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Dielectric properties of aqueous solutions, amorphous phases and hydrated minerals in support for future radar measurements of Jovian icy moons

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In the coming years The JUpiter ICy moons Explorer (JUICE) (ESA) and Europa Clipper (NASA) missions will study the icy crusts of the main Galilean moons of Jupiter. They will use the penetrating radars RIME and REASON, which will work at wave frequency ranges able to penetrate up to 9 and 30 Km depth respectively, in combination with other instruments [Bruzzone et al. 2013, Aglyamov et al. 2017].

In this regard, we have started a set of experiments to study the electrical properties of materials at low temperatures with the aim to help with the interpretation obtained from the level of attenuation of the radar waves. Ultimately, they will be useful to constrain the chemical composition, physical state and temperature of the upper layers of the icy crusts of Ganymede, Callisto and Europa (please see abstracts EPSC González Díaz et al. 2020 and EPSC Solomonidou et al. 2020).

The first set of experiments have been done in a high-pressure chamber equipped with pressure and temperature sensors in direct contact with the sample and a large sapphire window which allows textural and spectroscopic analyses. We have characterized aqueous solutions with salts ($MgSO_4$, NaCl, $MgCl_2$, $Mg(ClO_4)_2$, Na_2CO_3), volatiles (CO_2) and clays (nontronite, montmorillonite) at temperatures down to 223 K and pressures up to 60 MPa. Samples were studied by pressure-temperature (P-T) cycles in two ways: (a) first freezing the solution and pressurizing it (TPPT method) and (b) first pressurizing the solution and then freezing it (PTTP method), in order to examine textural and grain size heterogeneities and fracture formation depending on the method of formation. The cooling of the samples led to the final formation of water ice, hydrated salts and clathrate hydrates. Raman spectroscopy was used to control the mineral assemblages and understand better the crust environments and processes that can explain the resulting values, like the appearance of supercooled brines, amorphous phases and recrystallizations during the P-T cycles.

We measured the dielectric properties of these samples with a BDS80 Broadband Dielectric Spectroscopy system (Novocontrol) which allows to work in a frequency range from 1 Hz to 10 MHz and temperatures from 143 to 323 K. Both permittivity and electric conductivity were measured at 0.1 MPa while cooling the samples in temperature steps of 10 K. From these data we estimated, on the one hand, the activation energy for motion of the electric charges of each solution, and on the other hand, the attenuation of the radar wave depending on the chemical composition and the temperature of the sample, and the frequency of the electric field applied [Pettinelli et al. 2015].

The already obtained novel data will be used as reference for a second set of experiments, consisting on the same dielectric properties' characterization but, in this set, samples will be also subjected to high pressure conditions.

References

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