO_2 clathrate and water ice. Especially evident is the 2.7-µm absorption band for CO_2-clathrate hydrates, as previously reported ([6], [8]). This absorption is stronger for the pure CO_2-clathrate hydrate samples than for the mixtures. In addition, the CO_2-clathrate hydrate spectrum alone displays narrow bands near 2.00, 2.78, and 4.25 µm that are also due to the carbon dioxide trapped in the clathrate hydrate structure.

The position of the 2.7 µm band changes with the state of carbon dioxide. The band position for the clathrate hydrates is between the band positions of pure carbon dioxide gas and CO_2 ice. This is likely due to the CO_2 in the clathrate having a greater amount of freedom to vibrate than in the pure CO_2 crystalline material but not so much as in a gas.

The 2.7 µm band seems the best spectral feature for identifying CO_2-clathrate hydrates in this spectral range, and we will attempt using it to detect this component on planetary surfaces.

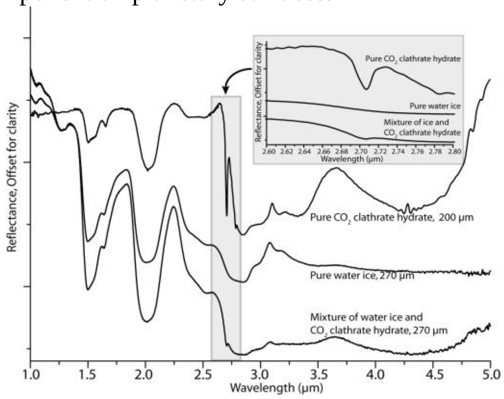

Figure 1: IR spectra between 1 and 5 µm of pure CO_2 clathrate, pure H_2O ice and mixture of the two. Inset : zoom on the 2.7-µm absorption band.

3. Application and discussion

Europa's surface is composed mainly of ice and hydrated minerals. In the Europa NIMS image in Fig 2a (17° to 22° N and 195° to 205° W), one particular area (small square), the E-region [9], displays an unusual spectral signature. A so-far unidentified spectral feature [9] for this possible vent or crater, is a 2.7-µm absorption band (see inset of the figure 2b). From our laboratory observations, this spectral feature could be carbon dioxide clathrate hydrates.

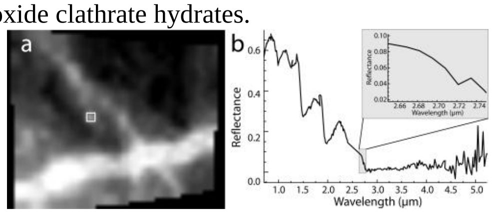

Figure 2: a) NIMS Image of Europa's surface, band 91 at 1.4980 µm of NIMS cube (e6e007ci). b) Spectrum of one pixel (23:24) of the image on which the 1.72-µm absorption band is observable in the inset.

An absorption band also has been reported at 2.72 µm on Phoebe [10]. This band was interpreted to likely be due to phyllosilicates [10]. This band could also be interpreted as due to carbon dioxide clathrate hydrates.

Phoebe and Europa surface environments mitigate against long term survival of these molecular components. These surfaces are bombardment by radiation and crystalline ice is sputtered and amorphized. However a vent, impact crater or fractures could expose the subsurface materials and reveal fresh ice and others components.

4. Conclusion

Specific absorption bands of CO_2-clathrate hydrates have been identified in laboratory IR spectral signature, [5], [6]. Clathrate hydrates are potentially detectable on icy moons surfaces from IR spectra. We are continuing to characterize the detectability of CO_2-clathrate hydrates on icy moons such as Europa and Phoebe, but a possible detection is presented here for Europa and Phoebe. We focus on relatively fresh surfaces, which more likely expose fresh components from the interior of the moons.

Acknowledgements

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