Dielectric Permittivity of Evaporite Minerals

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Summary

We measured the complex dielectric permittivity of synthetic and natural evaporite minerals using a coaxial sensor method in the frequency that range between 10MHz and 3GHz. The synthetic evaporate samples were fabricated using a cold compressing technique in which the sample's porosity can be controlled. The measurements of the dielectric permittivity of these natural and synthetic minerals, which have not been done before, present a useful data for the GPR analyst, since velocity and attenuation of the radar wave can be calculated from the complex dielectric permittivity data. Our results suggest that three factors affect the dielectric permittivity and therefore the velocity of the GPR. These are porosity (dry porosity in our case as we didn't include yet any water in our synthetic samples), crystal size and contamination.

Introduction

GPR is a non destructive technique that exploits the fact that different materials have a different dielectric permittivity and therefore different velocity and attenuation of the electromagnetic radiation. This is used to map formations in a similar manner to seismic imaging. The difference in the dielectric permittivity leads to a reflection of the electromagnetic waves travelling in these layers. The GPR technique is widely used in salt (potash) mines to provide information about anomalies within the salt in order to guide the drilling process and avoid clayey areas[1,2,3]. In Civil engineering the technique is used to determine the continuity of the various lithological units and locate hazards such as cavities, mine shafts and burried channels[4,5,6] .

Measurements of the complex permittivity of some of the evaporite minerals has been done before[7,8]. The values obtained were variable and that is because these different groups worked with naturally occurring evaporites, which are usually contaminated with different degrees of other minerals (depending on the environment they formed in) and their porosity is different as well. Such variation causes difficulties in the interpretation of GPR as one formation could be mixed with another, which justifies the need for a consistent study of the complex permittivity of evaporite minerals.

In this work we measured dielectric of porous synthetic evaporite samples and some natural samples. The aim is to study sysrematically the factors affecting the dielectric permittivity of evaporite minerals. These are preliminary results and further work is now being carried out.

Theory

The complex dielectric permittivity is given by

$$\varepsilon^{*} = \varepsilon' + i\varepsilon''$$

where ε' is the real dielectric permittivity and ε" is the imaginary dielectric permittivity. The real dielectric permittivity describes the ability of the material to store energy by polarization as a result of applying electromagnetic radiation. The imaginary part on the other hand describes the energy loss. In the microwave region this loss could be caused either by free conduction ions, which might be present in the material or because the dipoles in the system lag behind the rapidly fluctuating electric field.

The loss tangent is defined as the ratio between the imaginary permittivity ε" and the real permittivity ε'

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'}$$

The complex dielectric permittivity is a critical parameter for the GPR survey because it controls the velocity, attenuation and penetration depth. The velocity of radar wave in a non magnetic material is given by:

$$v = \frac{c}{\sqrt{\varepsilon'}}$$

Where v is the velocity of the electromagnetic waves in the material, c is the velocity of light.

The attenuation α is given by:

$$\alpha = \frac{\pi}{\lambda}\left[\tan\delta * \varepsilon'^{0.5}\right]$$

where λ is the free space wavelength.

The inverse of α is called the skin depth and is defined as the depth at which the input energy reduces by1/e, where $e \approx 2.7128$.

Method

The technique used to measure the complex dielectric permittivity is the coaxial line method (Agilent 4991 in conjunction with a network analyzer). The idea is to measure the reflection coefficient from which the impedance of the sample, and therefore the complex dielectric constant can be calculated using the vector network analyzer. Samples of few centimeters in dimension are required with one flat surface to provide a good contact with the probe head without any air gap.

Results

The results show that the real permittivity of dry halite is constant with frequency but decreases with porosity (the left hand side of Figure 1). The imaginary permittivity, which is almost negligible, is independent of frequency and porosity (the right hand side of figure 1).

Figure 2 shows the real permittivity of two natural evaporate mineral samples: dolomoite on the left hand side and magnesite on the right hand side. The eight measurements are repetitions along the same surface. The variation of the real permittivity is caused either by contamination or grain size effect. The effect of grain size on the real permittivity of minerals has been reported by Lebron et al[9] and Dervos et al[10]

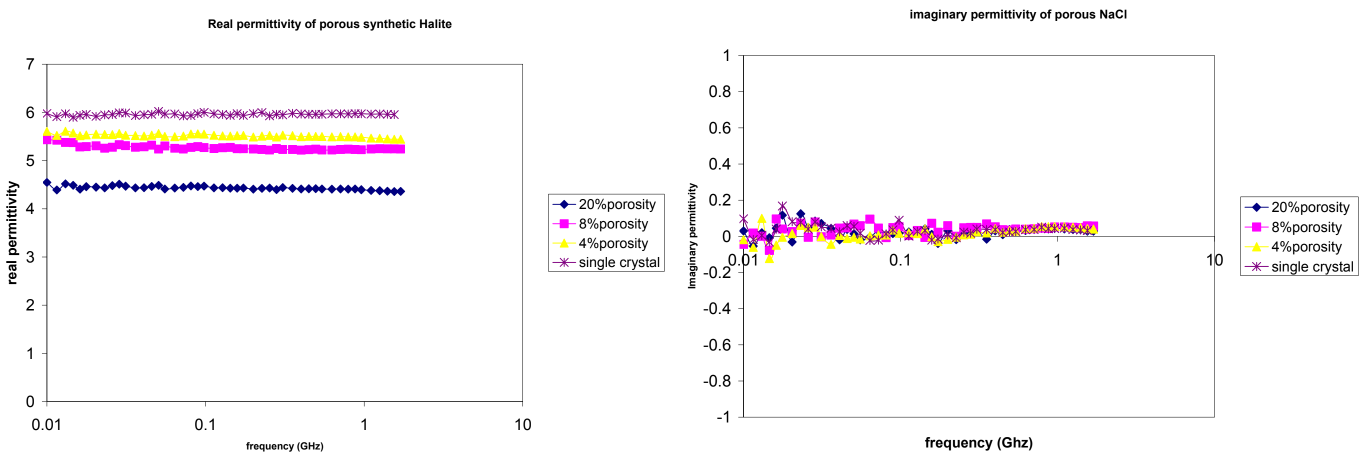

Figure1: the real (on the left hand side) and the imaginary (on the right hand side) permittivity of synthetic porous halite.

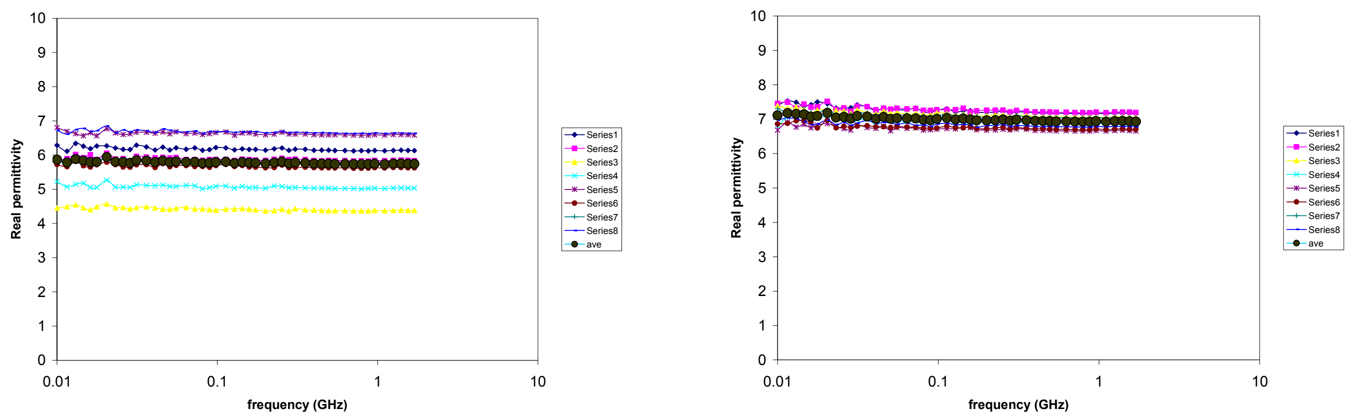

Figure 2: the real permittivity of a natural dolomite sample (on the left hand side) and a natural magnesite sample (on the right hand side).

Conclusions

The porosity of evaporate minerals, which is most likely to be in the from of cracks along the grain boundaries, affect its dielectric permittivity and therefore the velocity of the radar waves traveling in it. The permittivity (and therefore the GPR velocity) of natural evaporate minerals could vary significantly as a result of grain size and contamination.

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