

Characterization of Cl-bearing salts on Europa' s surface based on telescope observations and laboratory experiments

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Europa has been found to possess an interior ocean beneath the icy crust. Europa' s surface has been recently observed in the wavelength range 1.5–2.5 μm with large ground-based telescopes, Keck and VLT (Fischer et al., 2015; Ligier et al. 2016). Those observed reflectance spectra suggest that Cl-bearing salts exist on Europa' s geologically active chaos terrains, and those salts reflect the chemical composition of the interior ocean (e.g., Zolotov & Kargel, 2009; Tan et al., 2021). Moreover, the abundance and grain size of Cl-bearing salts would provide constraints on the formation mechanism of chaos terrains. However, those physicochemical properties of Cl-bearing salts on the surface are not well constrained due to the limitation in existing observation wavelengths and the lack of laboratory experiments.

Here, we report the results of our observations for Europa' s surface in the wavelength range 1.0–1.8 μm using the Subaru telescope/IRCS and adaptive optics AO188 with high spectral resolution and high signal-to-noise ratios. Our observed spectra show no significant absorption features at $\sim 1.2 \mu\text{m}$ due to hydrated salts (e.g., $\text{NaCl} \cdot 2\text{H}_2\text{O}$, $\text{MgCl}_2 \cdot n\text{H}_2\text{O}$, $\text{Mg}(\text{ClO}_3)_2 \cdot 6\text{H}_2\text{O}$, $\text{Mg}(\text{ClO}_4)_2 \cdot 6\text{H}_2\text{O}$), suggesting that surface salts would be likely anhydrous sodium chloride (NaCl).

On Europa' s surface, the spectrum of NaCl would be changed due to irradiation by high-energy particles (e.g., Hand et al., 2015). We also performed irradiation experiments on NaCl by 10-keV electrons to obtain the optical constants of irradiated NaCl in near-infrared wavelengths. To constrain grain size and abundance of irradiated NaCl on Europa' s surface, we performed spectral model fitting of the observational data using the obtained optical constants (Hapke, 1981; 1993; 2002). Through our results of the spectral fitting, the non-irradiated NaCl cannot reproduce dark reflectance well in wavelength of 1.1–1.3 μm . On the other hand, irradiated NaCl greatly improves the spectral fitting because irradiated NaCl has a red slope in the relevant wavelength range. The best fit of the observations suggests that the abundance and grain size of irradiated NaCl are 40–50% and $> \text{a few } \mu\text{m}$, respectively.

The high abundance and large grain size of NaCl on Europa can be explained by the formation of chaos terrains through slow freezing of subsurface brine reservoirs within the icy crust, and subsequent eruptions of slurry brines containing NaCl particles to the surface.

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