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Electrical properties of saline ices and ice-silicate mixtures: geophysical and astrobiological consequences (***Invited***)

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We performed broadband (1 mHz - 1 MHz) electrical-properties measurements of laboratory-produced saline ice, salt hydrates, and ice-silicate mixtures, as well as terrestrial polar ices and permafrosts (see also Grimm et al, NS04, this meeting), in order to understand investigation depths of EM induction and surface-penetrating radar, the recovery of interior properties, and habitability. The electrical properties of saline H2O are controlled by the binary phase relations between ice and salt hydrate. Above the eutectic temperature, formation of interconnected brine channels (manifested by high DC electrical conductivity) requires bulk salt concentrations exceeding ~3 mM. This is equivalent to a minimum brine-channel width of a few microns. Presumably high capillary pressures in submicron fluid spaces lead to segregation of brine into pockets and hence electrical cutoff. In ice-silicate mixtures, brine channels are evident above the eutectic temperature only when pore diameters exceed a few microns, regardless of salt concentration. This is also consistent with small-pore capillary segregation of fluid. Below the eutectic temperature, salt hydrate always forms electrically interconnected networks, even at trace volumes. Interfacial unfrozen water was measured by NMR to be present at 2-3 equivalent H2O monolayers but has negligible DC conductivity. Dielectric relaxations due to rotation of interfacial water and protonic defects in ice and salt hydrate were identified, as well as interfacial polarizations arresting charge translation in salt hydrates and interfacial water. Because the dielectric permittivities measured at 1 MHz approached known radiofrequency (RF) values, almost all of the dispersion is determined by "low frequency" mechanisms. At RF, the total intrinsic absorption in a surface-penetrating radar signal can be estimated, but understanding individual mechanisms must come from low-frequency measurements and geological context. In addition to the well-understood losses caused by trace impurities of acid or salt in relatively pure ice, we are now able to quantify additional absorption in subfreezing materials caused by salt hydrates, and, in the presence of silicates, unfrozen interfacial water. The latter has been suggested to be suitable to support subfreezing microbial life (Jakosky et al., Astrobiology, 3, 343, 2003; Mohlman, op cit, 5, 770, 2005). However, the DC electrical conductivity of interfacial water is many decades smaller than nominal fresh water, so the total rate of charge transport through interfacial water must be negligible compared to fresh water. Furthermore, a few monolayers of H2O (< 1 nm) are only a few times the size of major ions and much too small to accommodate large organic molecules. The possibility of subfreezing microbial activity on Mars would then be attributed to freezing-point depression of salt-rich ice, and not interfacial water.

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