

Complex Dielectric Permittivity Spectroscopy with ACROSS Measurement System V. Review of Studies on 1/f-type Dielectric Dispersion

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This work is motivated to examine the possibility of remote observation of H₂O and its tectonic roles by studying the nature of dielectric dispersion. Slight wetting of rocks appears to show a drastic increase in dielectric permittivity ϵ in reciprocal proportion to frequency below several hundreds kilohertz, whereas electric conductivity s is almost independent of frequency (Lockner & Byerlee 1985, Jonscher 1976, etc.). This peculiar dielectric dispersion may be useful to characterize H₂O within the Earth's crust remotely by low frequency electromagnetic sounding from the surface.

Field observation as well as property measurement in laboratory provide complex conductivity $s^* = s + j\omega\epsilon = s(1 + jg)$ (which is physically equivalent to complex dielectric permittivity, $\epsilon^* = \epsilon + s/j\omega$ as a function of frequency. Usually the quantity g is defined by $g = \omega\epsilon/s = \cot d$) has been supposed to be too small (less than ~ 0.1) in comparison with the observation error both in situ and in laboratory. Further, laboratory studies on the dielectric dispersion have been quite controversial so far. However, there is a hope in future availability of high-precision EM sounding method, EM-ACROSS (see Nakajima et al. in this session), and (1) we developed a reliable and precise four electrode method of measuring complex dielectric permittivity at low frequencies to a demanded precision of 10^{-3} , and (2) laboratory measurements of dielectric dispersion are made to clarify the basic characteristics in order to correlate with the observation in situ.

We noted that the ordinary measurement methods usually show the large (1) measurement error originated from noise, and also (2) significant bias in $\cot d$ due to the disturbance of electric field in the sample caused by potential electrodes in four electrode method. Therefore, we have used very accurately controlled sinusoidal signals to obtain the high S/N ratio by data stacking, and also a modified 4 electrode method to measure the bulk property and interface property simultaneously by using a new type of potential electrodes with the least polarization. As a result, we came to determine both real part of complex conductivity to a precision to 10^{-5} and imaginary parts at least to a precision of 10^{-3} at the frequency down to 10 mHz. This means that $\cot d$ can be determine to a precision of 10^{-3} .

Our results of measurements are as follows. (a) Heterogeneous materials such as mixture of glass beads soaked in water show that $\cot d$ is nearly constant 0.01~0.003. This suggests that ϵ is in reciprocal proportion to frequency and there should be some electrochemical reactions involved in this dielectric dispersion. The demanded precision in field observation to obtain the meaningful data on dielectric dispersion in situ is ~ 0.003 or better. (b) uniform materials such as water and glass do not show any increase of ϵ in reciprocal proportion to frequency, whereas some previous paper reported the frequency dependence of ϵ very probably due to the bias originated from the distortion of electric field by potential electrodes in the measurement.