Experimental Physics - III
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Lecture – 26
P-E Loop of Ferroelectric Material

I will demonstrate ferromagnetic similar to ferromagnetic Ferroelectric Material. There how to get this polarization versus electric filed loop. In magnetic material ferromagnetic material M-H loop or B-H loop is the characteristics of ferromagnetism. Similarly, for ferroelectric material that P-E loop is the characteristics of ferroelectric ferroelectrics. This experiment we will demonstrate in our solid-state physics laboratory.

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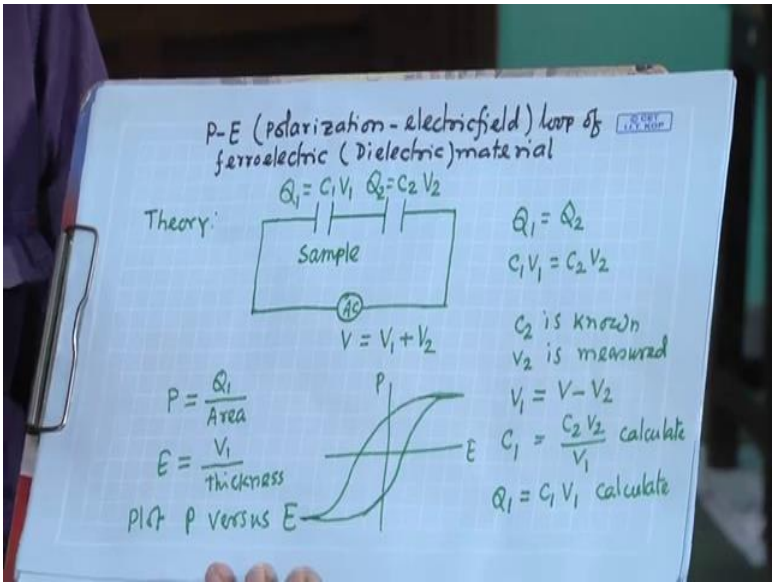

This the process we will use the process or the technique we will use for this P-E loop of ferroelectric material. That there will two capacitors parallel plate capacitor they are in series they are connected in series and AC voltage will be applied. Now, in one of the capacitor the sample our ferroelectric sample will be inserted between these two parallel plate. Which sample the capacity of capacitor is C 1 and the second capacitor is known capacitor C 2. Known capacitor is connected in series with the sample capacitor.

now, the charge will be stored in capacitor one that is Q 1 and in capacitor 2 that is Q 2 and their corresponding voltage drop V 1 and V 2, then you know that in case of resistance when resistance in is in series when resistance is in series and current is

flowing then what we do we tell that the current is same passing through the resistance, but voltage drop are different that depends on the resistance of the resistor.

Similarly, in case of capacitor, their charge will be same when they are in series charge will be same in the circuit, but voltage drop will be different. Q 1 will be equal to Q 2 and this is C 1 V 1 that is the other one C 2 V 2. C 1 V 1 equal to C 2 V 2 C 1 is known as I told then V 2 is measured. Across this what is the voltage drop V 2 if you measure then and V 1 V is the input voltage. That is also known one can find out V 1; V 1 will be V minus V 2. V 2 will be measured across to the across the known capacitor C 2 ok.

In addition, then corresponding V 1 I will get V minus V 2 since V also known is applied voltage. C 1 will be equal to from here you can see this C 2 V 2 by V 1 C 2 V 2 by V 1. V 2 is measured, C 2 is known supplied, V 1 also known from V and V 2. We will get this value C 1 we can calculate the value C 1 then when we will know C 1 and V 1 then we know the Q 1, Q 1 can be calculated equal to C 1 V 1. We know Q 1 and V 1. What is Q 1? The charge stored in the capacitor our sample capacitor and V 1 is the voltage across this capacitor ok.

now this charge on the surface Q 1 charge on the surface of this one side is will be positive charge, other side will be negative charge it is a it will form dipole electric dipole. P is it can be electric dipole per unit volume or it can be electric dipole for unit area. here we have taken polarization is equal to charge per unit area because here it will be found one side is plus charge other side will be negative charge Q 1 one can find out the P polarization Q 1 by area.

In addition, electric field – electric field from V 1 we can calculate V 1 divided by thickness of the sample thickness of the sample. We are using ferroelectric sample between two capacitor plate and one known capacitor will be used. Now, V that AC voltage will be applied in series then from here I showed I told you we have to; we have to measure these voltage drop V 2 and we have to know this V then we can get Q 1 and P 1. From Q 1 and P 1 from the known area of the sample and thickness of the sample we can calculate the polarization and corresponding electric field.

for different electric field what is the polarization that we want to measure then we will plot P versus E. if you want to see the hysteresis loop for ferroelectric material we have to start from the maximum electric field and go to the maximum negative electric field.

In addition, again go back to the positive maximum positive electric field. With some step of electric field, we have to take data then plot then we will get this kind of hysteresis loop ok.

from this hysteresis loop we can find out the what is the saturation polarization P s what is the saturation polarization P s. that value corresponding that value will be P s what are the remanent polarization that is P r and what is the coercive electric field coercive electric field E c that also you can find out Now, if we want to do the experiment as a function of temperature then what we want to know? We want to know the is the saturation polarization P s how P s varies with the temperature.

P s versus temperature we can measure for also every time we have to get this hysteresis loop for each temperature and from there one can find out P s and that P s can be plotted can be plotted as a function of temperature and then one can find out the transition temperature from ferroelectric to paraelectric phase transition one can find out ok.

Different kind of information's one can get from this experiment and I will show this experiment in our laboratory it is the computerized experiment, but I will explain what are the parts in this setup.

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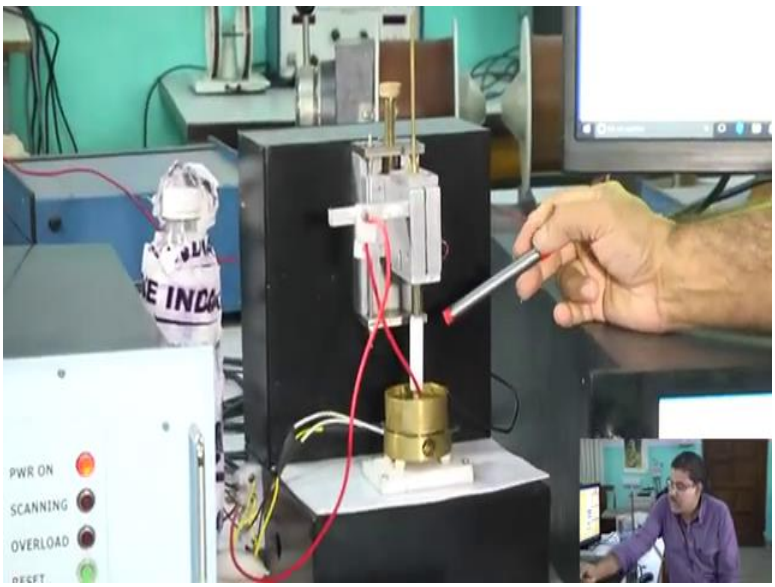

Here we have yes I will show sample. Here this is one electrode I think power is not given, yes. This is one electrode this is one electrode and one tablet type of sample is placed here.

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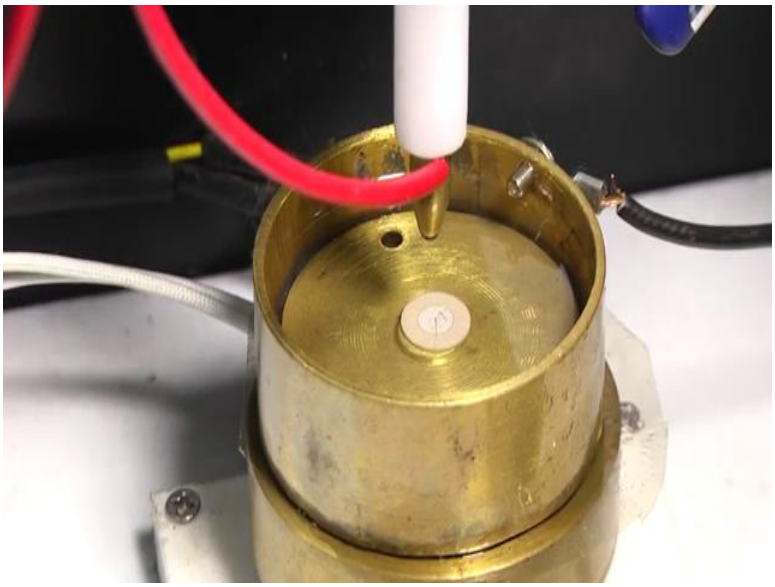

We have used this silicon oil for uniform heating of the sample. Here this is one electrode; this is one electrode, this falling on top of the sample top of the sample and bottom of the sample on this platform. It must be isolated from this other parts other part.

Here so here is the one connection and the other connection is this one from two electrode from bottom and from top. This two electric field or voltage will be applied through this.

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Now, this one has gone in a box this two wire has connected with this box. Inside this box there is known second capacitor is there is second capacitor known capacitor as I told C 2. this connection this is gone to like inside this type of connection is there is this our sample connection this two wire has come one has gone to the this AC power supply it is inside and other has gone to the that known capacitor C 2 this is inside the box and this other. This circuit is completed. This circuit is complete completed it is in this box.

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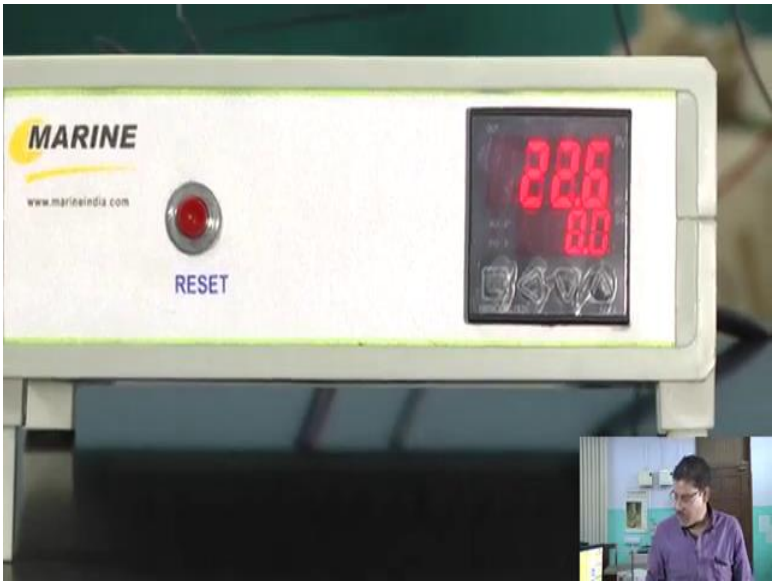

Now, what is the experiment we have to do? For a here we have option for setting of temperature this the temperature one we can set at different temperature we can do the experiment we can do the experiment. Here it is at present at room temperature 22.6 degree centigrade, it is a room temperature we have not applied any temperature. We will do the experiment at room temperature ok.

What we have to do we will apply we will apply different electric field means different voltage. We will apply different voltage V 1 and corresponding we have to; we have to get this what capacitor value C 1 and if I know the C 1 if I know the C 1 as I told the C 1 it will be C 2 is known and V 2. I will apply; I will apply from here I will for changing the for changing the electric field. I have to vary here V 1 should be different V 1 should be different for a particular V 1.

V 1 how can be varied how can be varied. this V this V can be varied this V can be varied corresponding V 1 will be different and V 2 will be fixed we will vary V 1 varying the V and we will get Q 1 and corresponding P different P. we are varying V and thus we will get P at different electric field that can be done manually.

manually I will vary the incident input this AC signal input AC signal and then I have to; I have to; I have to note down the value of V 2; value of V 2 then rest of the part I should calculate and find out the electric field and P. here what about the manually we can do here the computer programming we will do this job. This is the computer we are collecting these data through this computer ok.

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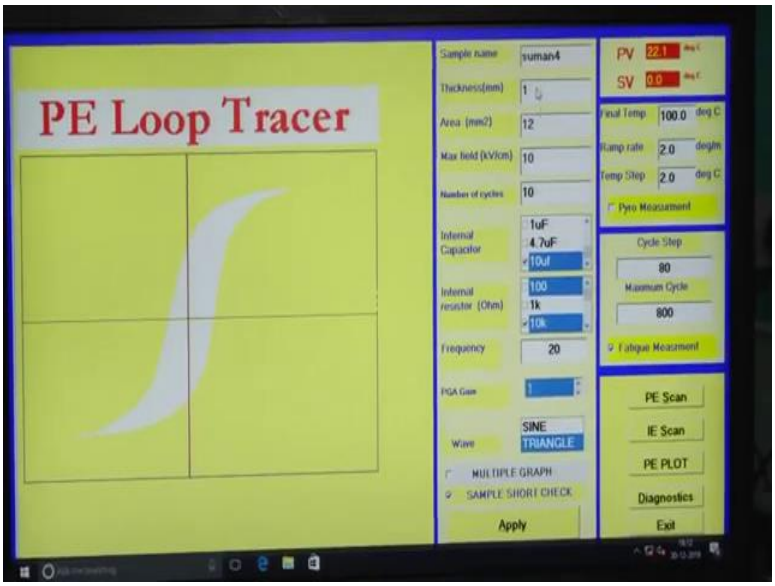

In computer all information is given here, you can see here you can see that thickness of the sample is 1 millimeter that we have to give information to the computer. What is the thickness of my sample? This is 1 millimeter what is the area of my sample? This is 12 millimeter. What is the variation of the field I want?

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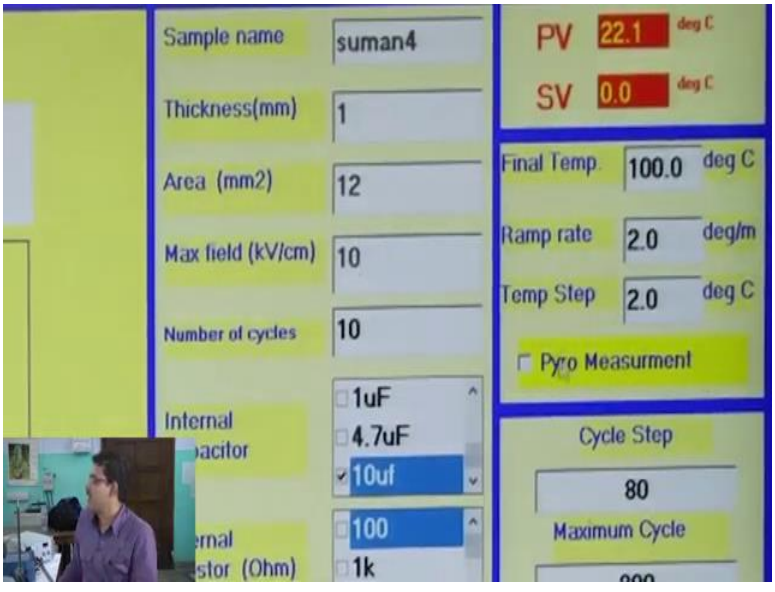

kilovolt per centimeter that electric field variation whatever I want. maximum electric field up to 10 kilo volt per centimeter that you can select depending on your sample you can select 5 kilovolt per centimeter or for 100 kilovolt per centimeter one can change

here. In addition, maximum field if I give. It will just vary it will just vary from plus maximum to the minus maximum to the again plus maximum ok.

if I just define these maximum field plus maximum field to minus maximum field and again it will go back to the plus maximum field and here number of cycles means I am input them I am telling that you measure this loop 10 times ok, then take the average of that one and plot.

that is why here number meaning of the number of cycles ok, how many cycles and here if it is there ramp speed ramp rate here you see ramp rate for temperature as I told we are not changing the temperature, we are not using the temperature; room temperature if you do the experiment this part for variation of temperature if you want. This part one should use.

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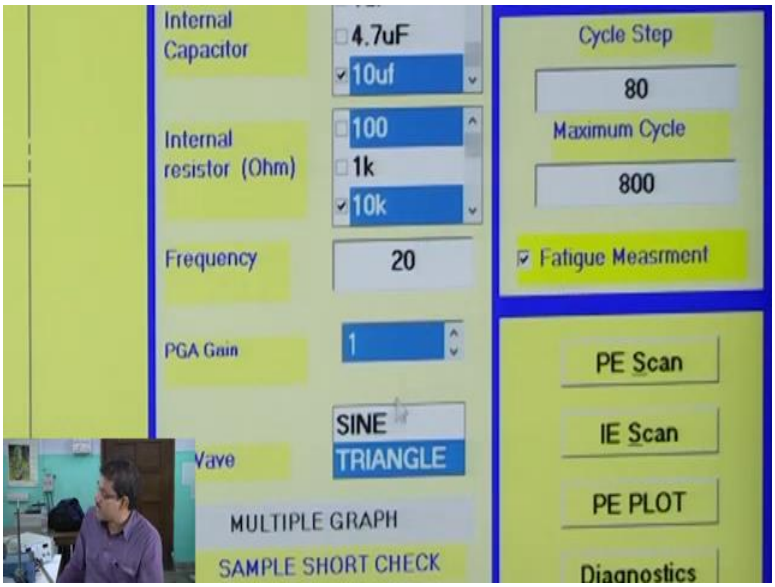

In addition, this part is for P-E loop P-E loop we are interested for P-E loop. We will do experiment in this condition this is pyro measurement means temperature variation varying the temperature this measurement and this a fatigue measurement is a varying the. Is not temperature variation varying an electric field we are measuring ok?

this in computer we have to give information and here internal capacitor I told that in that box there are known capacitors C 2 capacitor that is the here it is written internal capacitor therefore, three options there are three option 10 micro ohm, 4.7 micro sorry

not ohm farad. 4.7 microfarad 1 microfarad. You can choose one of them. We have chosen 10 microfarad and internal resistance that is not coming in our calculation, but see here circuit there would be internal resistance also. One can choose ok.

Whatever in internal this circuit is there a C 2 capacitor these are we are choosing 10 microfarad that is coming in our calculation and yes. this is the frequency this frequency of this internal resistance, frequency, PGA gain, wave type, sine wave or triangular wave one has to choose this one I think this frequency your whatever voltage I am applying this maximum field whatever I want for that I have to apply voltage depending on the thickness it will calculate this field. I have to give this some frequency of the field I am using all this information we are putting.

One has to one has to know about the are the things in the program for details use of this of this instrument. We do not give that much at present. At present, what I want to know; I want to know that how to how to plot P-E loop how to plot P-E loop of ferroelectric material instead of manual reading computer is doing our job very fast. It is very fast.

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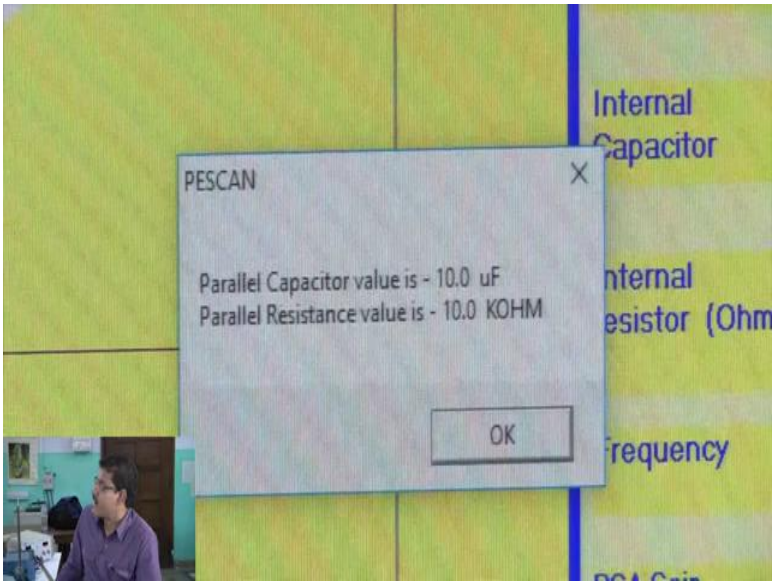

Here I have to here if I just click this one apply here it is showing parallel capacitor is 10 microfarad whatever we have chosen 10 microfarad and parallel resistance value here we that is 10 kilo ohm. Whatever value here. It is showing because there are other options also which options we have taken just it is telling us.

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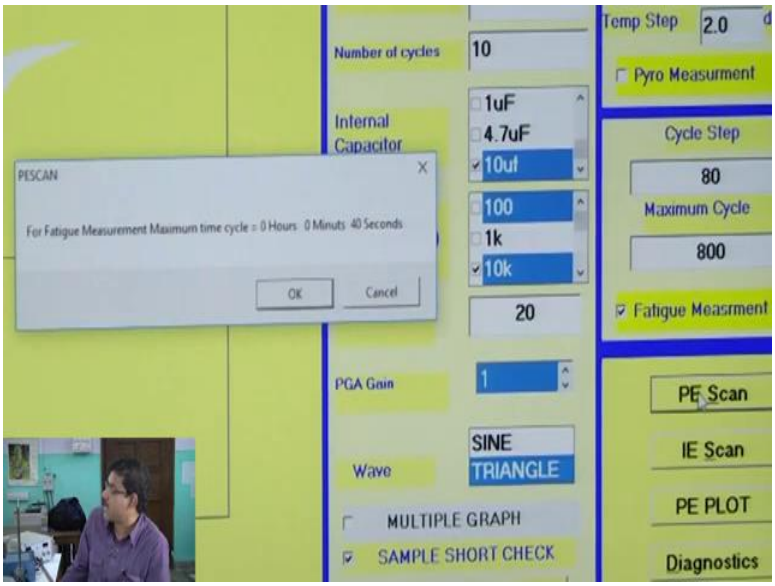

Then we will put and I think I have to I have to choose P-E scan and this for it will take data for 40 second. I think it started it started the experiment.

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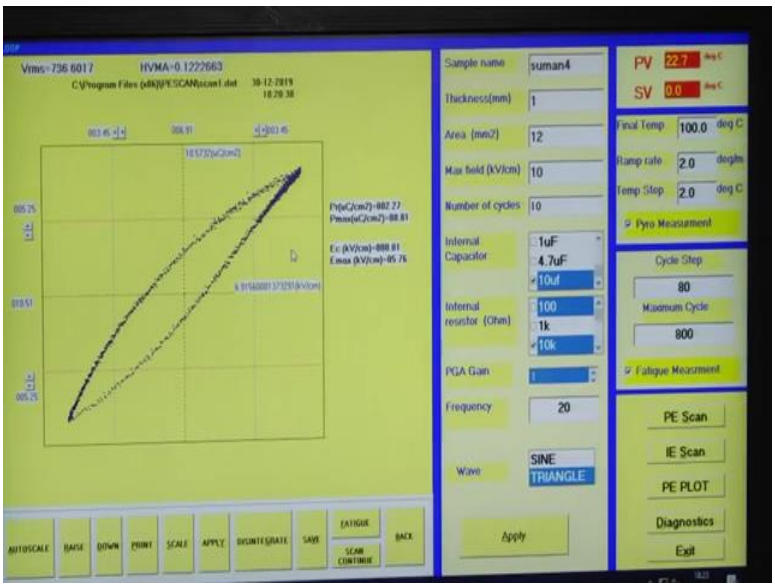

I asked for P-E loop between this maximum fields 10 kilovolt per centimeter, it will take 10 number of cycles, and take the each cycle it is varying the it is varying the electric field ok.

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How it is varying that I told you how computer programming itself it is calculating the electric field from the from the voltage V 1 and how it is getting V 1? V minus V 2 because it is measuring V 1 or V 2 across the C 2 capacitor known capacitor it is plotting. When we will do experiment manually we have to take data and we will plot we plot. For one loop, it will take at least maybe 1 hour, but here this computer is very fast. It is doing the things with within 40 second it is taking this I think 10 loops it is as this it is plotted you know. I think this data is taken.

Here also it is giving what is the Pr value. What is this is the Pr it is giving Pr P maximum it is giving, but here we can see that it is not saturated to get the saturation value again we need higher electric field. I have to change a field it is maximum value 10 kilovolt per centimeter I have given. This we have to change say we have to give for 20. Then we can get the maybe we can get the saturation value. anyway this is just one can play with this parameters and find out the Pr value, Ps value saturation value and then Ec value Ec coercive electric field Ec value this is for the room temperature.

Now, for different temperature you can get this value and plot it Ps. If we plot Ps as a function of temperature then you will get this type of variation of the P with temperature. This one can find out the find out the Curie temperature but in computer, we have this option for doing the experiment with temperature. That means, it will vary the

temperature each for each temperature it will measure the Ps, Pr and even Ec. all this parameter then it can plot as a function of temperature.

I think I will not do that. Here mainly I wanted to show you this how P-E loop measured. Although it is computerized, but manually also one can one can do though it is time taking now this also good means. When you want to measure as a function of temperature as a function of temperature then this we use this option pryo measurement; pyro means temperature. With temperature we can study and pyro measurement another. If sample is.