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STUDIES ON THE PIEZOELECTRIC LINES. I.
TEMPERATURE DEPENDENCE

By

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I. Introduction

Silver iodine, zinc sulfide, barium chlorate, rock crystal and Rochelle salt give rise radio-frequency absorption lines which are called piezoelectric lines.

The characteristics of piezoelectric lines were investigated by the researchers who had found these lines, and a suggestion on the mechanism was also given by them[1)2)3)]. However, the origin of the absorption seems to be not completely explained by such mechanism.

In the present experiment, the effects of temperature on the absorption lines of pure Rochelle salt, Rochelle salt including impurity, annomium dihydrogen phosphate and rock crystal were investigated in the frequency ranges from 3 MHz to 40 MHz.

II. Experimental Procedures

The block diagram of the apparatus used for this experiment is shown in Fig. 1. This apparatus is same as that used in the previous work[4)], and the recorder with lock-in amplifier is added to that.

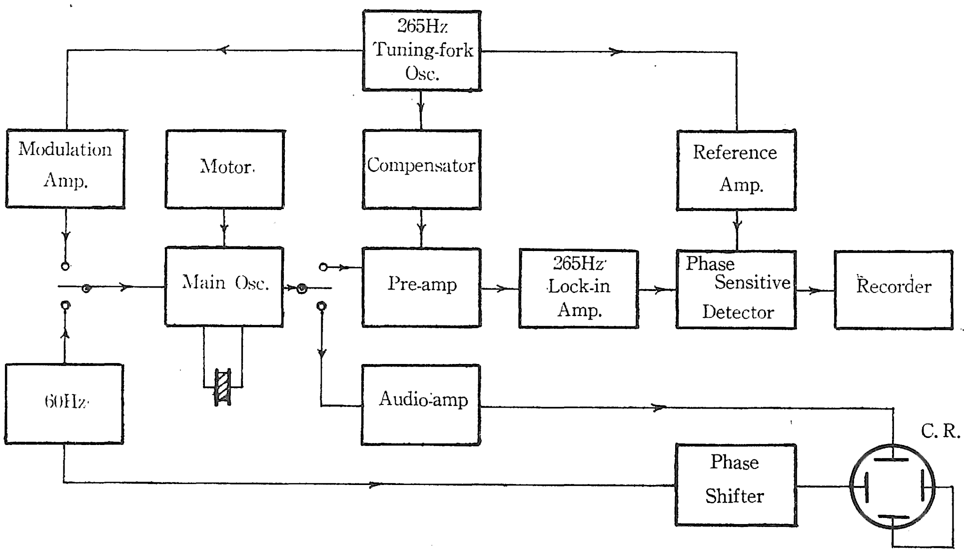

Fig. 1 Block diagram of apparatus.

The single crystals of Rochelle salt and ammonium dihydrogen phosphate were made from saturated solution by natural cooling method, and the samples of Rochelle salt were thin slabs normal to a-axis had obtained by the above mentioned method. The samples of rock crystal were commercial X cut, Y cut and R cut quartz resonators.

To keep the temperature constantly during an experiment, the sample was inserted between two electrodes which set in a vacuum bottle wrapped in adiabatic materials as shown in Fig. 2.

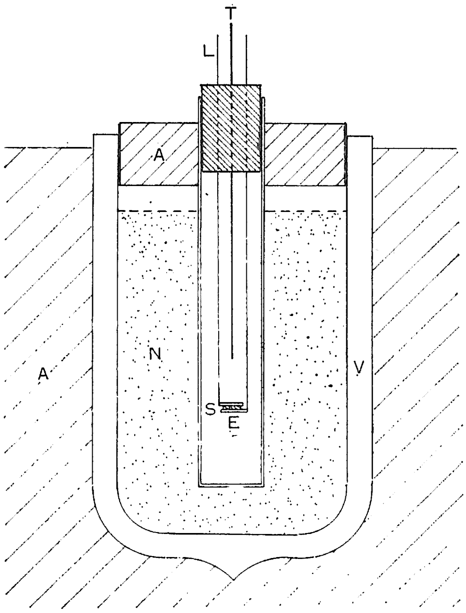

Fig. 2 Vacuum bottle.
S : Sample E : Electrode T : Thermo-electric thermometor V : Vacuum bottle A : Adiabatic materials
N : Liquid nitrogen (ethyl alcohol, water) L : Lead wire

The constant low temperature was obtained by melting dry ice in ethyl alcohol or using liquid nitrogen directly.

The absorption lines were observed by a cathode-ray oscilloscope and the pattern of the lines was recorded by the recorder.

The resonance frequencies were measured by the method of heterodyne.

III. Experimental Results

The change of the absorption lines in the pure Rochelle salt by the change of temperature from room temperature to $-149°C$ is shown in Fig. 3.

These lines change not only on resonance frequencies but also on figure, and it is remarkable that these lines disappeared at about upper Curie point. The aspect of change of the line whose resonance frequency is 3.94 MHz at room temperature is shown in Fig. 4. The pattern of absorption lines recorded by recorder at room tempera-

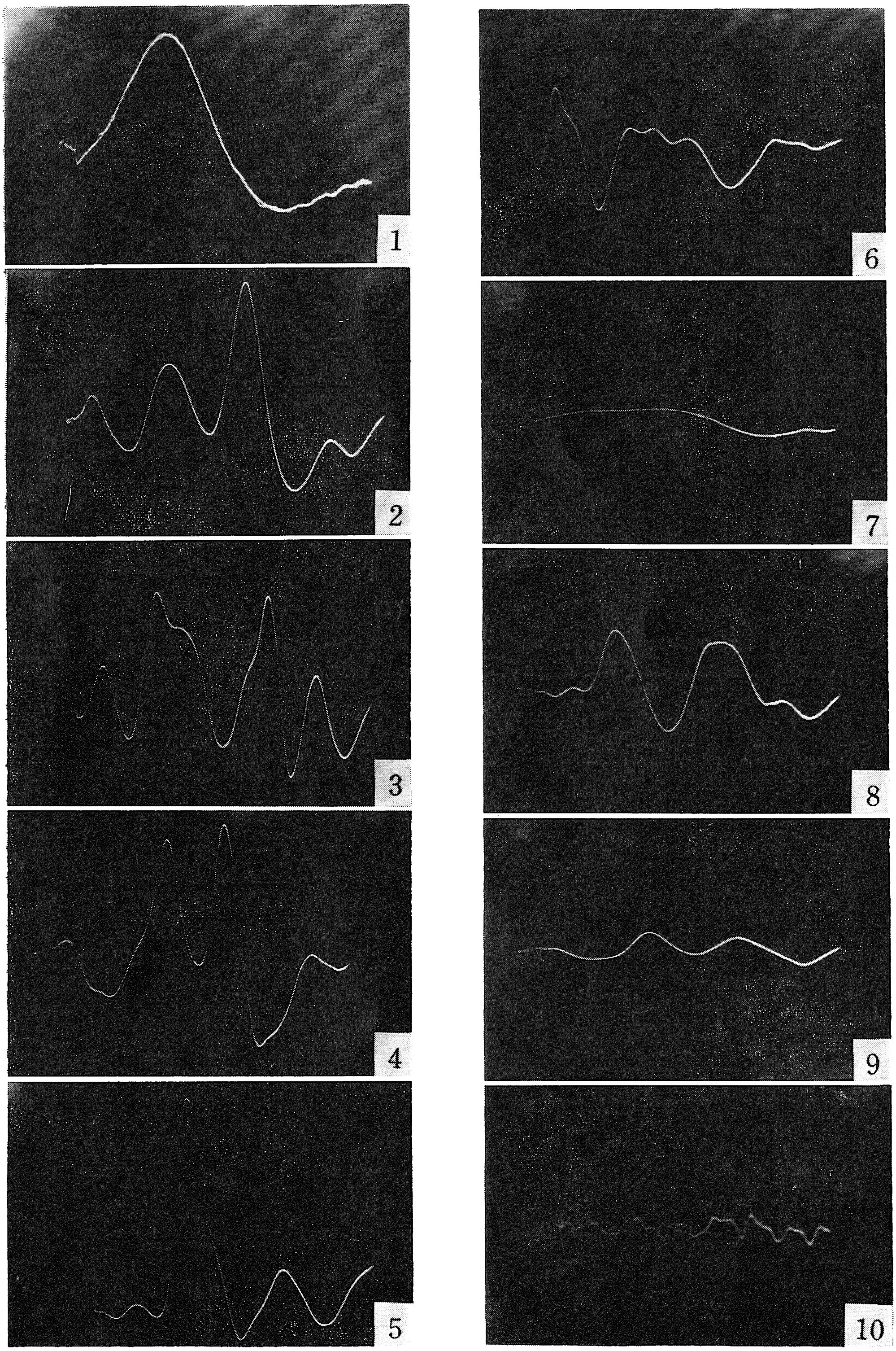

Fig. 3 The absorption lines in pure Rochelle salt observed by a cathode-ray oscilloscope.
(1) 27.8°C (2) 25°C (3) 24°C (4) 23.2°C (5) 22.8°C (6) 22°C (7) 20°C
(8) 17.8°C (9) 0°C (10) −149°C

ture, about Curie point, 0°C and −171°C is shown in Fig. 5. At −171°C, the pattern of absorption lines is very like that of rock crystal at room temperature.

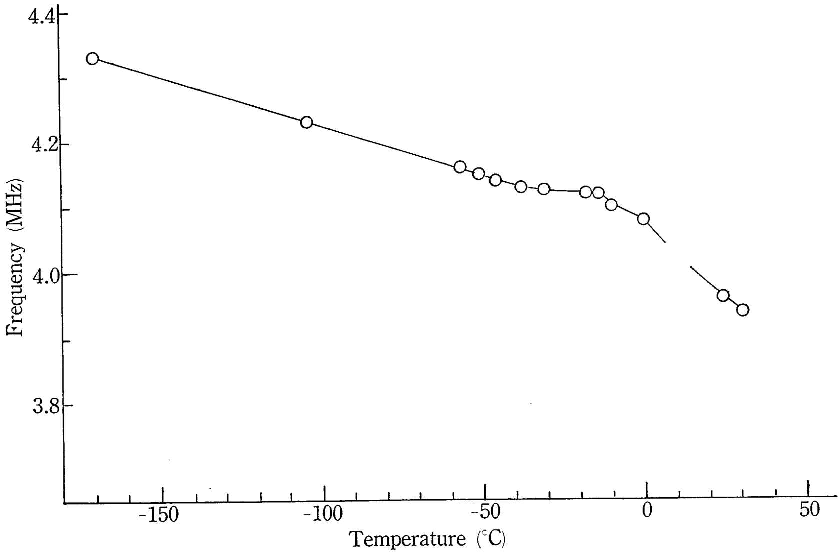

Fig. 4 Dependence of resonance frequency on temperature. The sample is the single crystal whose dimension is about $1.7 \times 3.6 \times 11 mm^3$.

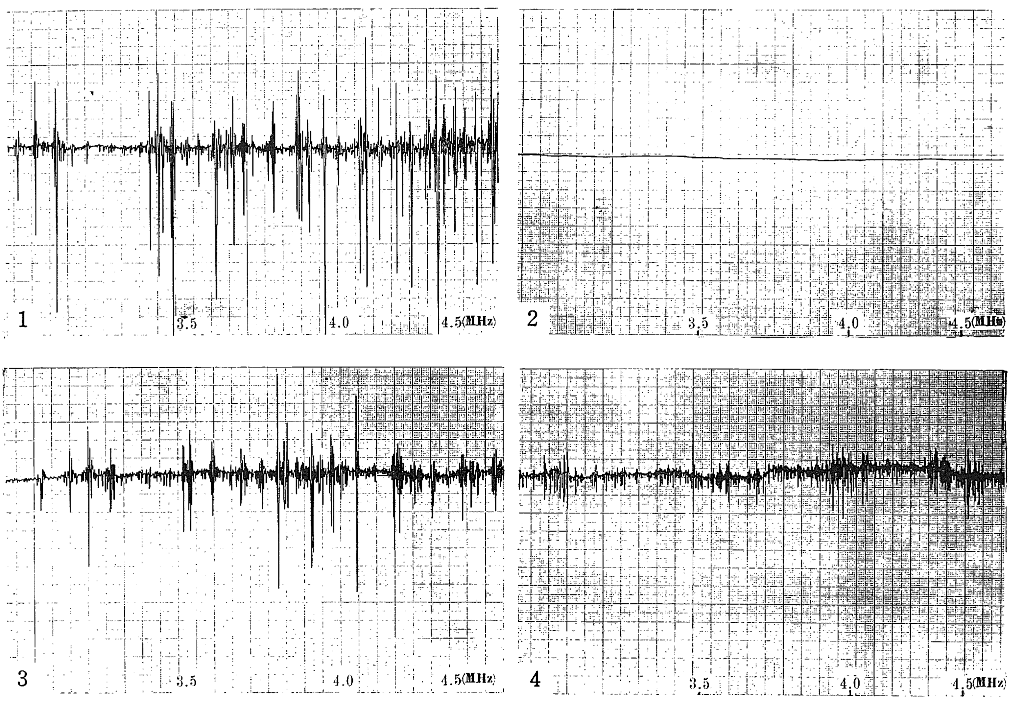

Fig. 5 The pattern of absorption lines recorded by the recorder. in pure Rochelle salt.
(1) 30°C (2) 22.5°C (3) 0°C (4) −171°C

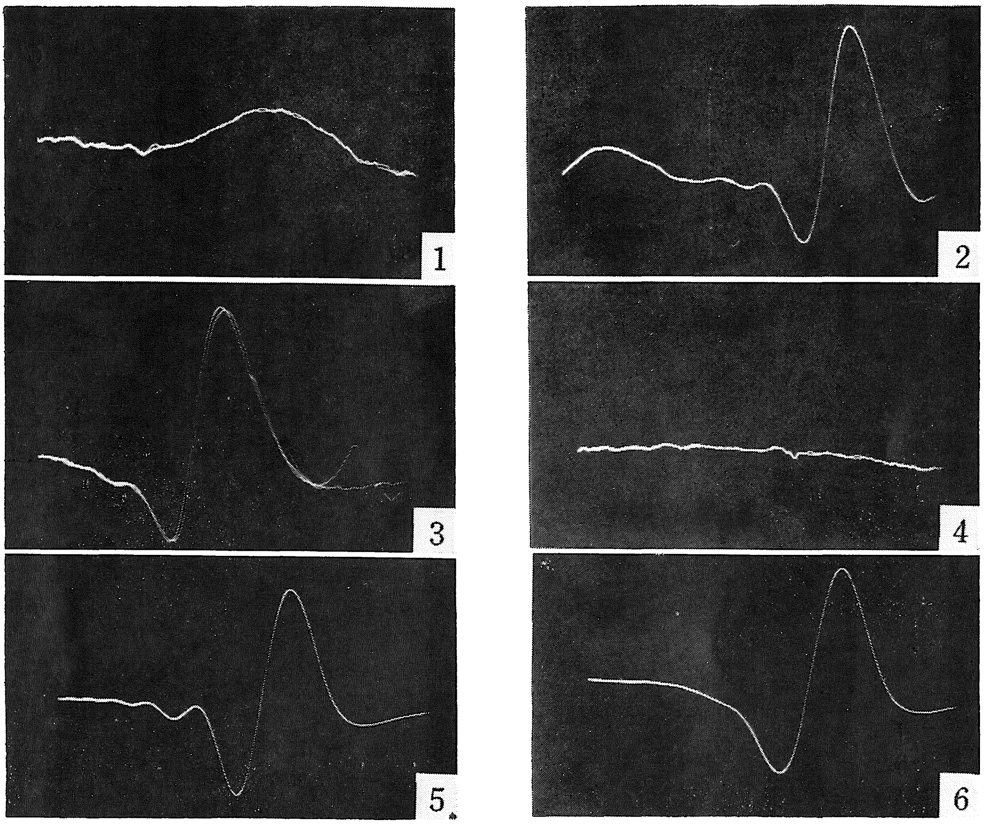

Fig. 6 The absorption lines in quartz resonators observed by a cathode-ray oscilloscope.

(1) X cut : 1.0000 MHz (2.85mm, 6.00mm), 29.2°C
(2) 〃 , −69°C
(3) Y cut : 1.0000 MHz (1.75mm, 5.00mm), 27.2°C
(4) 〃 , −149°C
(5) R cut : 21.816 MHz (0.15mm, 7.90mm), 27.5°C
(6) 〃 , −149°C

The changes of the absorption lines in quartz resonators are shown in Fig. 6. Among these resonators, although X cut and Y cut have the same fundamental resonance frequency 1.0000 MHz, the aspect of changes in X cut is very different from that in Y cut. The frequencies of the lines were shifted by the change of temperature. In Table 1, the temperature coefficients defined by $(1/\nu)$ $(d\nu/dT)$ are listed on several samples.

Table 1. Temperature coefficients.

Sample			Frequency (MHz)	Temperature (°C)	$\frac{1}{\nu}\frac{d\nu}{dT}$ (/°C)
Rochelle Salt	Pure	$1.7\times3.6\times11.0$ mm^3	3.94	$-170\sim-57$ $0\sim30$	-3.6×10^{-4} -11.6×10^{-4}
	Ni	$1.8\times4.3\times6.1$ 〃	6.13	$-44\sim29$	-8.7×10^{-4}
	Zn	$1.7\times7.4\times7.1$ 〃	6.12	$-44\sim29$	-12.5×10^{-4}
	Fe	$1.9\times6.6\times7.6$ 〃	7.17	$-44\sim29$	-9.8×10^{-4}
	B	$1.7\times6.4\times6.5$ 〃	7.34	$-44\sim29$	-10.8×10^{-4}
A D P		$3.7\times6.0\times6.9$ 〃	5.73	$-44\sim29$	-3.6×10^{-4}
Quartz Resonator	X cut	2.85mm, 6.00mm	4.23	$-69\sim29$	-9.6×10^{-5}
	Y cut	1.75〃, 5.00〃	4.23	$-38\sim27$	-3.1×10^{-5}
	R cut	0.015〃, 7.90〃	4.10	$-149\sim28$	-4.2×10^{-5}

The samples of Rochelle salt except pure include impurity of 1.5 mol%.

Quartz Resonators were round slabs and two dimensions indicate the thickness and diameter.

Frequency shows resonance frequency at room temperature.

IV. Discussion

The experiment on the quartz resonator indicated that the absorption lines are influenced by the direction of rf field.

On the pure Rochelle salt, the lines disappeared at about upper Curie point (23°C) but at lower Curie point (−18°C) were not so. Accordingly, it is not explained whether the disappearing of lines is owing to phase transition or no.

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