Complex Dielectric Permittivity Spectroscopy Using ACROSS Measurement System VI.Potential Measurement by Non-Polarizable Electrode

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This work is on the methodology of potential measurement in complex dielectric permittivity aimed to obtain reliable data of moist rocks, which have relatively small dielectricity of less than 10^-1 in cot d, where d is the loss angle. We have recently acknowledged the problem of polarization at potential electrode yielding significant bias of ~10^-2 in cot d, where d is loss angle. We devised the method of potential measurement using ionically conductive electrode to reduce bias to ~10^-3 in cot d. Here we report on the method and its application to the measurement of the profile of complex dielectric permittivity.

Polarization at electrodes occurring at frequencies less than hundreds kilohertz is the most critical and common problem in complex dielectric permittivity measurement of moist rocks. Polarization at current electrode is well recognized and four electrode method is commonly used to avoid its effect. Four electrode method is considered to be reliable if the leak of current through the circuit connecting potential electrodes is prevented by the use of amplifier having input impedance sufficiently larger than the sample.

Recently we realized another important and so far unrecognized problem in four electrode method of polarization at potential electrode. We consider that the polarization is caused because by the difference of electric property between the electrode and the sample; Commonly used metallic electrode has electron conductivity and moist rock samples have ionic conductivity. Migration of ions and electrochemical reaction will occur at the boundary of medias having different charge carriers (ion species and electron) leading chemical potential gradient which appears as dielectric polarization.

We therefore consider that polarization at electrode does not occur if one uses ionically conductive electrode for ionically conductive samples, instead of electronically conductive electrode. We tried electrode made of agar-agar having ionic conductivity similar to H2O. In our measurement of H2O water, apparent polarization was less than 10-4 in cot d with agar-agar electrode while the polarization up to 10^-2 in cot d was observed for the electrodes made of Pt or stainless. After successive measurement of moist samples with agar-agar electrode, we conclude that potential electrode must be ionically conductive in the measurement of moist samples.

The profile of complex dielectric permittivity is of interest for the sample having heterogeneity since the dielectric polarization arises from the heterogeneity such as clacks or boundary of texture. We tried to measure the profile of complex dielectric permittivity by using arrayed potential electrodes of agar-agar with insulating slits inserted in parallel and following the scheme of four electrode method. It will provide the spacing resolution ~ 1mm and small apparent polarization of less than 10^-3 in cot d. Test measurement of the sample of agar-agar showed that the complex dielectric permittivity was almost uniform but dielectric permittivity was large within 5mm to the current electrode. Large dielectric permittivity nearby current electrode is considered to be the chemical potential gradient induced by the electrochemical reaction occurring at the current electrode.