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The Radar Effects of Perchlorate-Doped Ice in the Martian Polar Layered Deposits

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The presence of perchlorate in soil at near-polar latitudes on Mars suggests that dust in the ice of the North Polar Layered Deposits (NPLD) may introduce perchlorate impurities to that ice. Because eutectic temperatures of perchlorate salts range as low as 206 K (for magnesium perchlorate), perchlorate doping of NPLD ice may result in grain-scale liquid veins and softening of ice rheology at temperatures comparable to those computed for the base of the NPLD in the present climate. Any such softening would be important for understanding how processes including ice flow have shaped the NPLD. Observable consequences of such softening, or of the combination of perchlorate doping and temperatures that could cause softening, are thus similarly important. In particular, the dielectric properties of perchlorate-laden ice in a temperature gradient will change relatively rapidly at the point in the gradient near the eutectic temperature.

Here we investigate the radar reflectivity of such a eutectic transition in ice with a model in which perchlorate concentration is constant and temperature varies linearly with depth in the ice. We have conducted measurements of the complex permittivity of Mg and Na perchlorate-doped ice over a range of temperatures (183 – 273 K) and concentrations. Below the eutectic temperature, the perchlorate-doped ice has electrical properties similar to that of choride-doped ice. However, above the eutectic temperature, some of the ice melts forming liquid at triple junctions. At concentrations above 3 mM, the liquid at triple junctions become connected forming brine channels, which greatly increase the dc conductivity and radar attenuation. At concentrations below 3 mM, the liquid at triple junctions are not connected and do not affect the dc conductivity. However, the liquid H2O molecules are able to rotate their permanent dipole at radar frequencies, thus causing an increase in radar attenuation. The MARSIS and SHARAD attenuation rates increase with temperature as the strength of the loss increases with a greater amount of liquid water even though the relaxation frequency (maximum loss) shifts to higher frequencies.

We combine our electrical property measurements with a model for radar reflection from a continuously-varying dielectric profile. Because the change in permittivity occurs over a range of depths depending on the value of the temperature gradient, radar detectability of the eutectic transition depends on the radar frequency as well as gradient and concentration values. We compute expected radar echo strengths for MARSIS and SHARAD and depths relative to the bed at which transitions may be expected, to address whether information of direct rheological relevance may be available from those instruments.

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