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The variable spectrum of kieserite: Grain size and temperature effects

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Abstract

Compositional analysis of the Martian and Europan surfaces often relies on remote sensing using such imaging spectrometers as MRO CRISM, Mars Express OMEGA and Galileo NIMS. To enhance their scientific returns, well-characterized laboratory spectra are required. Several variables affect the observed spectra that must be understood if the return data are to be fully interpreted. We have quantified the effects of temperature and grain size on the kieserite ($MgSO_4$•H_2O) spectrum. While only temperature seems to affect the band position, both grain size and temperature alter the band depths and band shapes.

1. Introduction

Hydrated magnesium sulfate salts are considered to be important components of the Martian and Europan surfaces [1-3]. For example, the monohydrate, kieserite ($MgSO_4$•H_2O), has been confirmed on Mars [4,5] and predicted to occur on Europa [2,3]. The highest spatial resolution spectra available for Europa are those from the Galileo Near-Infrared Mapping Spectrometer (NIMS), but even for these observations, spectral pixels inherently represent a combination of chemical species. Quantification of component species requires deconvolution of the individual spectral signatures. To aid this process, laboratory spectra of each chemical species must be measured under appropriate temperature and pressure and with relevant grain sizes.

2. Methodology

At the JPL Planetary Ice Characterization Laboratory (PICL) we have developed the capability to conduct diffuse reflectance spectroscopy while precisely controlling conditions that affect spectral behavior including composition, temperature, pressure, crystallinity and grain size.

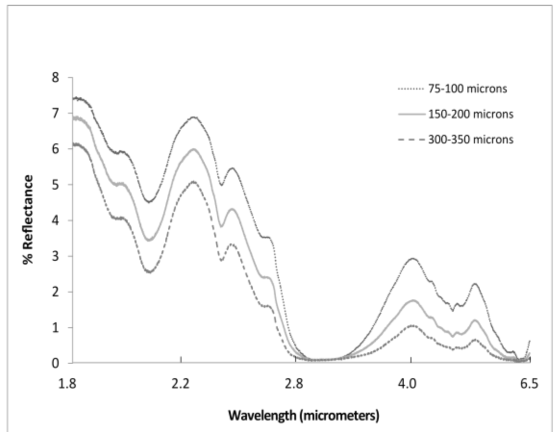

Figure 1. Kieserite shown at 3 grain sizes. While the band position was not affected by the grain size, the band shapes and strengths were.

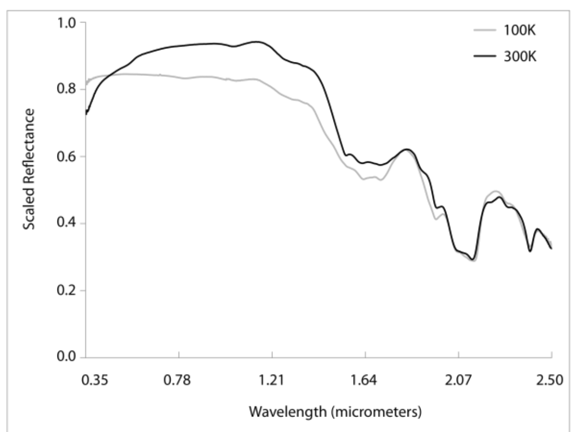

Figure 2: Kieserite at 300K (black) and 100K (grey) show noticeable spectral variability.

Our working wavelength range includes the visible to mid IR, covering the full spectral range returned by most spacecraft imaging spectrometers, such as Galileo NIMS, Cassini VIMS, LRO M3, Mars

Express OMEGA, MRO CRISM, and New Horizons LEISA.

In this investigation we acquired spectra of kieserite of different grain sizes and at different temperatures in order to characterize factors that affect the spectral response.

3. Results

The diffuse reflectance infrared spectra of three grain sizes of kieserite (75-100 μm, 150-200 μm, and 300-350 μm) are shown in Figure 1 to highlight their effects on the kieserite absorption bands. The differences in the spectra between each grain size arise from the varying relative contributions of volume and surface scattering combined with changes in the path lengths of photons traversing the grains. This alters the relative band depths and widths when comparing spectra of different grain sizes.

Notice the fine structure in the 4.7 μm region of Figure 1 becomes more “smeared” and less distinguishable as the grain size is increased. Also, in the nearly saturated 3.0 μm band, the larger grain size of kieserite produces a deeper and broader absorption when compared to the smaller grain sizes.

While the changing the grain size did not result in a shift of the band center position, lowering the temperature did. We recorded kieserite spectra at 300K and 100K and observed both a change in fundamental vibrational frequency and a change in the band shape and depth (Figure 2). The band centers shifted unpredictably and two bands centered at 1.8938 and 2.2245 μm at 300K all but disappeared at 100K (Table 1). As the temperature was lowered, the total available vibrational energy is decreased resulting in a reduction of absorptions due to coupled vibrations.

4. Summary and Conclusions

Systematically measuring the spectral dependence on grain size and temperature under controlled conditions will help us to better interpret remote sensing data. With careful laboratory studies accompanied by mixture modeling we are able to tease out compositional and grain size information from imaging spectrometer data.

This is a key step toward mapping distributions of magnesium sulfates on the surfaces of Mars and Europa and will help address important questions about their geochemical histories.

Table 1: Several band center minima are shown for two temperatures of kieserite in the 1.5-2.5 μm wavelength region. The band centers shift unpredictably as the temperature is lowered.

300K (μm)	100K (μm)	Shift (nm)
1.5460	1.5500	-4
1.6157	1.6280	-12.3
1.7247	1.7217	3
1.8938	unobserved	-
1.9644	1.9624	2
2.0554	2.0549	0.5
2.1327	2.1421	-9.4
2.2245	unobserved	-
2.2930	2.2908	2.2
2.3989	2.3978	1.1

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