Chapter - III

DIELECTRIC HYSTERESIS

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3.1 Introduction

Identification of the ferroelectric materials is generally made through that, they must show hysteresis loop, under the action of an alternating voltage. Such studies are usually made with the help of a Sawyer and Tower(1) type electrical circuit. Several physical properties may be obtained from investigations on the hystereses loops.

Shirane et al (2) reported earlier the ferroelectric properties of potassium niobate. They showed that it behaves qualitatively just as the barium titanate. Mathias (3) discovered ferroelectric properties of potassium tantalate, which has a very low curie temperature (13^{o}k). Geusic (4) et al studied the electro-optic properties of $KTaO_3$, KTN in the paraelectric phase. Tien et al (5) studied the solid solution of $KNbO_3$- $KTaO_3$. Gunter (6) reported ferroelectric properties of $KNbO_3$ doped with Fe. Yanovskii (7) studied the phase transitions and optical properties of $KNbO_3$ doped with several materials. Srivastava and Arya (8) studied the formation and semiconducting properties of lithium and potassium niobates.

Gaffar and Afuel-fadl (10) reported the physical properties of triglyceine sulphate single crystal containing different concentrations of Ni^{2+}. Triebwasser (9) determined the coercive field for $KNbO_3$ single crystal at 500 cps for Cubic Tetragenal transition.

3.2 Hysteresis loop

The phenomenological properties of ferroelectric materials can be conveniently studied by using hysteresis loop. The hysteresis loop depends strongly upon the perfection of the material as well the rate of change of externally applied electric field (E). The following parameters are described by a hysteresis loop.

(1) The spontaneous polarization P_s is present in the ferroelectric material even in the absences of external field. As temperature is decreased the spontaneous polarization rapidly increases and on crossing the curie point, it reaches a saturation value.

(2) The coercive field (E_c) is required to eliminate the ramanent polarization. It depends on the temperature, the measuring frequency and the wave form of the applied voltage.

3.3 Experimental details

The dielectric hysteresis of a sample is obtained on the CRO with the help of modified Sawyer and Tower circuit illustrated in Fig.3.1. The experimental set up consists of a

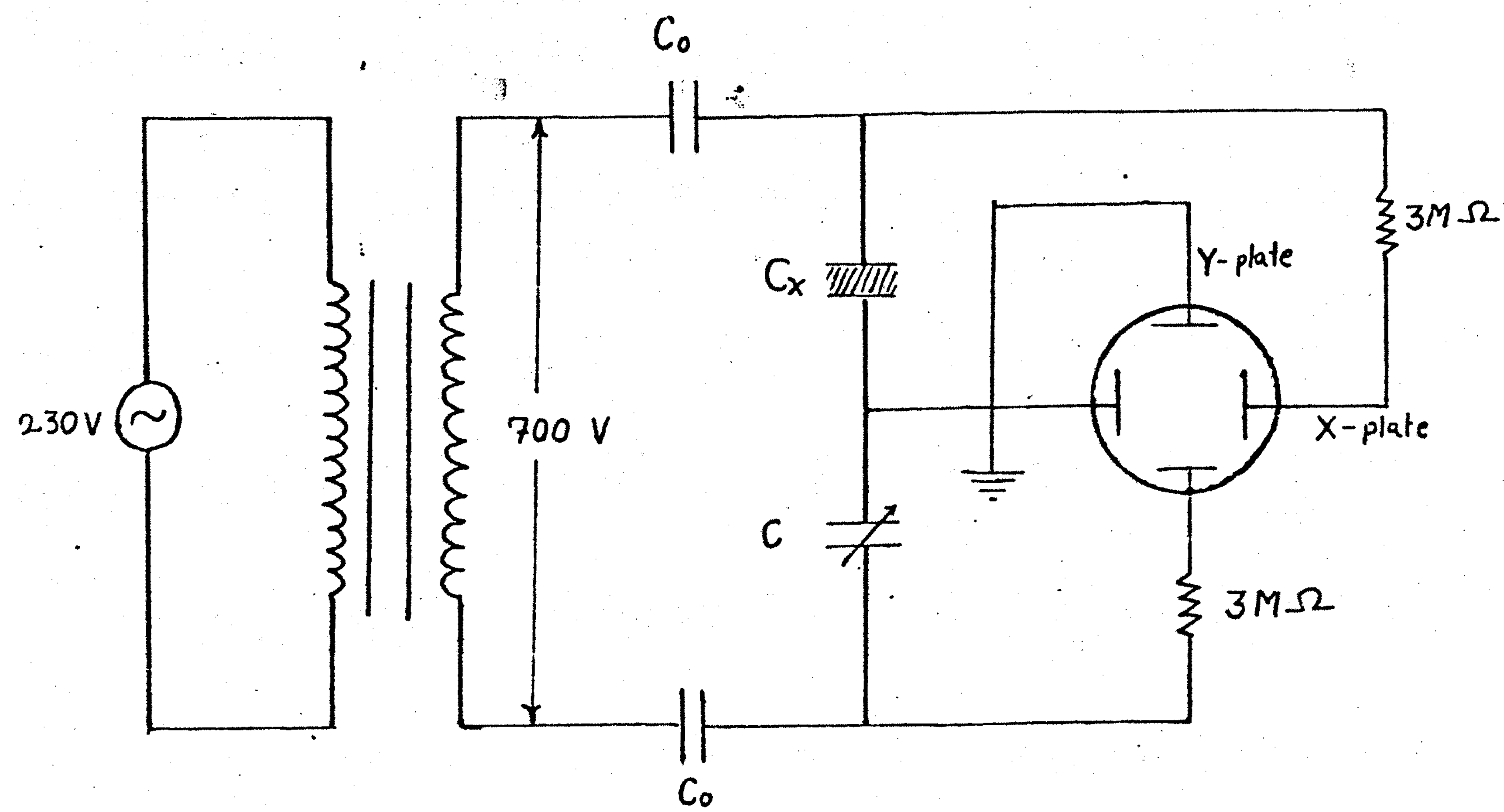


Fig.3·1 - MODIFIED FORM OF SAWYER-TOWER CIRCUIT FOR THE DISPLAY OF THE HYSTERESIS LOOP.

step-up transformor which gives output voltage of 700 volts, two oil filled condensers Co and a gang condenser C connected in series, with the sample of an assumed capacitence C_X.

The voltage across the sample is varied about 1000 v/cm. Frequency of applied field is 50 Hz to highest possible of the order of 1 KHz in our work.

3.4 Hysteresis loop of potassium niobate

The hysteresis loop for ceramic potassium niobate could be easily reproduced on the C.R.O. by using a modified Sawyer and Tower (1) circuit. The hystereis loops of $KNbO_3$ are observed at different temperatures and are shown in Fig.3.2. For potassium niobate the hysteresis loop is smaller at room temperature. The hysteresis loop height practically remains unchanged but the loop width gradually decreases and finally vanishes at the curie temperature. The curie temperatures of potassium niobate are found to be above the room temperature approximately around 498°k and 685°k.

3.5 Hysteresis loop of $K(Ni_x\ Fe_y\ Nb_z)O_3$ system

The hysteresis for ceramic $K(Ni_x\ Fe_y\ Nb_z)O_3$ has been observed on the screen of C.R.O. by using Sawyer and Tower (1) circuit. The hysteresis loops are observed at different temperatures. The height of ferroelectric hysteresis loop is practically found to remain unchanged. The width of the hysteresis loop is small at room temperature. Beyond this temperature the width goes on gradually decreasing and finally vanishes at curie temperature. The curie temperature of ceramic samples of $K(Ni_{0.02}\ Fe_{.02}\ Nb_{.96})O_3$, $K(Ni_{0.05}\ Fe_{0.05}\ Nb_{0.90})O_3$ $K(Ni_{0.10}\ Fe_{0.1}\ Nb_{0.8})O_3$ and $K(Ni_{0.15}\ Fe_{0.15}\ Nb_{0.70})O_3$ are observed at $460^{o}k$, $435^{o}k$, $598^{o}k$, $548^{o}k$ respectively.

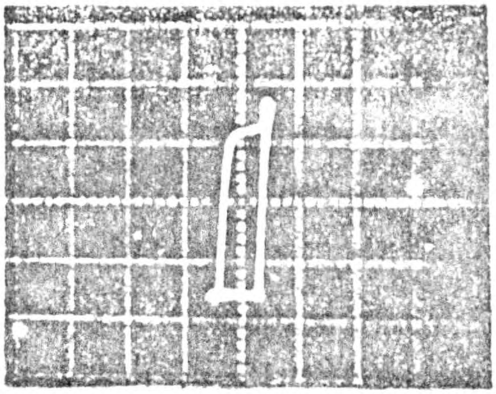
3.6 <u>Results and Discussion</u>

All the ceramic samples were found to exhibit very small hysteresis loop at room temperature. As the temperature increased the width of hysteresis loop slightly increased and at certain temperature hysteresis loop width almost became zero, that temperature is recorded as the transition temperature.

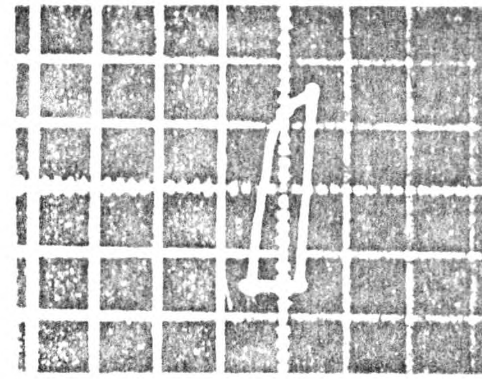
The ferroelectric curie temperatures of the samples are summerized in Table. 3.1.

<u>TABLE No.3.1</u>

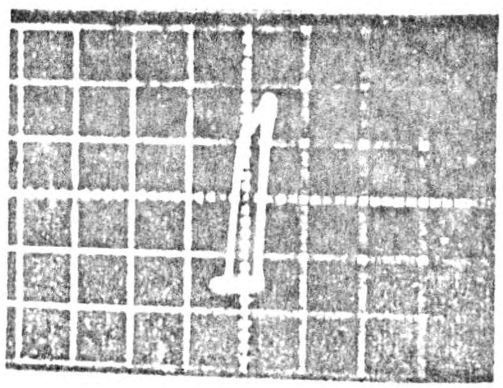
Sample	1st curie temperature	2nd curie temperature
$KNbO_3$	$498^{o}k$	$685^{o}k$
$K(Ni_{0.02}\ Fe_{0.02}\ Nb_{.96})\ O_3$	$460^{o}k$	$685^{o}k$
$K(Ni_{0.05}\ Fe_{0.05}\ Nb_{0.90})O_3$	$435^{o}k$	$685^{o}k$
$K(Ni_{0.1}\ Fe_{0.1}\ Nb_{.80})\ O_3$	-	$598^{o}k$
$K(Ni_{0.15}\ Fe_{0.15}\ Nb_{0.70})O_3$	-	$548^{o}k$



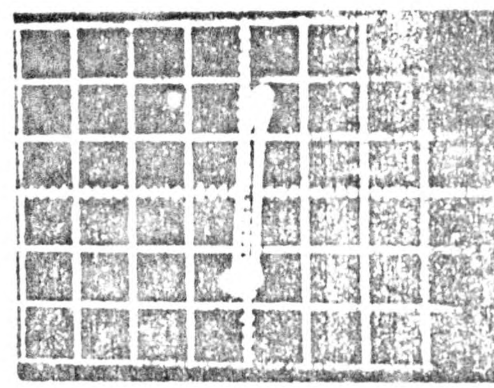
(a) 323°K



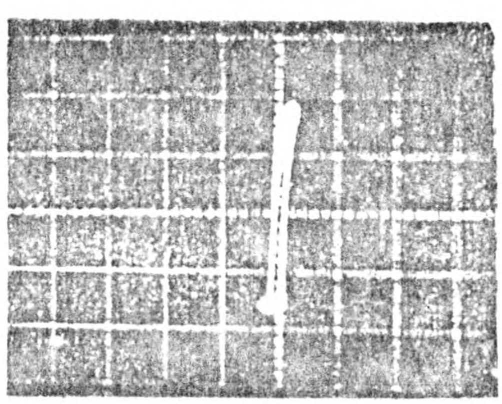
(d) 523°K



(b) 448°K



(e) 623°K



(c) 498°K

(f) 685°K

Fig. 3·2 — FERROELECTRIC HYSTERESIS LOOP OF $KNbO_3$ AT DIFFERENT TEMPERATURES.

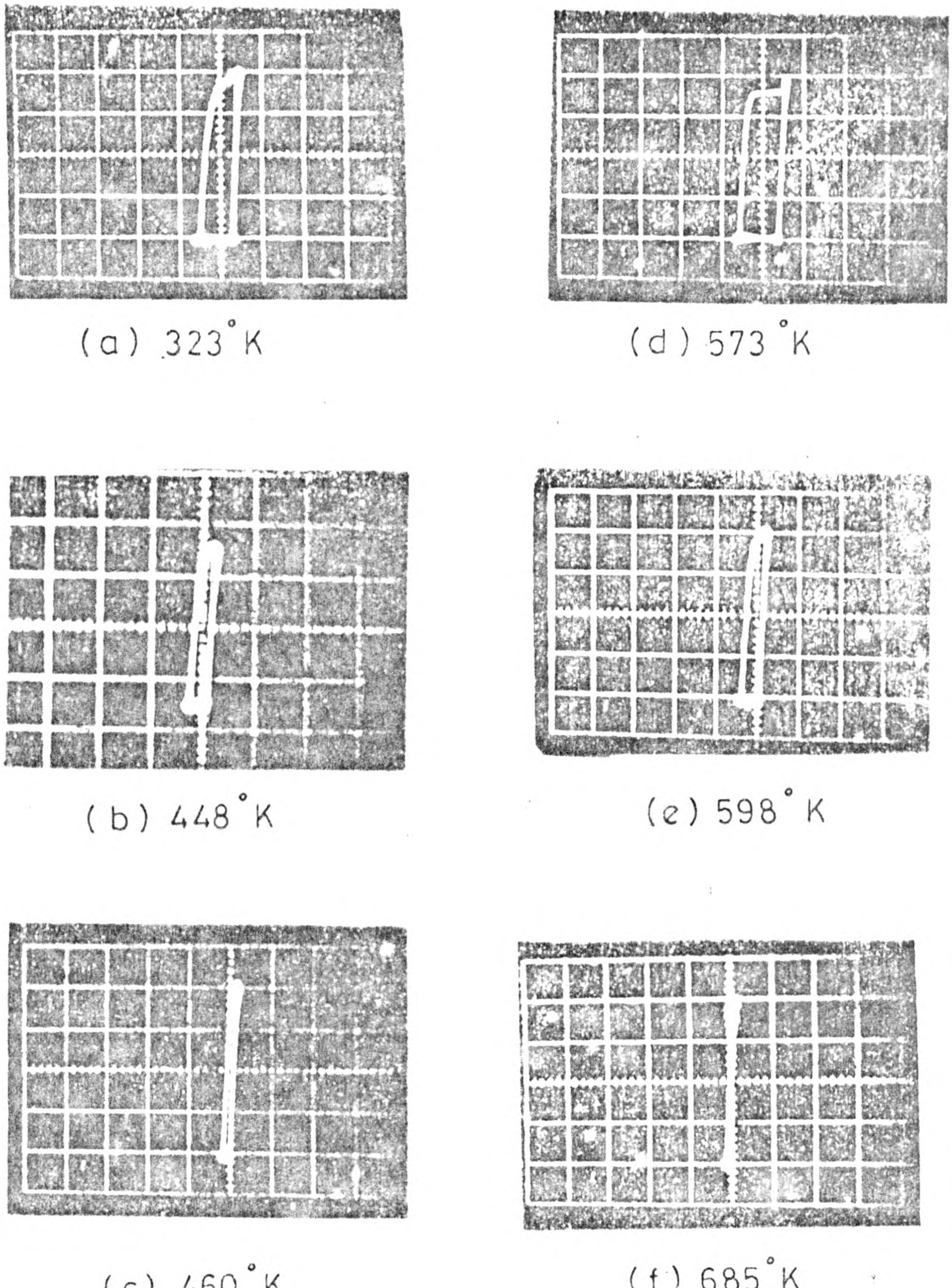
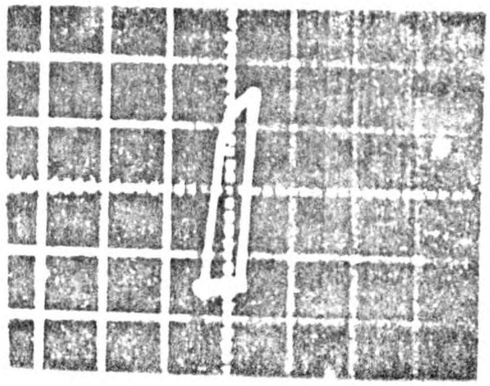
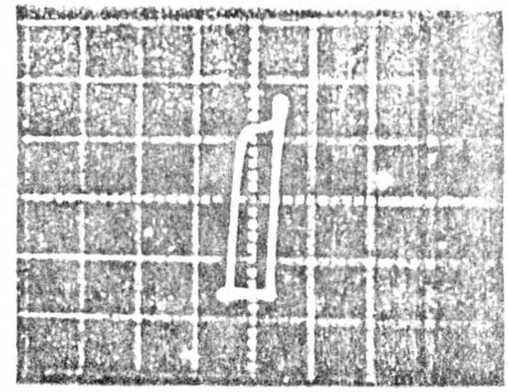


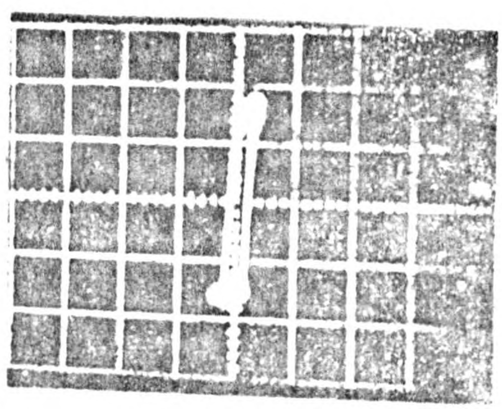
Fig. 3·3 — FERROELECTRIC HYSTERESIS LOOP OF $K(Ni_{0\cdot02}\,Fe_{0\cdot02}\,Nb_{0\cdot96})O_3$ AT DIFFERENT TEMPERATURES.



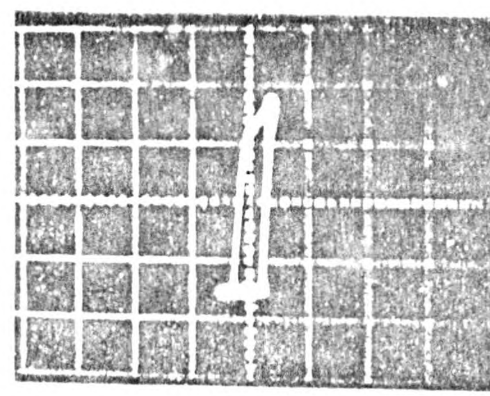
(a) 323°K



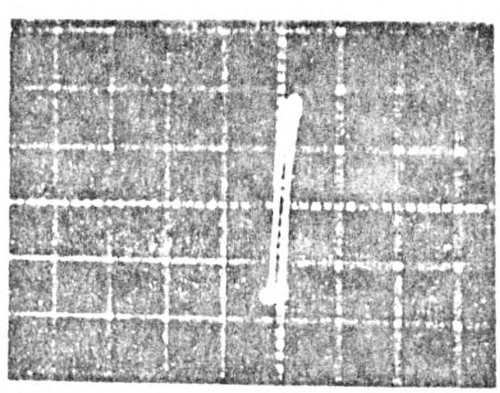
(d) 448°K



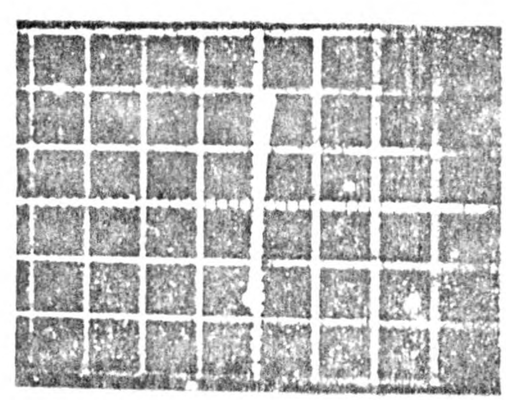
(b) 423°K



(e) 573°K



(c) 435°K



(f) 685°K

Fig. 3·4 — FERROELECTRIC HYSTERESIS LOOP OF $K(Ni_{0\cdot05}Fe_{0\cdot05}Nb_{0\cdot90})O_3$ AT DIFFERENT TEMPERATURES.

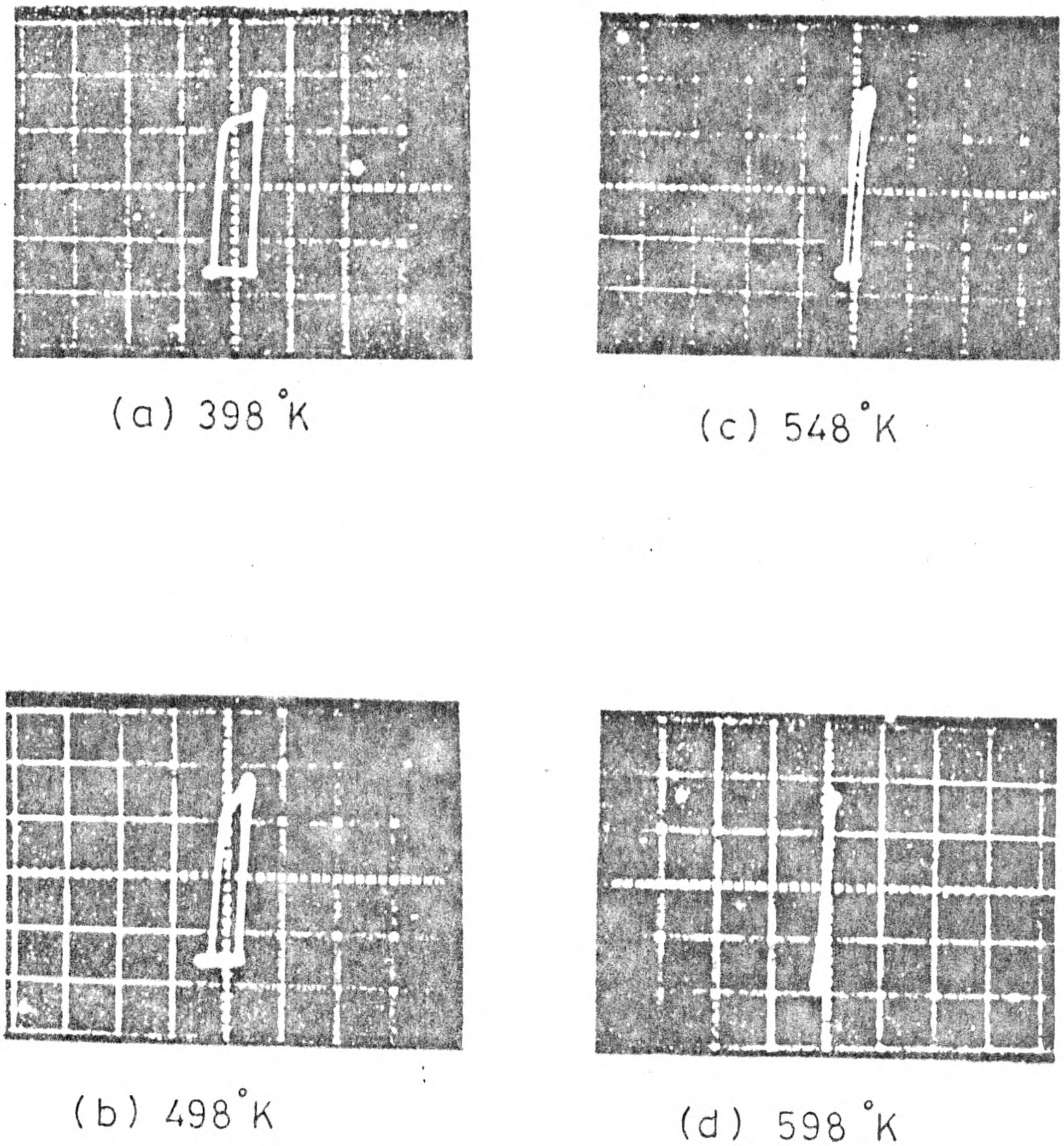
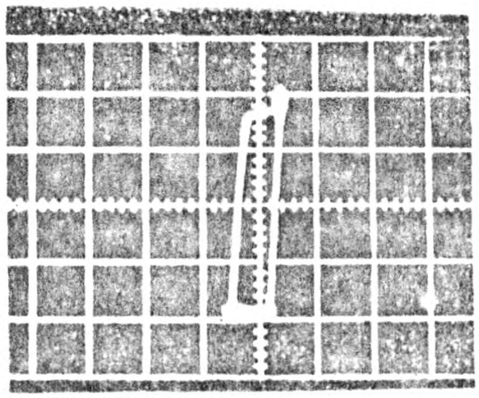
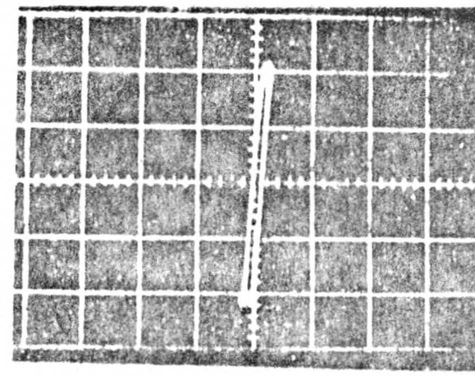


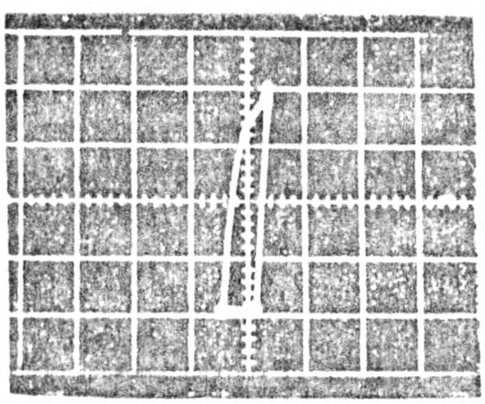
Fig. 3·5 — FERROELECTRIC HYSTERESIS LOOP OF $K(Ni_{0.10}Fe_{0.10}Nb_{0.80})O_3$ AT DIFFERENT TEMPERATURES



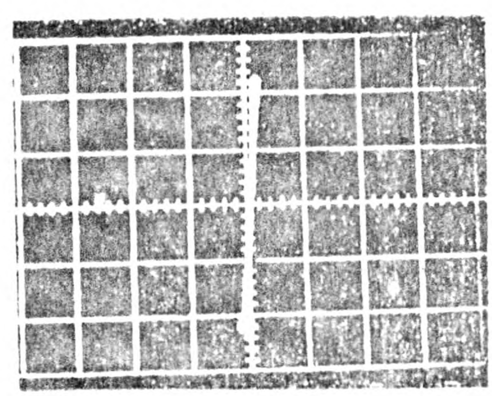
(a) 398°K



(c) 498°K



(b) 448°K



(d) 548°K

Fig.3·6 — FERROELECTRIC HYSTERESIS LOOP OF $K(Ni_{0.15}Fe_{0.15}Nb_{0.70})O_3$ AT DIFFERENT TEMPERATURES.

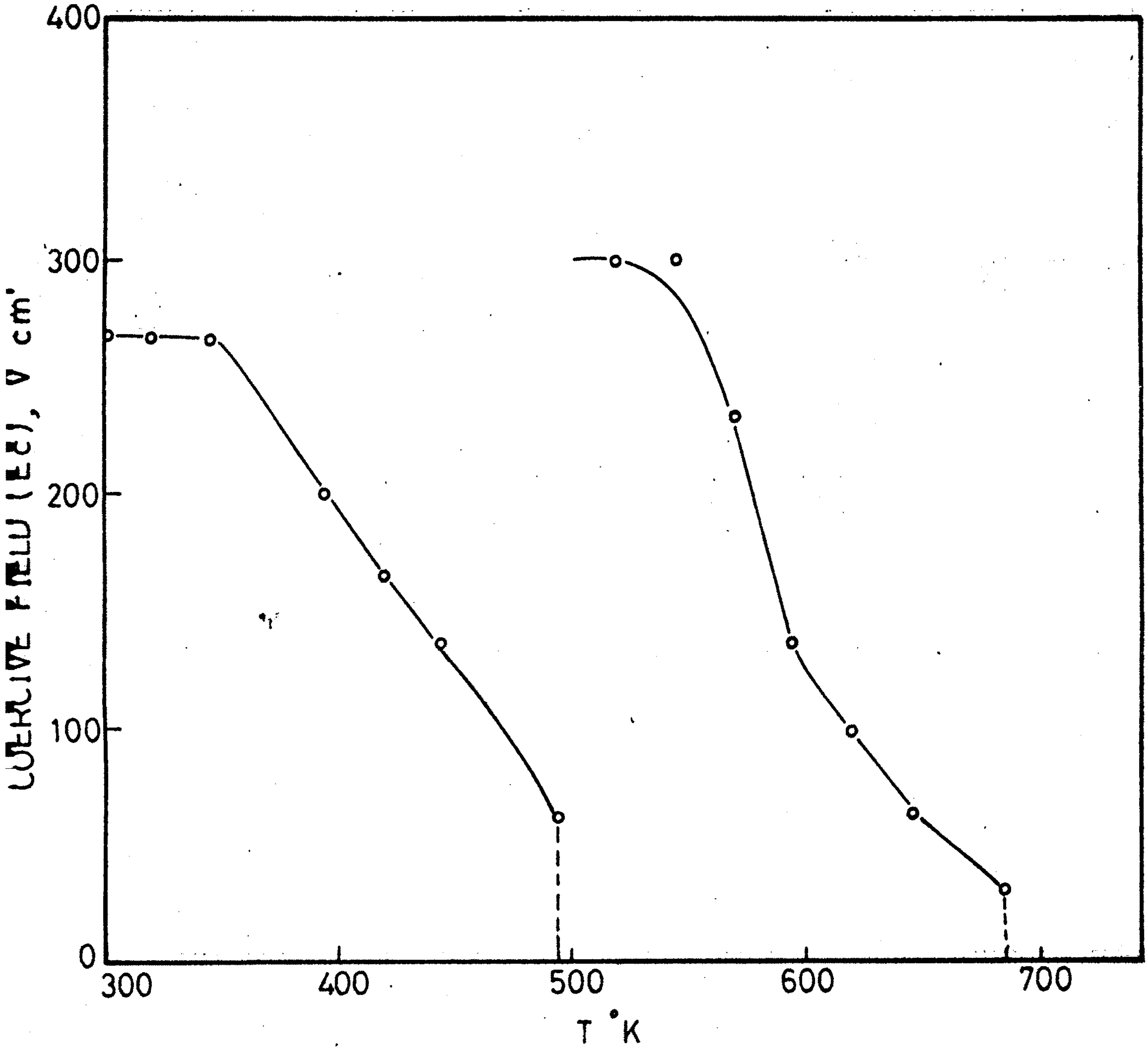


Fig. 3·7 - THE VARIATION OF COERCIVE FIELD WITH TEMPERATURE IN $KNbO_3$.

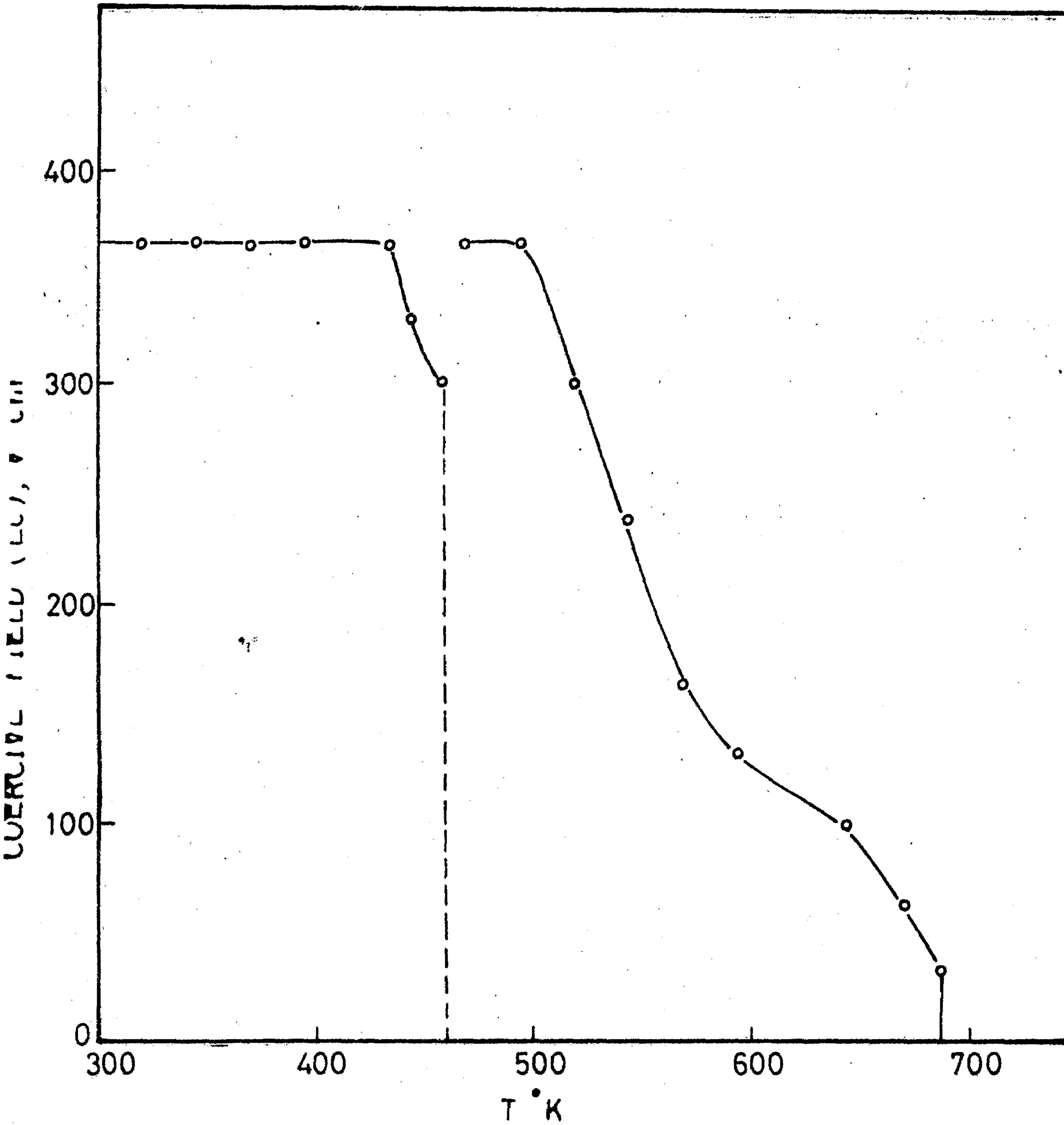


Fig. 3·8 - THE VARIATION OF COERCIVE FIELD WITH TEMPERATURE IN $K(Ni_{0\cdot02}Fe_{0\cdot02}Nb_{0\cdot96})O_3$.

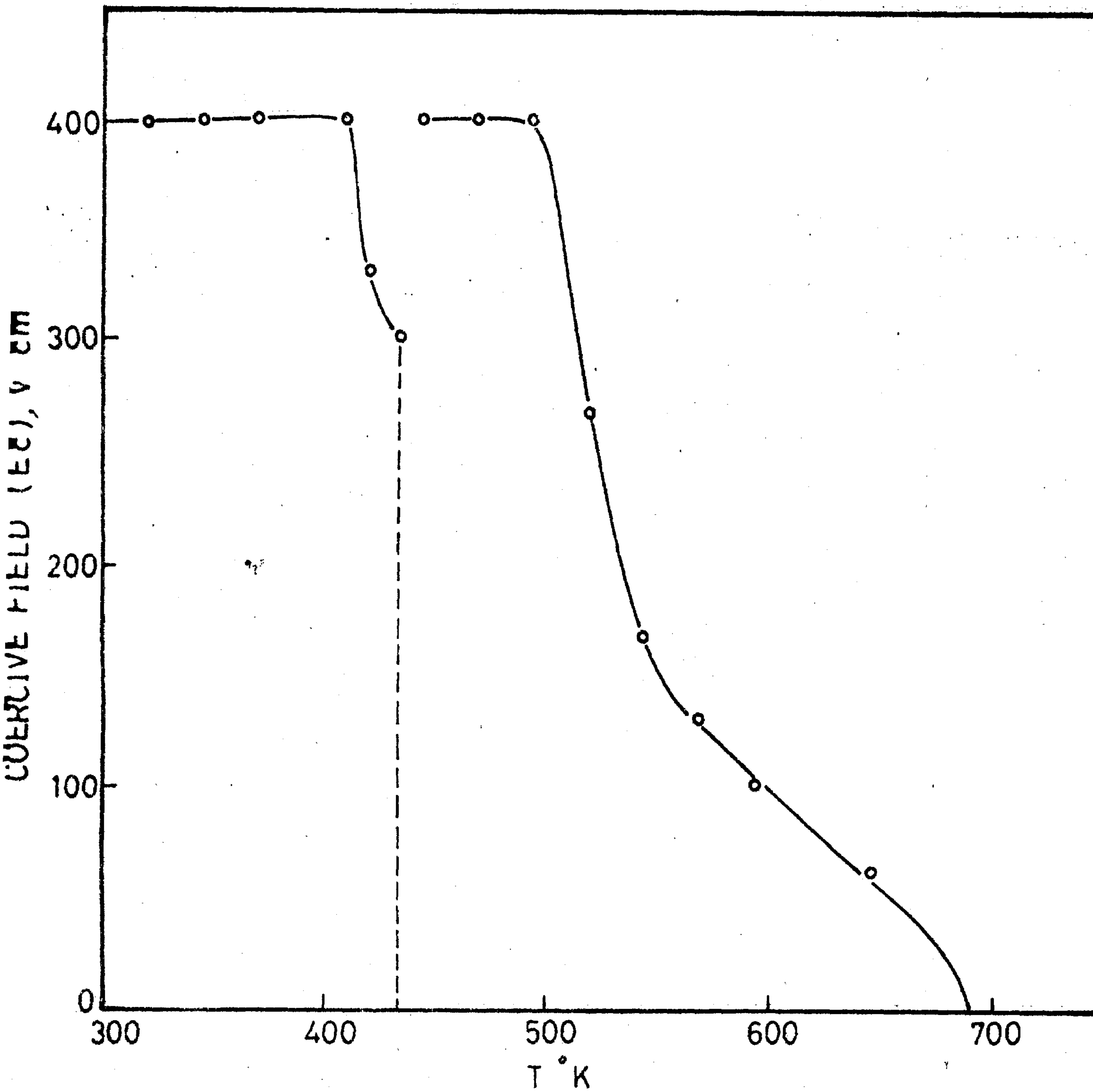


Fig. 3·9 – THE VARIATION OF COERCIVE FIELD WITH TEMPERATURE IN $K(Ni_{0.05}Fe_{0.05}Nb_{0.90})O_3$.

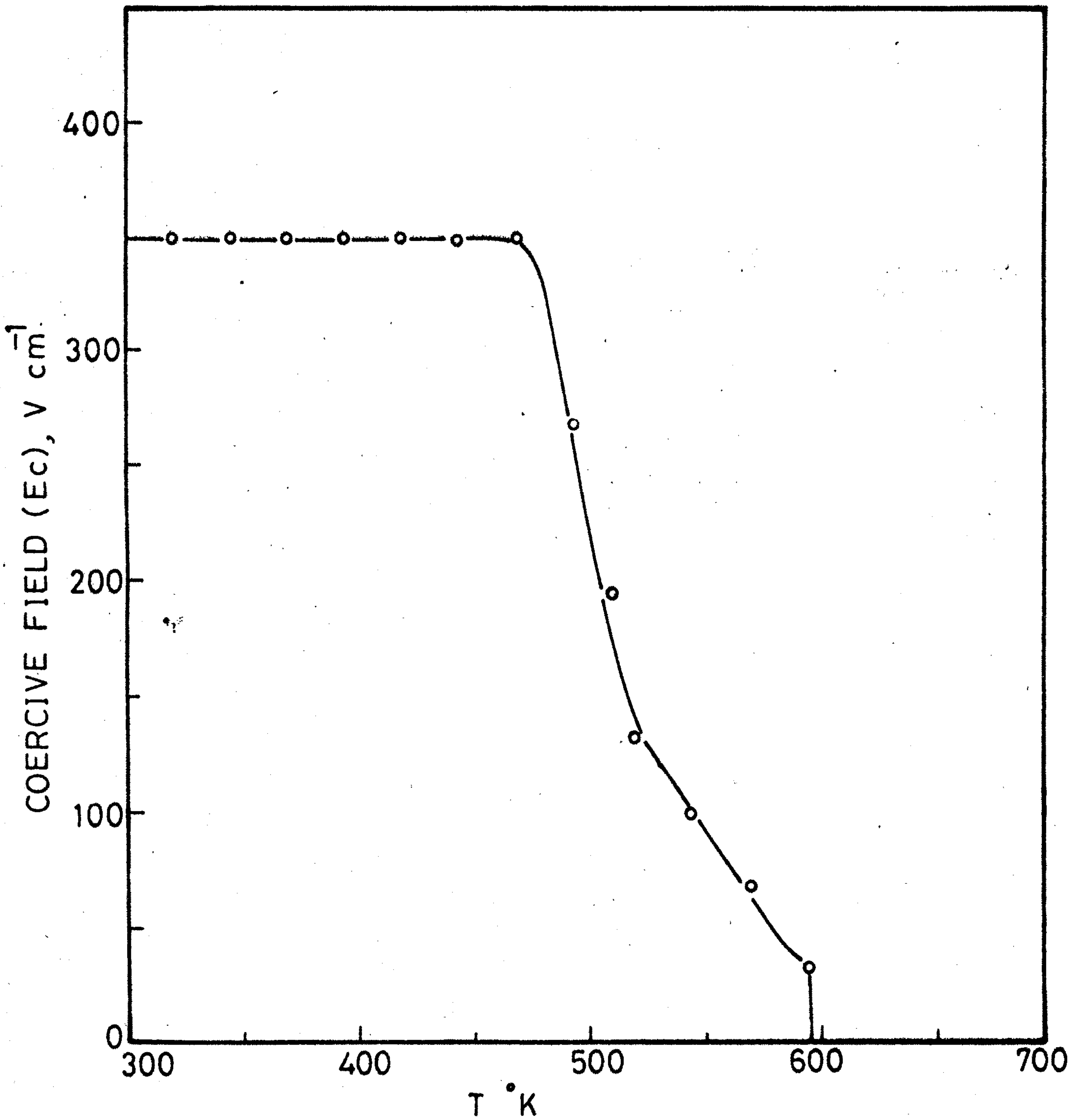


Fig. 3·10 - THE VARIATION OF COERCIVE FIELD WITH TEMPERATURE IN $K(Ni_{0\cdot10}Fe_{0\cdot10}Nb_{0\cdot80})O_3$.

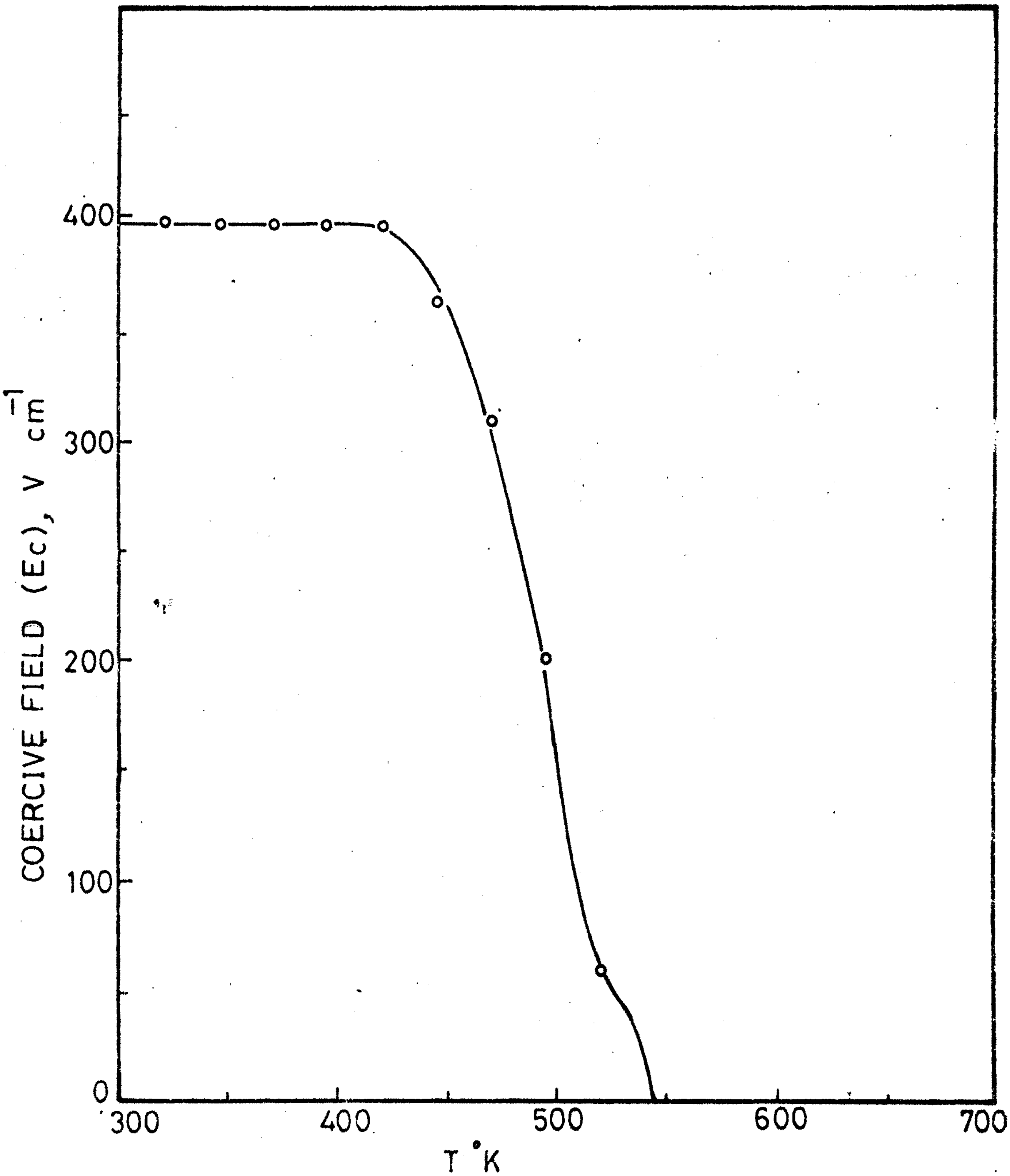


Fig. 3·11 - THE VARIATION OF COERCIVE FIELD WITH TEMPERATURE IN $K(Ni_{0.15}Fe_{0.15}Nb_{0.70})O_3$.

The curie temperatures of potassium niobate are in agreement with those reported by Shirane et al (2) Triebwasser, (9) Wood, (10) and Mattians (12).

The following observations are specifically noted.

(1) The curie temperature decreased with the increasing concentration of the impurities.

(2) The coercive field increased with increasing concentration of the impurities, and exhibited peaks.

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