

How to detect sodium chloride on Europa's surface? B. Jost¹, R. Hodyss¹, P. V. Johnson¹, ¹Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive Pasadena CA 91109, USA (bernhard.jost@jpl.nasa.gov).

Introduction: The analysis of evaporites on Europa's surface will remain the only way to probe its sub-surface ocean in near future. The ocean composition, and therefore potential habitability, is assumed to be driven by geophysical/chemical processes on the seafloor.

Contrary to previous assumptions, recent observations indicate that chloride salts – rather than sulfate salts - could be Europa's most abundant non-ice surface species. Nevertheless direct evidence of salt species has been largely inconclusive.

The main problem in detecting salts is their spectral nature: most species are spectrally neutral across the visible and infrared wavelength range. The search has therefore to be concentrated on hydrated or radiolytic altered states of minerals.

The presence of hydrated salt minerals was proposed after the Galileo mission [1]. Hydrated states of salts usually display characteristic absorption features in the near- and mid IR range. The same is true for Raman scattering.

The only hint to the presence of salts in the visible range is the formation of color centers: a crystallographic defect where anionic vacancies are replaced by unpaired electrons, which leads to specific absorption bands. [2] suggested this mechanism as an alternative explanation for Europa's surface coloration, rather than sulfur chemistry.

This work will provide the means to interpret the data acquired by future missions to icy worlds such as Europa Clipper and JUICE. Sodium chloride on Europa's surface may be directly and unambiguously identified, if the characteristic spectral features of hydrohalite or color centers were observed. If features of hydrohalite were found, they would indicate a relatively young terrain.

Methods: We selected sodium chloride dehydrate (hydrohalite; $\text{NaCl}\cdot 2\text{H}_2\text{O}$) as candidate material for our study since it is the only stable hydrated state of sodium chloride under Europa conditions and NaCl has been proposed to be relatively abundant on Europa. Hy-

drohalite forms below -0.15°C under varied conditions of NaCl concentrations and water activity.

To analyze the hydration state of hydrohalite samples at JPL we use a combination of two different, but complementary techniques: 1. Passive near-infrared reflectance spectroscopy in the $1.4\text{-}7.0\mu\text{m}$ spectral range (Thermo Nicolet 6700 FTIR; Pike Tech DiffusIR) 2. Raman spectroscopy (Horiba Jobin-Yvon LabRam HR). The sample is irradiated using a krypton arc lamp primarily emitting at 116.5 and 123.6nm, however the 116.5nm line is cutoff by the MgF_2 window.

Results: Comparison studies show that the freezing rates of NaCl-brines play a crucial role in hydrohalite formation efficiency. Flash frozen droplets contain a significant lower concentration of hydrohalite than slowly frozen slabs. This finding might be important when comparing exposition scenarios on Europa such as vapour driven plumes or effusive flows.

By freezing a saturated brine volume, the hydrohalite crystals are embedded within the ice matrix. Initially the ice suppresses the dehydration process. Only when the ice starts to sublime at the surface, the non-ice component forms a residue layer of pure hydrohalite, which starts to dehydrate.

The formation of color centers has, so far, been observed by UV irradiation and electron irradiation. However, timescales, necessary doses and penetration depth are different.

References:

[1] McCord, T.B., et al.: Non-water-ice constituents in the surface material of the icy Galilean satellites from the Galileo near-infrared mapping spectrometer investigation. *J. Geophys. Res.* 103, pp. 8603-8626, 1998.

[2] Hand, K.P. & Carlson, R.W.: Europa's surface color suggests an ocean rich with sodium chloride. *Geophys. Res. Lett.* 42, p. 3174-3178, 2015.