An investigation of the ferroelectric properties of Rochelle salt

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NOTES ON EXPERIMENTS

'Notes on experiments' enables teachers at both sixth-form and tertiary level to share their ideas with other readers. *Physics Education* welcomes submissions from readers who know of some simple improvement to a commercially made piece of apparatus, or who have designed a new gadget or improved a standard experiment. In particular the Editor would welcome brief descriptions of experiments devised or procedures evolved during the course of project work or investigation undertaken by students; such submissions should be made under the joint name of the teacher and the student.

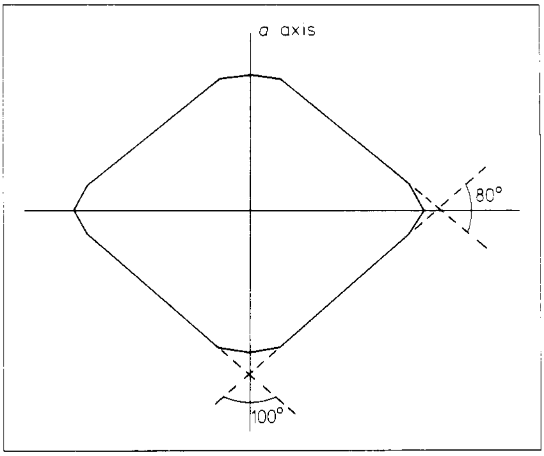

Figure 1 Section through Rochelle salt crystal, showing the polar *a* axis

AN INVESTIGATION OF THE FERROELECTRIC PROPERTIES OF ROCHELLE SALT

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This investigation was performed by the author as a project experiment in the third-year practical class at the Physics Department, Durham University, in 1978. It can be started 'from scratch' with just a bottle of Rochelle salt powder and it demonstrates the salient features of ferroelectric behaviour, that is the hysteresis effect and the existence of domains.

Rochelle salt is sodium potassium tartrate ($NaKC_4H_4O_6 . 4H_2O$), and was the first ferroelectric known. It has disadvantages as a practical material in that it must be stored under conditions of 40–85% humidity, decomposes at 328.8 K and is extremely soluble in water. However, it is suitable for a laboratory experiment because it is cheap, easy to prepare in the form of large single crystals, the polar axis can be easily identified and the Curie points are conveniently close to room temperature.

Single crystals of dimensions approximately 3 cm × 1.5 cm were grown by the evaporation technique (Holden and Singer 1960) from small seed crystals suspended by fine nylon thread in a saturated solution. Crystals of the required size took about two weeks to grow. At least two crystals were needed for the observation of the hysteresis loop and the domain structure. The crystals were then ground down on emery paper (grades 1G and 1F) to slabs about 2 mm thick perpendicular to the polar axis. This may be accomplished satisfactorily holding the crystal with tissue paper, but more accurately using a small jig with a groove of angle 100°. Figure 1 shows a Rochelle salt crystal with the polar axis marked.

To observe the hysteresis loop gold electrodes were evaporated through a mask on to the sides of one slab at a pressure of 13 mPa. The pump-down time to this pressure was kept as short as possible to prevent loss of water from the crystal. The electrodes were circular and 0.5 cm^2 in area. Electrical contact was made by means of fine wires fixed to the electrodes with silver preparation (supplied by Johnson Matthey Metals Ltd) and soldered to a small piece of circuit board on which the crystal was mounted so that it could fit into a boiling tube. The circuit used to display the hysteresis loop was that designed by Schmidt (1959). The hysteresis loop was displayed on an oscilloscope and from the trace the spontaneous polarisation and the coercive field could be measured (Schmidt 1959). These properties were then studied as a function of temperature and of the frequency of the applied a.c. voltage.

Rochelle salt is an unusual ferroelectric because it has two Curie points, at 255 and 297 K, and its ferroelectric behaviour only occurs between these temperatures. The crystal was heated to 308 K and cooled to about 243 K to demonstrate the growth and decay of the spontaneous polarisation. This was done by enclosing the boiling tube containing the crystal in a water bath or in a dewar of dry ice. For the low-temperature measurements dry argon gas was passed through the tube to prevent condensation. The temperature of the crystal was measured by means of an iron–constantan thermocouple. Figure 2 shows the spontaneous polarisation and the coercive field as functions of temperature.

To study the dependence of the hysteresis loops on frequency the applied voltage was supplied by a variable-frequency oscillator. The coercive field was found to increase with frequency while the spontaneous polarisation decreased. These changes are due to the changes in response of the domain structure with frequency. Figure 3 shows these results.

The domain structure of Rochelle salt was observed

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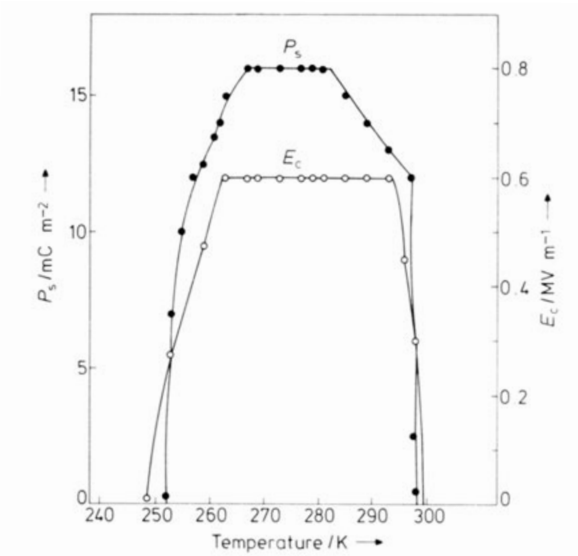

Figure 2 Spontaneous polarisation and coercive field as functions of temperature

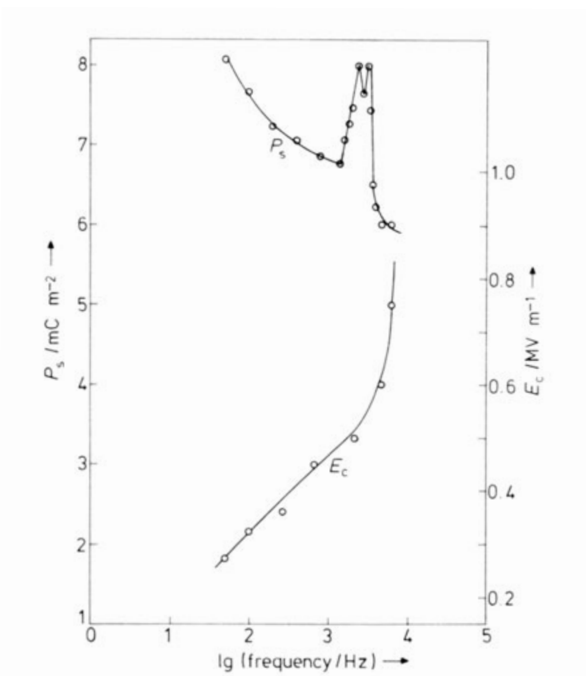

Figure 3 Spontaneous polarisation and coercive field as functions of frequency

by means of a polarising microscope. Above 297 K Rochelle salt is optically active. Below the Curie point the spontaneous polarisation deforms the crystal and the optic axis is displaced, the displacement being in opposite directions for regions of opposite polarisation. If the crystal is viewed under a microscope between crossed polaroids, domains of opposite polarisation have different extinction positions and can be seen as light and dark regions (Mitsui and

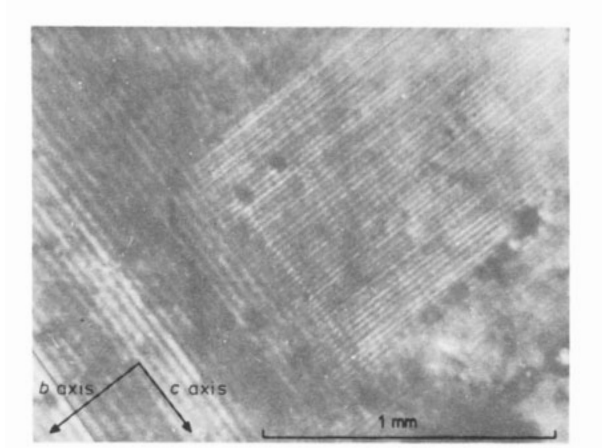

Figure 4 Domains in Rochelle salt

Furuichi 1953). The second slab of crystal was carefully polished with diamond paste (down to 0.25 μm grade) to give smooth surfaces, and then viewed at a magnification of 40. Figure 4 shows both the broad *c* domains, which covered the bulk of the specimen, and some finer *b* domains. The domains were easily seen and a photograph required an exposure of 4 s using Polaroid film of speed 3000 ASA.

This experiment can be performed using fairly simple apparatus and it provides both qualitative and quantitative results demonstrating the behaviour of a class of substance of some commercial importance.

Acknowledgments
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References

Holden A and Singer P 1960 *Crystals and Crystal Growing* (New York: Doubleday)

Jona F and Shirane G 1962 *Ferroelectric Crystals* (New York: Macmillan)

Kittel C 1971 *Introduction to Solid State Physics* (New York: Wiley)

Mitsui T and Furuichi J 1953 *Phys. Rev.* **90** 193

Schmidt V H 1959 *Am. J. Phys.* **37** 351–4

A SIMPLE DIFFRACTION KIT

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It is possible to demonstrate a number of phenomena to a whole class of students by issuing each of them with one or both of the slides illustrated in figure 1. The slides are prepared by photographing an original formed from black tape on white card with a reduction of 20 times. For best results high-contrast film should