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STUDIES ON THE PIEZOELECTRIC LINES II.
ON ROCHELLE SALT

By

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I. Introduction

Rochelle salt gives rise resonance lines which are called piezoelectric lines in the wide range of 550 MHz from 3 MHz [1,2]. In a previous paper[3], temperature dependence of these lines was reported and it was revealed that in Rochelle salt the temperature coefficients defined by $(1/\nu)(d\nu/dT)$ was about -12×10^{-4} at room temperature. The purpose of the present experiment was to investigate properties of the piezoelectric lines and to derive suggestions on mechanism of the resonance from these.

II. Experimental Procedures

The apparatus for the detection was similar to that used in the previous experiment[3], and it was a regenerative detector with LC tuning circuit having a frequency range between 4 MHz and 9 MHz. The single crystals were made from an aqueous solution of Rochelle salt by cooling method. The samples used were thin slabs normal to a-axis, whose dimensions were about 1～3 mm in thickness and $4\times3\ cm^2$ in area. The sample was placed between two plane electrodes connected in parallel to LC circuit. Then the upper electrode was replaced by a rod electrode whose diameter was 1 mm as shown in Fig. 1. When the rod electrode was moved keeping nearly contact with an a-face of the sample and its end came over at a few special points on the face, sharp resonance lines were observed with an oscilloscope. This rod electrode made possible to search special character of the resonance.

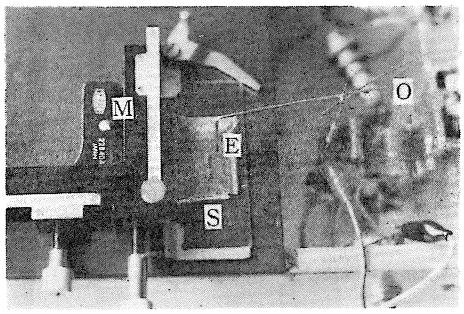


Fig. 1. A part of detector.
O : oscillator E : rod electrode
S : sample M : mechanical stage

III. Experimental Results

(1) Among about eighty samples twelve showed sharp resonance lines. An example of these lines is reproduced in Fig. 2. The number and the geometrical distribution of the resonance points were different for each sample.

(2) When the rod electrode was moved, one of the results is shown in Fig. 3. In the

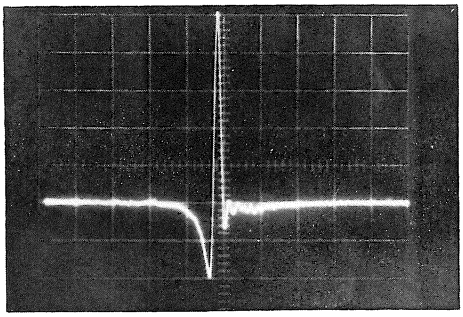


Fig. 2. Sharp resonance line.
The frequency was swept from the left to the right between 9.25 MHz and 9.35 MHz.

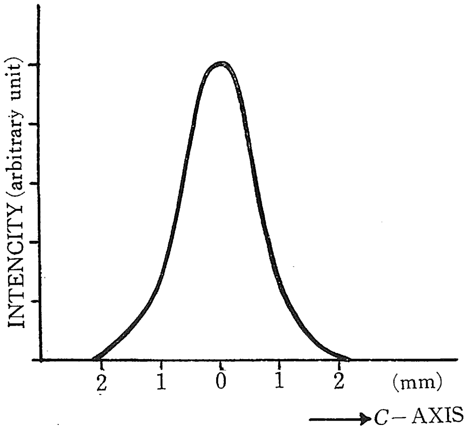


Fig. 3. Relation between the intensity of absorption and the distance from the resonance point.

figure, a transverse axis shows the distance between an arbitrary point and the resonance point. It indicates that the resonance is originated from a very narrow region.

(3) Resonance frequencies were related to neither shape nor size of the sample but only to its thickness, and as the thickness was decreased the frequency was increased.

(4) Changing the frequency of the oscillator with a constant speed, a spectrum of the sharp resonance lines was obtained with a recorder. As shown in Fig. 4, the spectrum was composed of a series of equidistant lines. The spacings were about inversely proportionate to the thickness.

(5) An c-face of the sample was rubbed lightly with a wet filter paper and observed

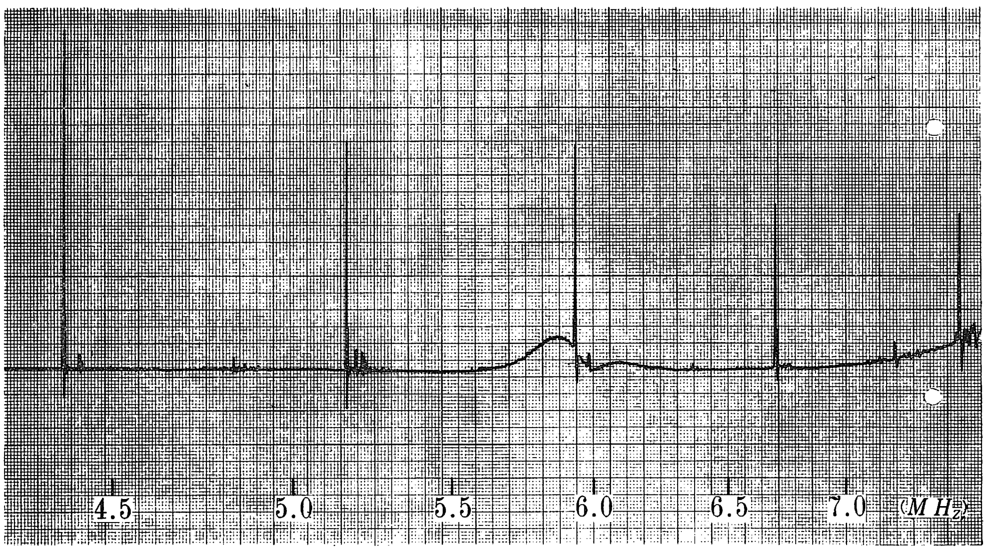


Fig. 4. A spectrum of the sharp resonance lines.
A transverse axis shows frequencies of the oscillator.

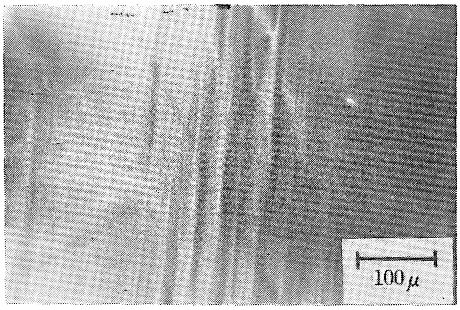
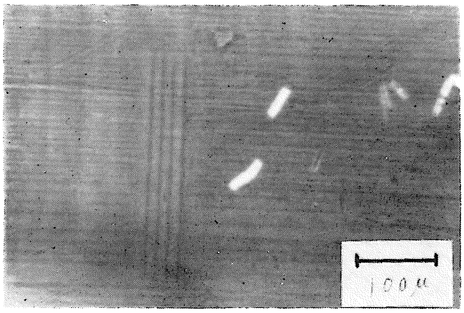


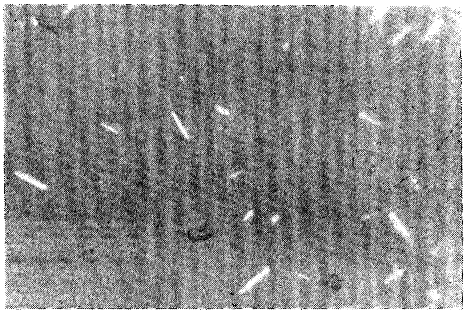
Fig. 5. Etch pits at the resonance point on an a-face.

under a microscope. Etch pits as shown in Fig. 5 were observed at the resonance point, and this appearance was not remarkably different from that at the other points.

(6) The sample was cooled below the upper Curie point and the domain pattern was observed by a polarization microscope. In Fig. 6, (a) shows the domain pattern near the resonance point and (b) shows that for the others. It seems that some imperfection exists at the resonance point.



(a)



(b)

Fig. 6. Domain pattern.
(a) shows the domain pattern near the resonance point and (b) shows that for the others.

(7) Since the resonance seemed to depend on the imperfection of crystals, effect of irradiation of γ-rays were studied. The intensity of absorption was slightly decreased by receiving the irradiation of γ-rays of about 10^5 roentgen.

IV. Discussion

It seems from (1), (2) and (6) that these resonances is originated from a very narrow region due to imperfection of crystal. From (3) and (4), the resonance frequencies were related only to the thickness and the spacings of the resonance lines were about inversely proportionate to the thickness. The elastic vibrations which were related to the thickness were studied and it was found that this resonance was closely related with torsional vibration of a-axis.

The frequency f of a fundamental vibration of torsional vibration is given by

$$f = \frac{1}{2t}\sqrt{\frac{n}{\rho}}$$

where t is thickness, ρ is density and n is rigidity of the sample. On Rochelle salt,

$$\rho = 1.766 - 0.0002522\,\theta,$$

$$n = \frac{2}{s_{55}+s_{66}} \quad ,$$

where θ is temperature, s_{55} and s_{66} are the elastic constants. Using s_{55} and s_{66} of Table 1, f was made calculations. In Fig. 7, f vs t theoretical curves were shown. The solid line and dotted line are the curves for the elastic constant measured by Hinz and Mandell respectively. Small circles show the spacings of spectra of the sharp resonance lines. Since the spacing is considered as the fundamental frequency, experimental values agree well with the theoretical values.

Table 1. Elastic constant.
(10^{-13} cm^2/dyn)

Elastic constant / Experimentalist	s_{55}	s_{66}
Mandel	305	80
Hinz	338	118
Mason	328	101

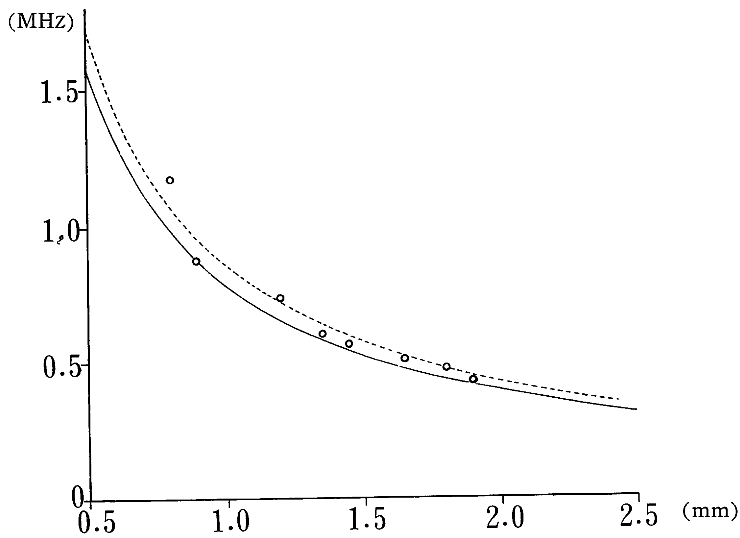


Fig. 7. The frequency of a fundamental vibration of torsional vibration as a function of thickness.

The solid line and dotted line are the theoretical curves for Hinz and Mandell respectively. Small circles show the spacings of spectra of the sharp resonance lines.

Although the mechanism of the resonance has not yet been made clear, it becomes evident that some of these resonances are intimately related with torsional vibration originated from a very narrow region due to imperfection of crystal.

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References

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