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Electrical Properties of Ice and Ice-Silicate Mixtures for Mars Exploration

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We are measuring the complex permittivity of materials relevant to the cryosphere of Mars in order to interpret data from current missions and to plan future exploration. Measurements are made over a temperature range of 180- 273 K and a frequency range of 1 mHz-1MHz. Materials include "pure" ice, doped ice, and saline ices, either alone or mixed with reference solids (glass beads, Ottawa sand) or with Mars-regolith analogs (JSC Mars-1, smectite clays). Initial solute concentrations are always undersaturated. We find a regular increase in overall conductivity of ice with solute content. This occurs at temperatures above the eutectic temperature where brine channels are expected to exist and also deeply below the eutectic temperature where solutes are expected to be almost completely excluded from the ice and precipitated along grain boundaries. We hypothesize this is a kinetic effect of incomplete segregation, leaving hydrated salts in the former brine channels. For CaCl2 as a representative solute, initial concentrations must be much greater than 1 mM to develop significant brine channels. Mixtures of ice and sand or glass beads behave as expected for two-component systems, with conductivity dominated by the ice and precipitated solutes. The conductivity of JSC Mars-1 and ice is much lower than expected and may be due to solute fixation by clays with high ion exchange capacity. We find no evidence of significantly enhanced conductivity due to thin films of adsorbed or capillary water at subeutectic temperatures. The dielectric relaxation frequency of protonic point defects in ice was found to vary regularly between a previously established low value for "pure" ice and a higher limit mapped by us corresponding to 3-10 ppm Cl- saturation of the ice matrix. We found no changes to the ice relaxation due to mixing with sand; however, JSC Mars-1 caused the ice relaxation frequency to decrease, presumably because even trace Cl- was removed and not incorporated into the ice matrix. These results have implications for surface-penetrating radars and microbial habitability of Mars. The DC conductivity of saline ice is too small to cause significant attenuation of sounding radars and the dielectric relaxation is also inefficient unless the ice is warm. The low DC conductivity even for ice-silicate mixtures where water layers of a few monolayers are present further implies that microbes in the cryosphere cannot transport nutrients and waste in quantities sufficient even for dormancy: warming cycles to periglacial conditions are necessary to activate brine channels and solute transport. These measurements can also be used to help interpret the simple electrical properties measurements that will be made by the Phoenix lander. Ongoing investigation includes the effects of dielectric relaxations due to bound water and interfacial polarizations on radar loss, and testing the ability to map subsurface ice using the strength of the dielectric relaxation.

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