

**SPECTRAL PROPERTIES OF HYDRATED SALTS AT LOW TEMPERATURE: IMPLICATIONS FOR EUROPA MISSION SPECTROMETER DESIGN.** J. Brad Dalton (dalton@mail.arc.nasa.gov) SETI Institute/NASA-ARC, Moffett Field, CA 94035.

**Introduction:** Knowledge of the surface composition of Europa is critical for modeling of surface and interior processes and especially for evaluation of astrobiological potential [1]. While much information has been derived from the Galileo NIMS investigation, some breakthroughs have created more questions than answers. Any future Europa mission will attempt to capitalize on lessons learned from NIMS and try to answer these questions. At present, the surface composition appears to be a mixture of water ice, hydrated salts, sulfur compounds, radiolysis products (such as hydrogen peroxide and possibly simple organics like formaldehyde) and some as yet unidentified component [2,3]. The small spatial scale of heterogeneity in Europa's surface geology poses additional challenges for orbiting spectrometers due to spectral mixing effects.

**Hydrated Salts at Cryogenic Temperatures:** Examination of cryogenic reflectance spectra of hydrated salts under simulated European temperature and pressure conditions provides important design criteria for spectrometers intended for deployment to Europa. Of the Europa candidate materials that have been characterized at relevant temperatures thus far, the hydrated salts remain the most popular surface components in the published literature and are likely to comprise a significant proportion of the surface materials [4]. These materials, as with most hydrates, exhibit pronounced spectral variations at low temperatures (below 150 Kelvin). As the temperatures on Europa typically range from 80 to 130 Kelvin, such cryogenic reflectance spectra are important references for the study of Europa's surface composition.

Hydrates typically exhibit distorted and asymmetric absorption features at the primary water feature locations of 1.5 and 2.0 microns. These features in water ice and all water-containing compounds are composed of several separate vibrational transitions of the water molecule [5]. The electric fields of the hydrogen and oxygen orbitals overlap, distorting the configurations of their oscillating neighbor mole-

cules, altering the oscillation frequencies and combining to spread the narrow transitions into broad and easily recognizable absorption features. At cryogenic temperatures, however, the transitions are less influenced by the energies of their neighbors, and these individual absorption features become more distinct. In the hydrates, this effect is amplified by the presence of the host molecule which acts to further separate the water molecules. At low temperatures, the hydrated salts exhibit discretized and easily separable absorption features [3] which can be exploited to distinguish among them.

**Separation of Spectral Features:** One example of this behavior is provided by bloedite ( $\text{MgNa}_2(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}$ ), which may comprise as much as 60% by weight of the surface salts on Europa [2]. At temperatures below 150 Kelvins, the 1.5 micron water absorption feature in these salts separates into several distinct narrow features, providing highly unique spectral signatures. These features have widths ranging from 10 to 18 nm (see figure 1). Widths for the C-H absorptions prevalent in organic materials range from one-half to five times this value. Another absorption feature diagnostic of hydrates is the 1.35 micron cation-OH stretch [6]; this is about 40 nm wide, but occurs in most hydrated materials and thus is not useful for discriminating between them.

**Required Resolution:** Resolving narrow features requires several spectral channels covering the wavelength space from the centers to the wings of the features; a single spectral channel at the center is not sufficient. Examination of laboratory spectra of Europa candidate materials reveals a number of unique features at this level of detail. The ability to unequivocally identify these spectral signatures will require a spectrometer having a 5 nm or better bandpass. The maximum information can be extracted if the sampling interval is equal to or smaller than the bandpass (Nyquist sampling); thus, a spectrometer having 5 nm bandpass and sampling should help constrain the identities of most of the surface materials. An instrument capable of 2 nm resolution would leave little doubt.

**Conclusion:** If such an instrument were deployed at the surface it would be able to definitively answer

many of the remaining questions regarding both surface and subsurface conditions, provided that it was able to move around enough to sample many different terrain types. If such an instrument were placed in orbit it could also address these questions, if it was capable of resolving surface features on a scale of 100 meters. This would enable spectral measurements of contiguous sections of disrupted and discolored terrains, allowing the identification and evaluation of the enigmatic European surface composition.

**References:** [1] Dalton, J.B. (2002) *Lunar Planet. Sci. Conf. XXXIII*, 1555. [2] McCord, T.B. *et al.* (1998) *Science* 280, 1242. [3] Dalton, J.B. (2000) *Ph.D. dissertation*, Univ. of Colorado, Boulder. [6] Dalton, J. B. and R.N. Clark (1999) *Lunar Planet. Sci. Conf. XXX*, 2064. [4] McCord, T.B. *et al.* (2002) *J. Geophys. Res.* 107, 4-1. [5] Pauling, L.(1935) *J. Am. Chem. Soc.* 57, 2680.

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