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Dielectric Behavior of Water Adsorbed on Solid Surfaces at Very Low Frquencies (I)

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1. Introduction

Dielectric behavior of water adsorbed on solid surfaces has been investigated by many authors. Several results were obtained by Yager and Morgan(1), Garbatski and Folman(2), and Kurosaki et al(3)(4) about water on glass. No study, however, seems to have been carried out at frequencies as low as a few c/s. So we studied experimentally the dielectric dispersion at very low frequencies mainly on soda lime glass and for comparison on mica, fused silica and polystyrene, and found a conspicuous low frequency dispersion which was considered to be attributed to electrode polarization.

2. Experimental Procedure

Two aluminum foils mounted on a plate surface and seperated by a slit were used as electrodes. The adhesive was grease, vaseline or water. For comparison evaporated silver electrodes were also used. The specimen was first dried in a desiccator containing concentrated sulfuric acid, and then was transferred to another desiccator containing dilute sulfuric acid corresponding to the desired humidity. All the measurements were made after the specimens had remained in the second desiccator for 24 hours, because it had been found to take that long for the specimens to reach hygroscopic equillibrium with the surrounding atmosphere. The dielectric measurements were carried out with the apparatus described previously(5)(6).

3. Experimental Results and Discussion

The frequency dependence of the capacity of soda lime glass surface between aluminum foils attached with grease is shown in Fig. 1. The slit was 0.38mm wide and 78 mm long. The relative humidity was 93%.

It is seen that the capacity sharply increases below 10 c/s with decreasing frequency, reaching about 1000pF at 1 c/s. The Cole-Cole diagram in this case is shown

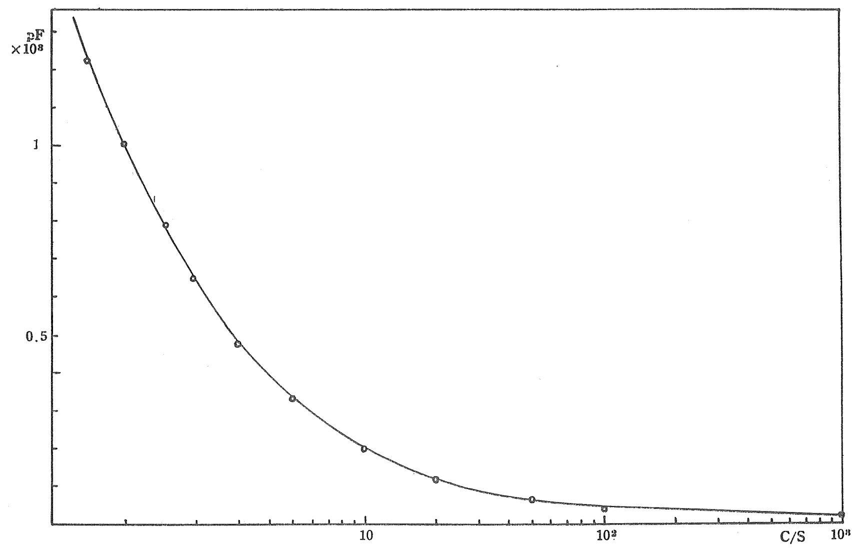

Fig. 1. The frequency dependence of the capacity of soda lime glass surface at 93 %relative humidity.

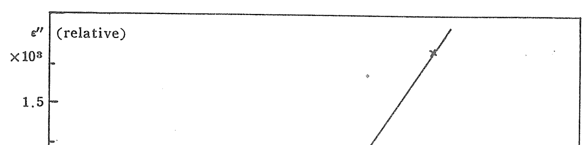

Fig. 2. Cole–Cole plot of complex dielectric constant of soda lime glass surface at 93% relative humidity (electrodes attached with grease).

in Fig. 2. As the geometrical capacity of the condenser could not be found the absolute values of ε' and ε'' were not calculated, and the Cole-Cole diagram was plotted with relative values. In curve (1) ε'' was calculated from the total conductance, and in curve (2) the additive contribution to ε'' due to dc conductance was eliminated by subtracting the dc conductance from the total conductance at each frequency.* In this case the dc conductances measured by a vacuum tube electrometer was found to vary with the dc voltage used as shown in Fig. 3. So we first measured by an oscilloscope the peak-to-peak value of the oscillating voltage to be applied and then measured the conductance at dc voltage equivalent to the effective value of the oscillating voltage. By these procedure the Cole-Cole diagram appears as a part of a circular arc, curve (2). Similar dielectric dispersion was found at 83% or 72% relative humidity but it decreased with humidity. Fig. 4 is an example.

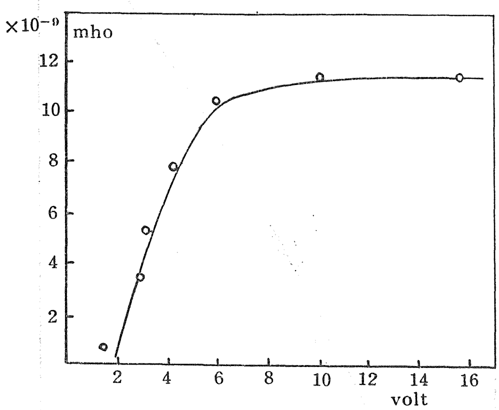

Fig. 3. Variation of dc conductance with voltage.

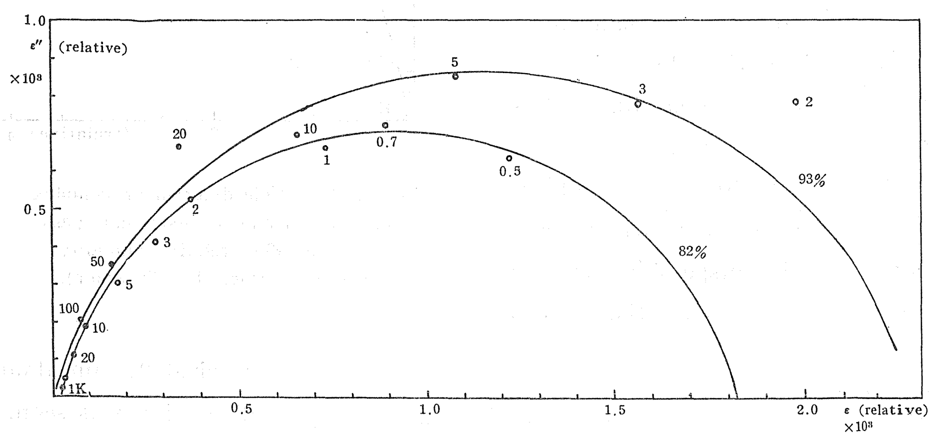

Fig. 4. Cole–Cole diagrams of complex dielectric constant of soda lime glass surface at 93% and 83% relative humidity.

When aluminum foils were attached with vaseline we found the same result as above but when they are attached with water the values of ε'' appeared to be larger as shown in Fig. 5. If we consider this locus also to be a part of a circular arc the relaxation time in this must be very large.

* This procedure was adopted in the following calculation of ε''.

When evaporated silver electrodes were used the dielectric dispersion was very small. This is perhaps due to the small thickness of the electrodes. On mica we obtained the same result as on soda lime glass. Fig. 6 is the Cole-Cole diagram of the result with mica at 93% relative humidity. The slit was 0.54mm wide and 50mm long. The electrodes were aluminum foils attached with grease.

On fused silica the dielectric dispersion was very small as shown in Fig. 7. The slit was 0.52mm wide and 50mm long. The electrodes were aluminum foils attached with grease. On polystyrene no dielectric dispersion was seen. No water seems to be adsorbed on polystrene.

Now to study the mechanism of conspicuous dielectric dispersion of water adsorbed on soda lime glass surface we examined the effect of the width of the slit. The result is shown in Fig. 8. As the width increased the dielectric dispersion sharply decreased. And when the width reached 2.5mm almost no dispersion was seen.

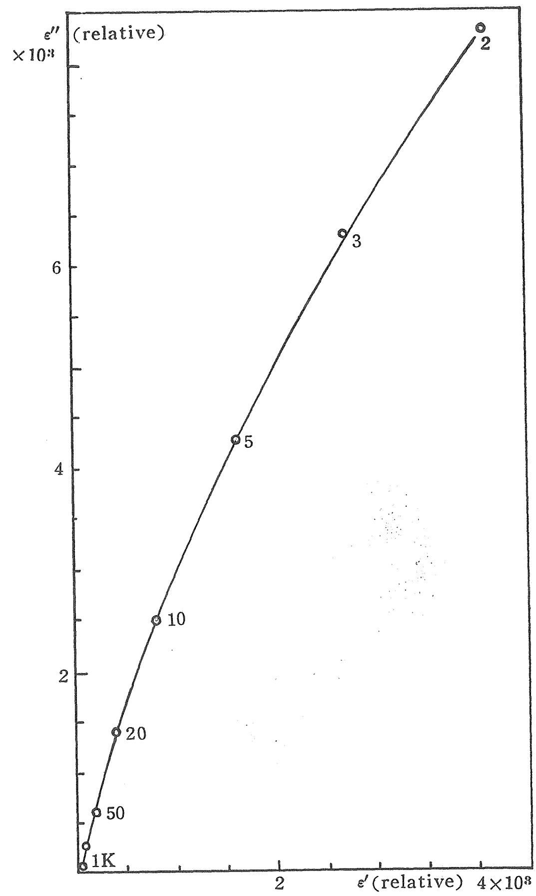

Fig. 5. Cole-Cole diagram of complex dielectric constant of soda lime glass surface at 93% relative humidity (electrodes attached with water).

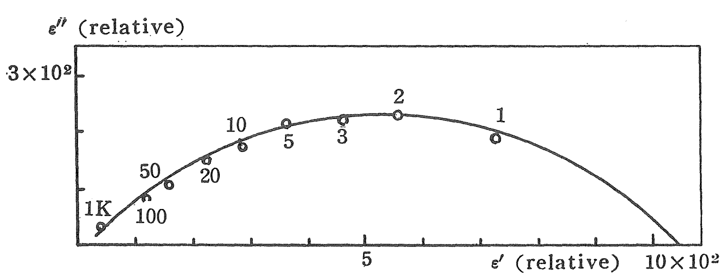

Fig. 6. Cole-Cole diagram of complex dielectric constant of mica surface at 93% relative humidity.

On the other hand the water films at 93% relative humidity seems to consist of a few tens of molecular layers according to result of Yager and Morgan(1). So the film will behave as bulk water or ice in some way.

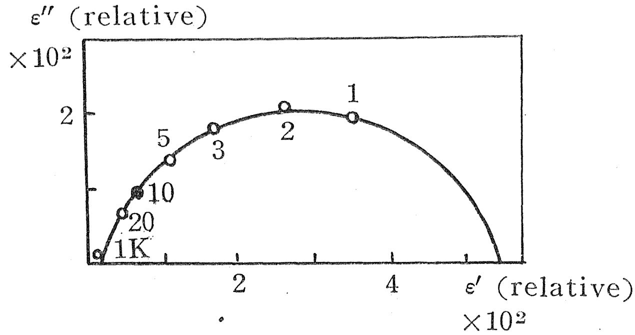

Fig. 7. Cole–Cole diagram of complex dielectric constant of fused silica surface at 93% relative humidity.

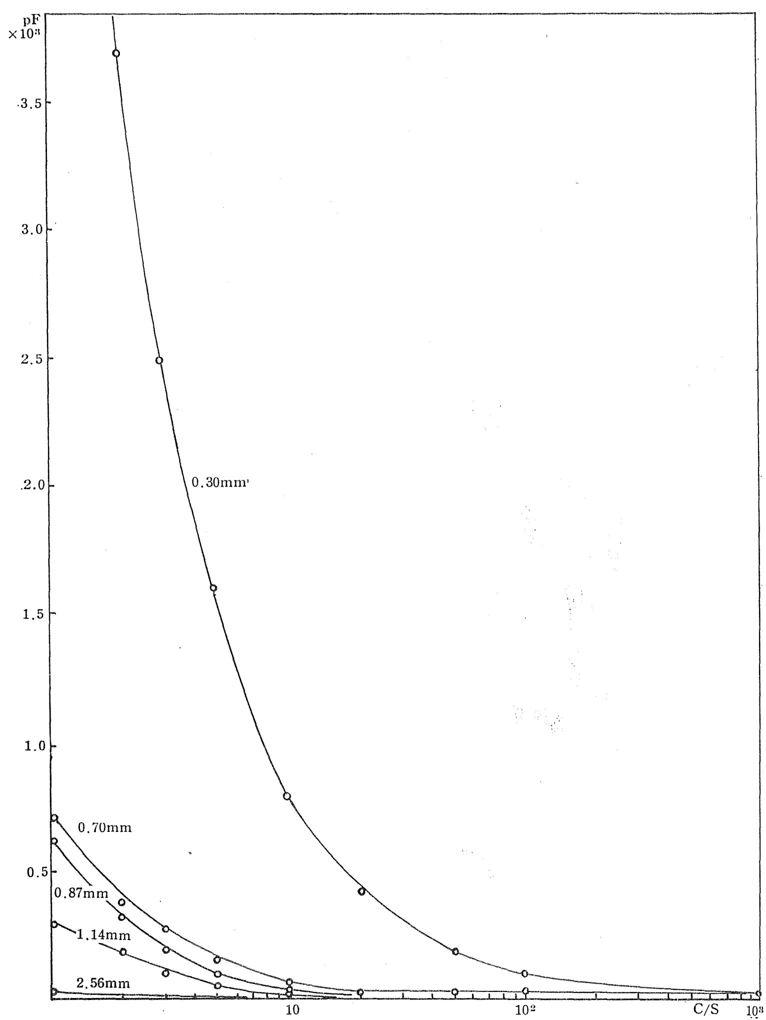

Fig. 8. The effect of the width of slit.

From these facts we guess that the remarkable dielectric dispersion at low frequencies may be attributed to electrode polarization mentioned by Yager-Morgan(1) and Johnson-Cole(7). And the marked difference between the facts in the case of electrodes attached with grease or water will be explained by the difference of electrode impedances in each case.

Finally it should be noted that in dielectric measurement at low frequencies one must remember the effect of humidity on the insulator of the condenser used in the electric circuit.

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