Dielectric Dispersion of Rochelle Salt Crystals at Low Frequencies

Dielectric Dispersion of Rochelle Salt Crystals at
Low Frequencies

By

Mitsuo IDA* and Shuji KAWADA*

(Received September 10, 1960)

1. Introduction

On the dielectric dispersion of rochelle salt crystals at low frequencies, several measurements have been made by Kawai and Marutake.[1] They investigated the behavior of the dielectric constant by special devices at frequencies as low as $\frac{1}{4}$ c/s. Their results are mainly of the real part ε' of the complex permittivity and little has been known about the negative imaginary part ε''. For the purpose of studying the dielectric mechanism it is often useful to determine the relation of ε' and ε'', so the present authors measured the two values at low frequencies from 1000 c/s to 1 c/s and plotted Cole-Cole diagrams.

2. Experimental Procedure

The apparatus employed was generally the same as those described in the preceding paper[2], but the very low frequency oscillator of the Toa Denpa Co. was used this time. a-cut plates of rochelle salt crystals kindly offered by Dr. Marutake were used. They were of about 10 cm² area and 2 mm thick coverd with aluminum foils on both faces using vacuum grease as adhesive. The relative humidity was kept at about 17 % during the measurement. Alternating electric fields of about 15 V/cm were employed and in such a weak field it seemed that the effect of the intensity of the electric field was negligible. By these procedure we could measure the value of ε' at frequencies as low as 1/10 c/s, and that of ε'' at 1 c/s.

3. Experimental Results and Discussion

The relations of the real part ε' and the negative imaginary part ε'' of the complex dielectric constant at several temperatures above the Curie point are shown in Fig. 1.

In the calculation of the values of ε'' the dc conductivity errors were not corrected because they were negligibly small compared to the total conductance. In every curve in

---

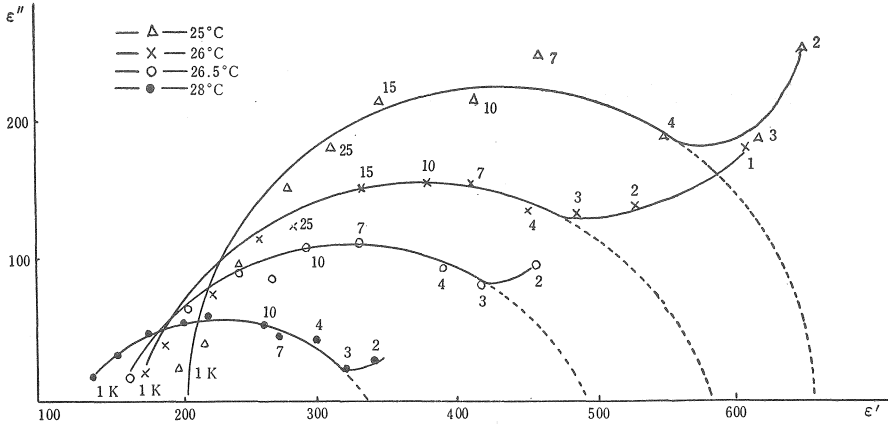* Department of physics, Faculty of Science, Kanazawa University.

Fig. 1. Complex dielectric constants at several temperatures above Curie point

Fig. 1 the points corresponding to frequencies between 1000 c/s and a few c/s are on or near circular arcs, but they deviate from the circular arcs at lower frequencies. That is, there seem to be two dispersions. We say the dispersion at higher frequencies as the first dispersion and that at lower as the second dispersion. From the figure it is found
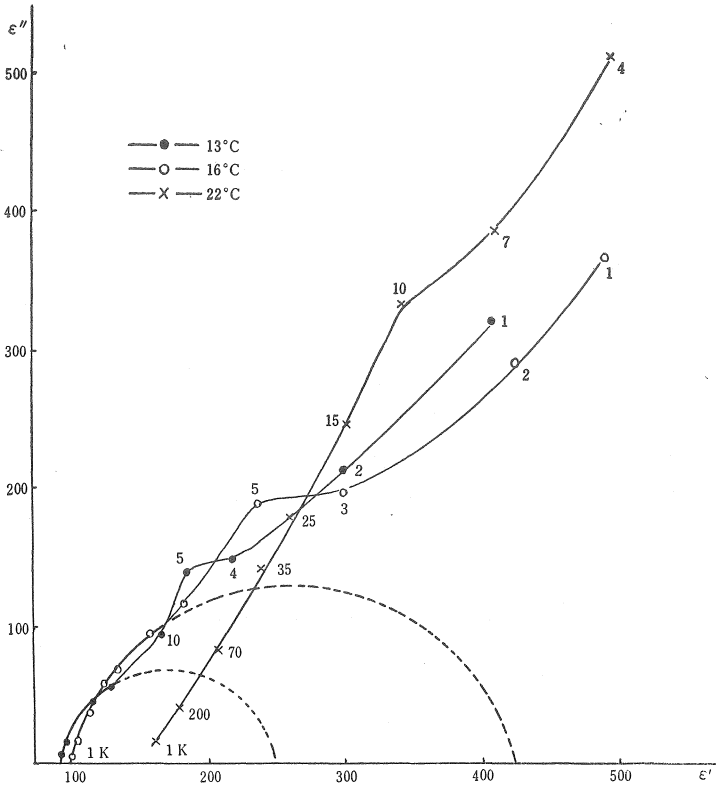

Fig. 2. Complex dielectric constants at several temperatures below Curie point

that, as the temperature approches the Curie point, the arc of the first despersion gradually changes to a semicircle showing a single relaxation time. The figure is similar to that of BaTiO$_3$ below the Curie point described in the preceding paper[2], though the frequencies at which the second dispersion occur are much lower than those of the latter.

The result obtained with the same specimen as the above at temperatures below the Curie point is shown in Fig. 2 as an example.

The aspect of the figure appears to be different from that of Fig. 1. But we can interpret the curves as superposition of the first and second dispersions and regarding the latter to occur at higher frequencies below Curie point than above. In this case the second dispersion seems to occur at frequencies higher than that corresponding to the top of the circular arc.

And we can imagin that the charge carriers of the two dispersions are of different kinds. Perhaps the charge carriers of the first dispersion are the protons of hydrogen bonding and that of the second dispersion the space charge.

Comparing the figures of Fig. 1 and Fig. 2 we find that the second dispersion can happen below Curie point more easily than above. The cause of the phenomenon can not be attributed to the dc conductivity because the dc conductivity increases as the temperature rises. In the case of BaTiO$_3$ the second dispersion occurs more easily above Curie point than below as described in the preceding paper[2]. At present we can not explain the difference in behavior of rochelle salt and BaTiO$_3$.

The effect of humidity

With the humidity at 57% the values of ε' and ε'' (not corrected for the dc conduc-
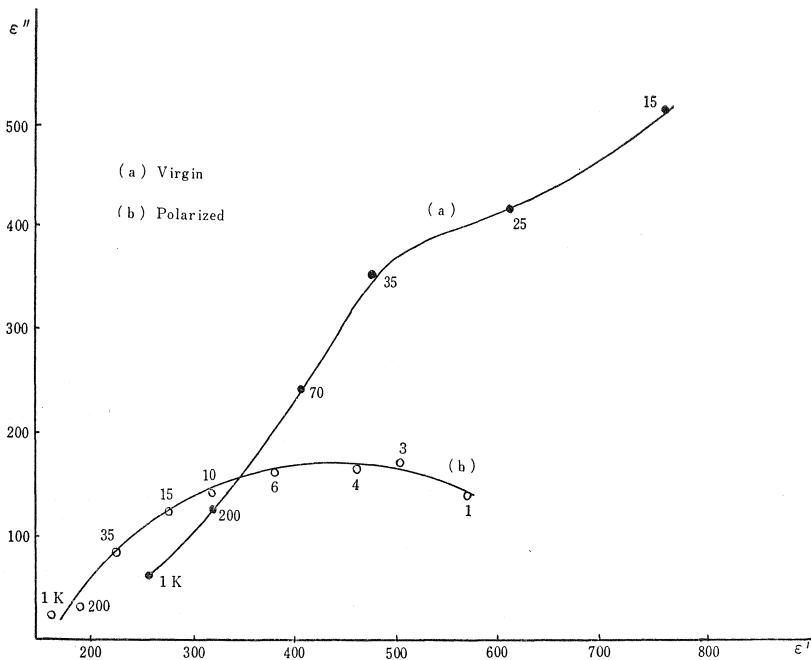

Fig. 3. The effect of poling (20℃)

tivity) increase remarkably and we can not obtain circular arcs even at temperatures above the Curie point.

The effect of poling

Fig. 3 shows the effect of poling.   Curve (a) is the result with a virgin sample.

Curve (b) is the result with the sample treated as follows.   The virgin sample used in the measurement (a) was polarized in a dc field of 800 V/cm for 30 minutes, and measured after the sample was aged for 20 hours with the two electrodes short circuited. It is found that the values of ε' and ε'' decreased remarkably and the second dispersion disappeared by the poling.   When the sample was depolarized by heating it above the Curie point in an alternating electric field of 350 V/cm for 30 minutes, the effect of the poling nearly but not completely disappeared.

The effect of X ray damage

Eisner[3] reported that the 50 c/s permittivity of X ray damaged rochelle salt at the Curie point was approximately halved compared with the virgin sample, but the permittivity between 500 and 5000 kc/s was not very sensitive to radiation.   We exposed *a*-cut crystals of rochelle salt to 40 kV, 5 mA X rays from a tungsten target at a distance of 10 cm.   The temperature of the crystals was about 15°C during the irradiation. The Cole-Cole diagrams of the X ray damaged sample are shown in Fig. 4.
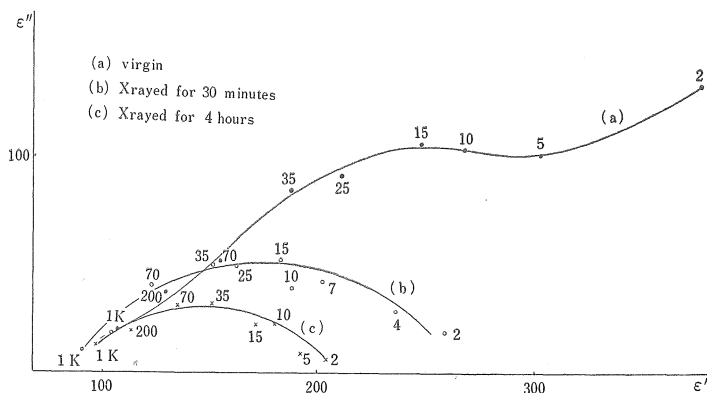

Fig. 4.   Complex dielectric constants of X ray
damaged sample (18°C)

Curve (a) is the result with a virgin sample.   Curves (b) and (c) are the results with the sample exposed to X rays for 30 minutes and 4 hours respectively.   These curves show the following facts.

(1)   The effect of X ray damage on ε' and ε'' was not conspicuous at frequencies in the neighborhood of 1000 c/s.

(2)   At the frequency region of a few c/s the values of ε' and ε'' were decreased remarkably by the irradiation and the second dispersion disappears.

(3)   Distibution of times of relaxation becomes conspicuous by the irradiation.

Extending the irradiation beyond 4 hours caused only a small reduction in permit-

tivity. When the X ray damaged crystals were heated above the Curie point and cooled again, the effect of the X ray damage still remained. So the X ray damage effects seem to be permanent. And X ray irradiation seem to be useful for reducing low frequency dispersion.

The authors have not yet succeeded to explain the mechanisms of the effects of poling and X ray damage.

The authors express their gratitude to Dr. Marutake for supplying samples of rochelle salt crystals.

References

(1) H. Kawai and M. Marutake : J. Phys. Soc. Japan **3** (1948) 8
     M. Marutake : Bullet. Kobayasi. Phys. Research **6** (1956) 62
(2) M. Ida, S. Kawada and T. Kesho : Sci. Rep. Kanazawa Univ. **7** (1960) 5
(3) I. Y. Eisner : Kristallografiya **2** (1957) 296