

MODELING MID-INFRARED SPECTRAL EFFECTS OF TRANSPARENT MINERAL-BEARING MEDIA: IMPLICATIONS FOR SPECTRA OF CHLORIDE-BEARING DEPOSITS ON MARS. Cheng Ye¹, Carey Legett IV², Gen Ito³, Allison M. Zastrow¹, and Timothy D. Glotch¹, ¹Department of Geosciences, Stony Brook University, Stony Brook, NY, 11794-2100 (cheng.ye.1@stonybrook.edu); ²Los Alamos National Laboratory, Los Alamos, NM; ³NASA Goddard Institute for Space Studies, New York, NY.

Introduction: The identification of chloride salts on Mars is based on the presence of a distinctive blue slope (decrease in emissivity with increasing wavelength) relative to the surrounding terrain in THEMIS emissivity spectra, which is explained by the presence of chloride salts that have non-unit emissivity over the THEMIS spectral range [1]. The same deposits show a featureless red slope (increase in reflectance with increasing wavelength) in CRISM reflectance spectra [2]. Since chloride salts are highly soluble, they are often formed as the last stage of evaporite deposits following the precipitation of carbonates and sulfates in evaporative environments and could preserve information about aqueous activity on ancient Mars.

Laboratory measurements and light scattering models of chloride salt and silicate mixtures have been used to reproduce the unique spectral features of chloride salt deposits on Mars and constrain the abundance (10-25 wt%) and particle size (generally 63-180 μm , with a few instances of finely particulate <10 μm surfaces) of salt in these deposits [3, 4]. However, no additional evaporite minerals or chemical weathering products have been found to be intimately mixed with chloride salt-bearing deposits on Mars. Laboratory VNIR reflectance and MIR emissivity spectra of mixed mineral samples suggests that additional evaporite or chemical weathering phases could only be present at less than ~5 wt.% in Martian chloride deposits [5].

The accurate extraction of salt abundance using standard radiative transfer models from remote sensing data is difficult because chloride is transparent and has no diagnostic features in both the VNIR and MIR ranges. In order to better interpret the remote sensing data of media with transparent components, such as chloride-bearing deposits on Mars, scattering properties of such media must be understood. In this work, we test the ability of Multiple Sphere T-Matrix (MSTM) [6] method combined with a Hapke [7] model to forward calculate the spectra of mineral mixtures with a variety of compositions and particle sizes containing a transparent phase, halite, in the MIR region.

Methodology: In order to make a comprehensive investigation of spectral effects of chloride-bearing mixtures, we test three cases: (1) single mineral, labradorite, to represent the basaltic surface of Mars; (2) two component mixtures, labradorite and halite, to represent chloride-bearing deposits on Mars; (3) three

component mixtures, labradorite-halite-gypsum, to represent evaporite assemblages on Earth.

The MSTM code produces the scattering parameters that are the inputs to Hapke model for the emissivity calculation. The MSTM input is a cluster that contains the positions, diameters, and optical constants of the spheres in the cluster. We first constructed a cluster composed of closely packed spheres with random positions of each sphere [8]. The desired diameter (4 μm or 63 μm) and optical constants (labradorite [9], halite [10], or gypsum [11]) were assigned to each sphere. For two and three component mixtures, different numbers of spheres were assigned with optical constants of end-members to reach the desired abundance mixing ratio. The MSTM code was run using NASA's Pleiades supercomputer and the Stony Brook University Seawulf cluster.

The outputs of the MSTM, including the extinction efficiency (Q_{ext}), scattering efficiency (Q_{scat}) and asymmetry parameter (g), were further used as inputs into the equation of Hapke for emissivity calculation:

$$w = Q_{scat}/Q_{ext}, \gamma = \sqrt{1 - w}, \zeta = \sqrt{1 - g \cdot w}, \\ \epsilon = 2\gamma/(\gamma + \zeta).$$

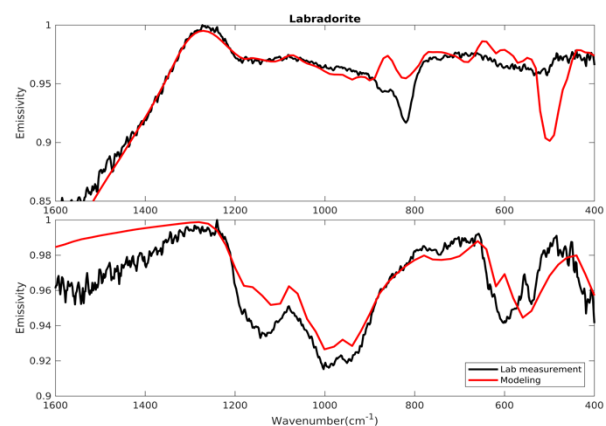


Figure 1. MIR emissivity spectra of single mineral, labradorite, calculated by MSTM/Hapke hybrid model. Top: fine particle size (4 μm). Bottom: coarse particle size (63 μm).

Results and Discussion: For a single mineral (Figure 1), the emissivity spectra of labradorite matches with the laboratory measurement quite well at high frequencies for both coarse and fine particulates. But it

has reduced accuracy below $\sim 900\text{ cm}^{-1}$ for fine particulates due to the cluster scattering light as a whole at low frequencies. The discrepancy between the modeled and measured emissivity spectra at $\sim 600\text{ cm}^{-1}$ region for coarse particulates might be caused by the inaccuracy of derived labradorite optical constants or inappropriate assignment of oriented optical constant percentage from [9].

For two component mixtures (**Figure 2**), the addition of halite into labradorite decreases the emissivity for both coarse and fine particulates. The transparency features of fine particulate labradorite at $\sim 800\text{ cm}^{-1}$ and $\sim 500\text{ cm}^{-1}$ become stronger with the increase abundance of halite, which proves that the presence of halite makes the cluster more transparent.

For three component mixtures (**Figure 3**), the addition of third component gypsum has no significant change to the emissivity spectra. But the increased content of gypsum makes the $\sim 1160\text{ cm}^{-1}$ gypsum diagnostic band much deeper for coarse particles. When the abundance of gypsum reaches $\sim 5\text{ wt.}\%$ the characteristic double water bands at $\sim 1600\text{ cm}^{-1}$ become significant for fine particulates. This result is consistent with the detection limits of other evaporite minerals that could be present in the chloride-bearing mixtures from previous laboratory work [5].

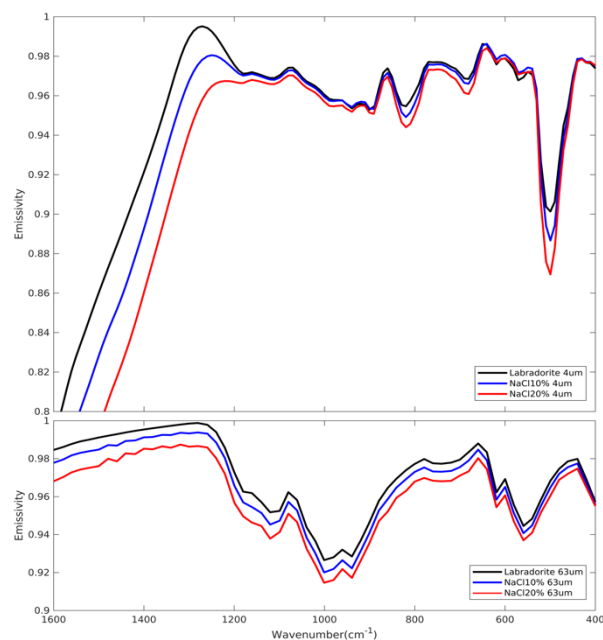


Figure 2. MIR emissivity spectra of two component mixtures, labradorite and halite, calculated by MSTM/Hapke model. Top: fine particle size ($4\ \mu\text{m}$). Bottom: coarse particle size ($63\ \mu\text{m}$).

Conclusions: The MSTM/Hapke method is generally able to characterize the scattering properties and model emissivity spectra of chloride-bearing media.

The presence of chloride in the media decreases the emissivity spectra and increases transparency of the cluster. In addition, very low content of other evaporite phase could be identified from labradorite/halite mixtures which makes the formation mechanism of chloride-bearing deposits on Mars still a mystery.

Our future work will include calculating reflectance spectra of the same media in the VNIR region, modelling the spectra of more realistic poly-disperse particle clusters, and replacing the Hapke method with the more robust invariant-embedding radiative transfer method, to provide more comprehensive assessment of the spectral effects of chloride-bearing mixtures.

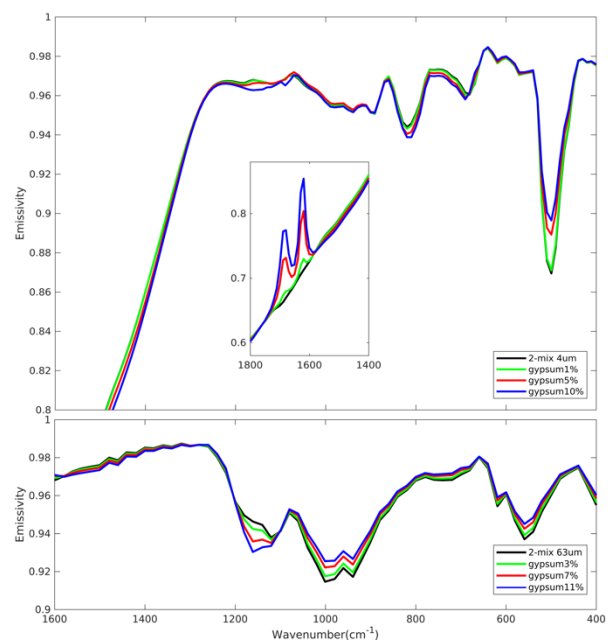


Figure 3. MIR emissivity spectra of three component mixtures, labradorite, halite and gypsum, calculated by MSTM/Hapke model. Top: fine particle size ($4\ \mu\text{m}$). Bottom: coarse particle size ($63\ \mu\text{m}$).

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