§4. Experimental Study on Microwave Propagation in Liquid Medium

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Researches on applications of microwave or millimeter wave energy to the sintering of ceramics and metal powders, the chemical reactions have been widely performing. For such researches, it is important to know microwave or millimeter wave absorption behavior of subjected materials prior to these experimental studies. Particularly, attempts to apply microwave energy to the chemical reaction is actively performing nowadays, and such data are needed. In this study, we aimed to have such basic data for the development of the microwave chemical reaction technology, and experimentally examined microwave propagation behavior (attenuation) in liquid medium.

The measurement system is composed from a network analyzer (Agilent Technologies: 8753E), antennas (handmade ones; a monopole antenna and a loop antenna), a tuner (inline type impedance matching unit, Yokowa: TUN-4500), and microwave cables. Transmitter side antenna is a 6.8mm monopole antenna which length is designed as 1/2 λ in the water medium at 2.45GHz. Receiver side antenna is a loop antenna which diameter is about 2mm. Antennas were made from semi-rigid coaxial microwave cable (RG402/U). The tuner is inserted between the monopole antenna and the transmitting port of the network analyzer. By adjusting the tuner, return signal level (S11) became -40 dBm or less. This means that almost all microwave energy was radiated into the liquid medium. Measurements were performed for pure water and 05M-KCl aqueous solution at 2.45GHz. The distance between antennas was changed from 2mm to 30mm by 1mm step, and the signal level (S21) was measured at each position.

Fig. 1 shows the measurement results of S21 power level change by changing distance between antennas in pure water and 0.5M-KCl aqueous solution. Both curves show decrease of S21 power level with increase of distance between antennas. Comparing two curves, slope of 0.5M-KCl aqueous solution is larger than that of pure water.

Figs. 2 and 3 show the complex permittivity of pure water and 0.5M-KCl aqueous solution measured by the coaxial probe method. tan δ ($\varepsilon''/\varepsilon'$) values at 2.45GHz are 0.13 and 0.68 for pure water and 0.5M-KCl aqueous solution, respectively. It is recognized that liquid which has bigger tan δ value shows rapid decrease of S21 power level as seen in Fig. 1.

When the antenna distance is 15 mm, S21 power level decreased to -30dBm (1/1000 as electrical power) in pure water and to -50dBm (1/100000 as electrical power) in 0.5M-KCl aqueous solution. At 30mm, S21 power level in 0.5MKCl aqueous solution reaches -70dBm, this value is almost measurement limit (noise level) of the measurement system. These results means that almost all microwave energy is absorbed near the transmitter side antenna in high loss liquid medium which has large tan δ value.

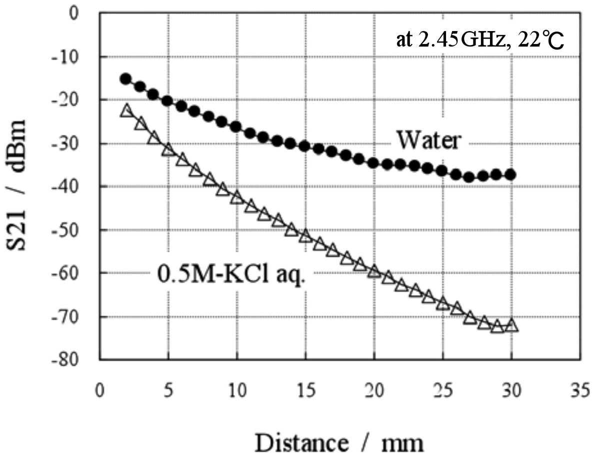

Fig.1 Measurement results of S21 for pure water and 0.5M-KCl aqueous solution

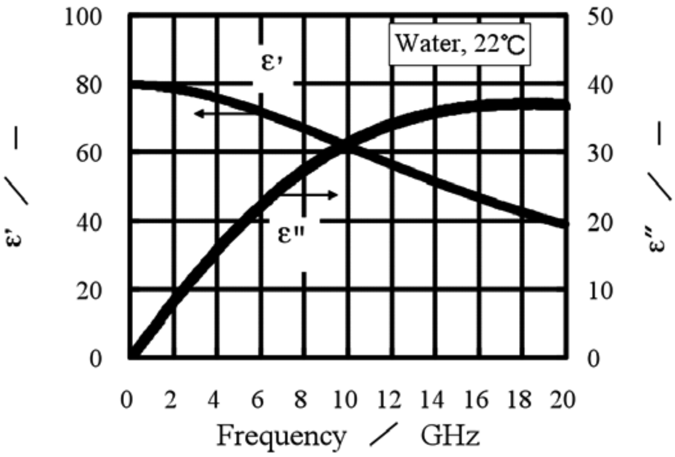

Fig.2 Complex permittivity of pure water

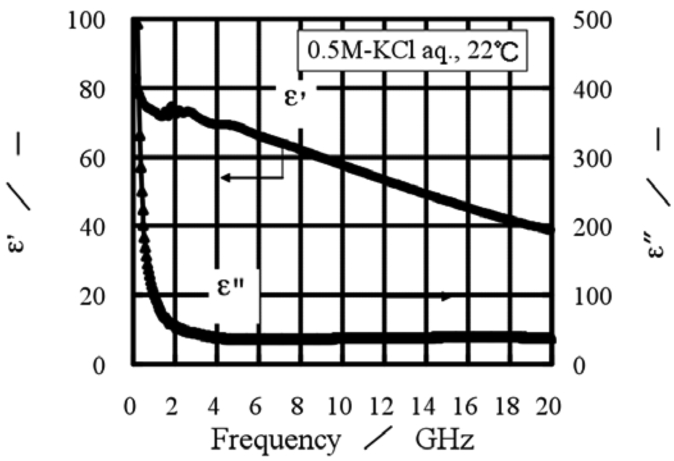

Fig.3 Complex permittivity of 0.5M-KCl aqueous solution