Experimental Physics - III
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Lecture - 24
Dielectric Constant of Solid

I am demonstrating some experiments in solid state physics laboratory. So far, I have demonstrated some transport measurement like, magneto resistance as a function of magnetic field, resistance or resistivity as a function of temperature, then Hall Effect as a function of magnetic field as well as a function of temperature. In addition, I have demonstrated some experiment to study the magnetic material. How to measure magnetic property as a function of magnetic field. magnetization, susceptibility, permeability these are the parameters of magnetic material.

For ferromagnetic material for paramagnetic for diamagnetic. these are the types of magnetic materials and how to measure their parameters like susceptibility like magnetization permeability. That we have demonstrated using VSM method, using Gouy's method as well as Quinck's cube method.

There are other classes of materials that is dielectric materials. it is a dielectric materials and magnetic materials there are similarities in properties of this two materials in case of magnetic materials whatever we tell magnetic dipole moment. In case of dielectric material, we tell this the electric dipole moment and dipole moments per unit volume in case of magnetic material, we tell magnetization and in case of dielectric material, we tell polarization.

Magnetic material responds to the magnetic field and dielectric material it responds to the electric field. now, I will demonstrate experiment how to measure dielectric constant of a dielectric material.

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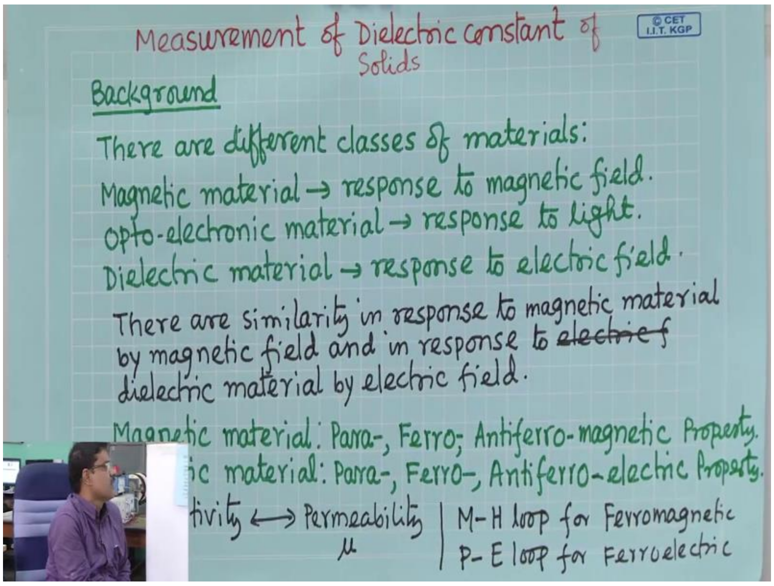

Measurement of dielectric constant of solids. As I describe the background of this experiment. There are different kind of dielectric materials like para electric, ferro electric, antiferro electric. It is similar to para magnetic ferro magnetic antiferro magnetic permittivity epsilon; that is in case of the dielectric material. that is equivalent to the permeability of magnetic material.

M H loop for ferro magnetic material or B H loop. that is characteristics of ferro magnetic material. Similarly, in case of ferro electric material P E loop is the characteristics of ferro electric material. After magnetic material, we will perform some experiment on dielectric material. first experiment I will demonstrate how to measure the dielectric constant of a solid.

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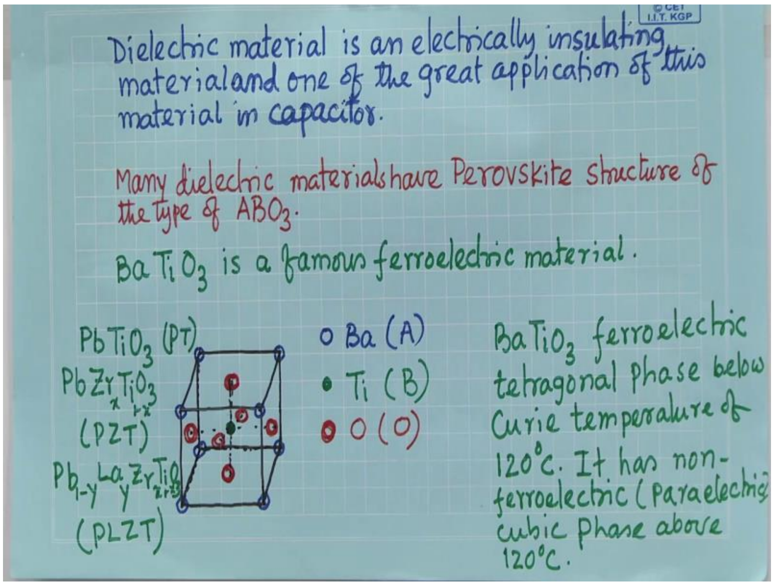

Dielectric material is an electrically insulating material and one of the great application of this material is in capacitor there are many dielectric materials and if a major portion of the material dielectric materials have Perovskite structure perovskite structure it is an ABO 3 type chemical formula of this material. barium titanate is a very famous ferroelectric material. first material if we if we consider in perovskite structure. That is the barium titanate material. its structure perovskite structure this is cubic structure you can see.

Now, in corner of the cubic this material A type AB3 an A type atom are at the corner. In this case, barium titante that is barium. In addition, in the body center and in the body center these B type atoms. this in this case the titanium and at the phase center at the phase center they are oxygen, oxygen. This number of atoms per unit cell is A type that is 1. 1 A contribution for each corner. It will be 8 corners. it will be one eighth of 8 corner.

it will be 1 and titanium or B type it is in body center. per unit cell is a 1 and phase center 6 phase. Each phase have half contribution to the unit cell. from 6 it will be 3. AB O3 that is the; that is the chemical formula and the structure is called the pervoskite structure right.

Now, there are other materials famous materials ferroelectric or dielectric material. Dielectric material have now some materials are ferroelectric, some materials are piezoelectric, some materials are pyroelectric. various kind of materials are there and depending on their responds to external parameters like electric field and some other external parameter like stress, like temperature.

Lead titanate, it is also called PT material P b T i O 3. this is also ferroelectric material and having these pervoskite structure and this one this if this is the basic material. Now, doping with some other material like zirconium lanthanum zirconium P Z T, it is called lead zirconate titanate, lead lanthanum zirconate titanate P Z T material P L Z T material.

These are all also this of same kind. One of them we will use for this experiment and barium titanate is ferroelectric material and if you, it has Curie temperature around 120 degree centigrade. Below Curie temperature, below curie temperature it is ferroelectric and its structure is tetragonal means, tetragonal means; an equal to b is not equal to c but other angle is 90 degree

Its structure if you increase the temperature its structure from cubic it goes to the it goes to the tetragonal structure. that means; there is a displacement along the c axis and this is the reason to become the ferroelectric because ferroelectric it will have the permanent dipole moment electric dipole moment.

in cubic phase; generally, this a center of the positive charge and center of the negative charge it coincides whereas, in tetragonal structure what happens it is there will be this center of positive charge and center of negative charge will not coincide. There will be distance difference in distance between these two. that will form the dipole moment. That is the reason of seeing this ferroelectric property.

Below this curie temperatures; not below, I think it is an above this cubic temperature, 120 degree centigrade. This there is a phase change from ferroelectric to paraelectric ok, or ferroelectric to non-ferroelectric phase change at 120 degree centigrade associated with the structural phase change from tetragonal to cubic this 120 degree centigrade is the Curie temperature for this ferroelectric barium titanate ok.

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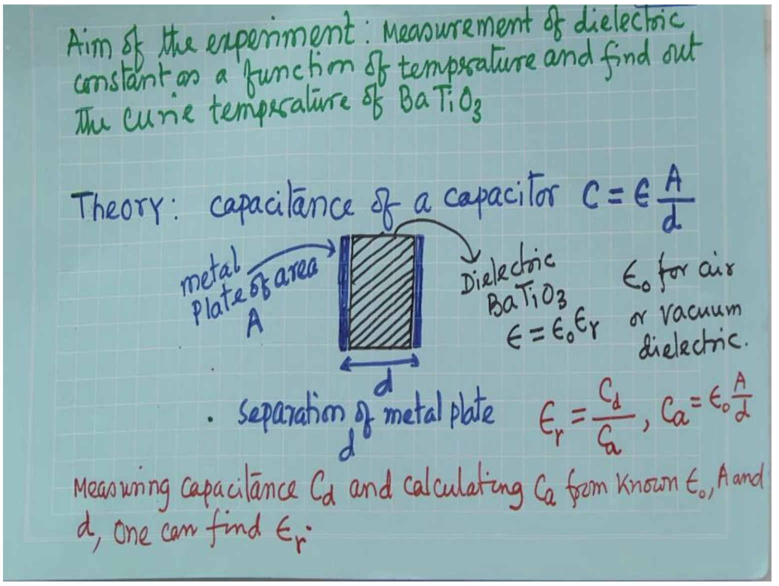

We will our aim of this experiment is the measurement of dielectric constant as a function of temperature. In addition, find out the curie temperature of barium titanate. That is the; that is the aim of this experiment.

We have to, we will take a dielectric material black part this is the dielectric material; we will place between two metal plate two metal plates. that is capacitor. Now, this capacitor with this dielectric material, if this separation of this metal plate is d and this dielectric material barium titanate it is a dielectric constant epsilon equal to epsilon 0 epsilon r.

Epsilon r is the, is a relative dielectric constant. our aim is to find out this epsilon r that epsilon 0 is dielectric constant of free space. this metal plate we will use as a if there a i is A and their separation is d. epsilon r is ratio of this capacitance with dielectric and capacitance without dielectric air an air it is A epsilon 0 A by d air or free space

Epsilon 0 is known A is known d is known. C a we can calculate. C a is known to us then C d with this dielectric. If we can measure this C d then we will get epsilon r. measuring capacitance C d and calculating C a from known this epsilon 0 A and d one can find epsilon r.

This will find as a function of temperature and then, we will plot and then from this plot we will find out the Curie temperature that is around 120 degree centigrade. this is the theory behind this experiment next we will demonstrate this experiment in our laboratory. Let us go to the experimental set up and do the experiment.

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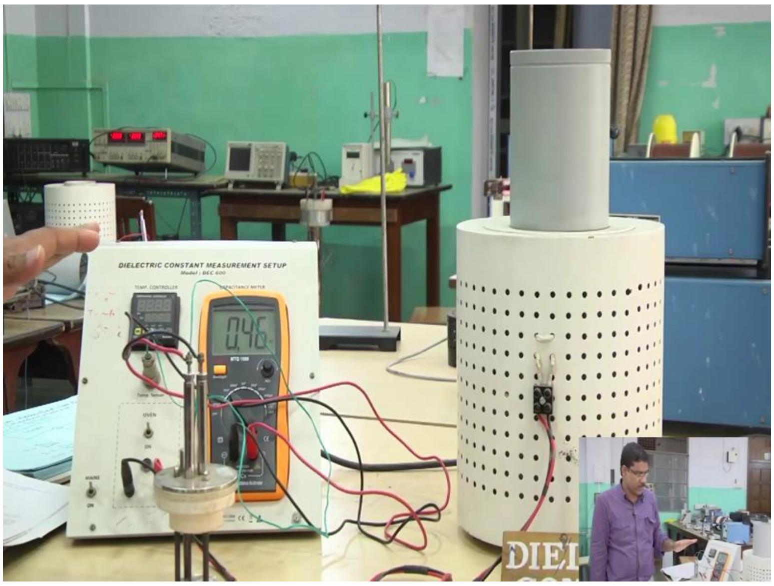

This is the experimental setup for measuring the dielectric constant of a solid. Here you can see this in our sample; this is the sample it is a tablet kind of things looks like tablet ok.

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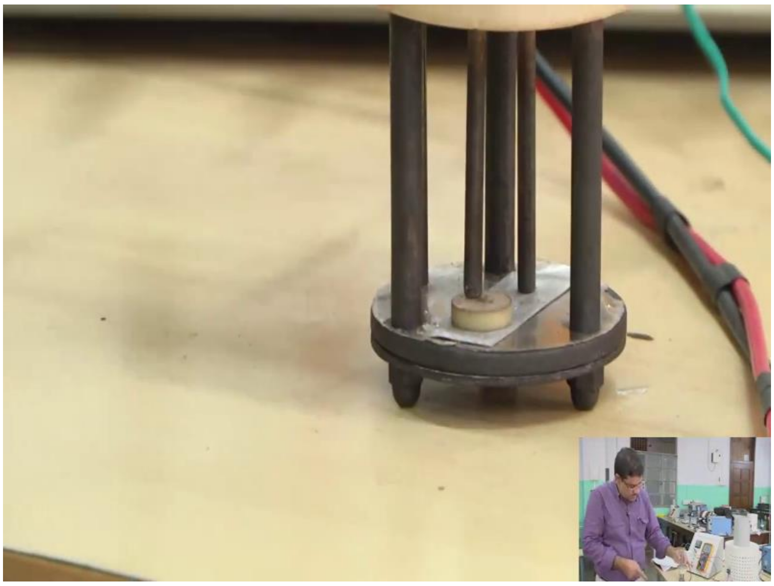

Here you see in bottom, there is a metal plate in bottom that tablet is put on a bottom. I think yes this is isolated from this base using the mica foil for electrically isolated. Only this sample have contact from bottom this one electrode this side this one and from top this is the electrode. On top and bottom it is a connected with this two electrode wire we will apply the voltage and corresponding we will get the electric field.

Now, as I told that experiment is we will vary the temperature and measure the capacitance in presence of dielectric and then from capacitance C d; we can calculate the, we can calculate the dielectric constant epsilon r as a function of temperature. Now, this sample we have, this is the setup for applying electric field and we have to measure the capacitance as a function of temperature we need oven.

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This is oven. You can see it is an oven inside ceramic hole is there this is the oven this outside, outside in this inside is box. Outside of this ceramic tube there are coils heating coils ok.

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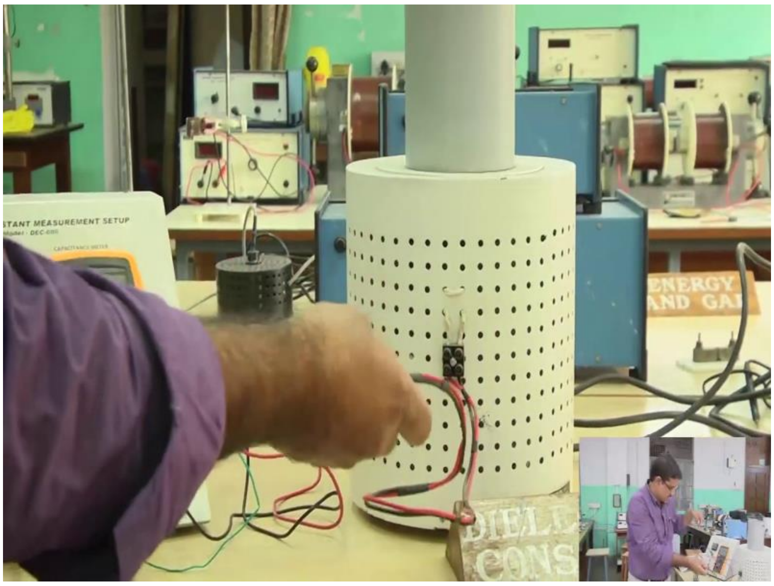

This we will apply power to this coils by this from here it is written it is an oven ok.

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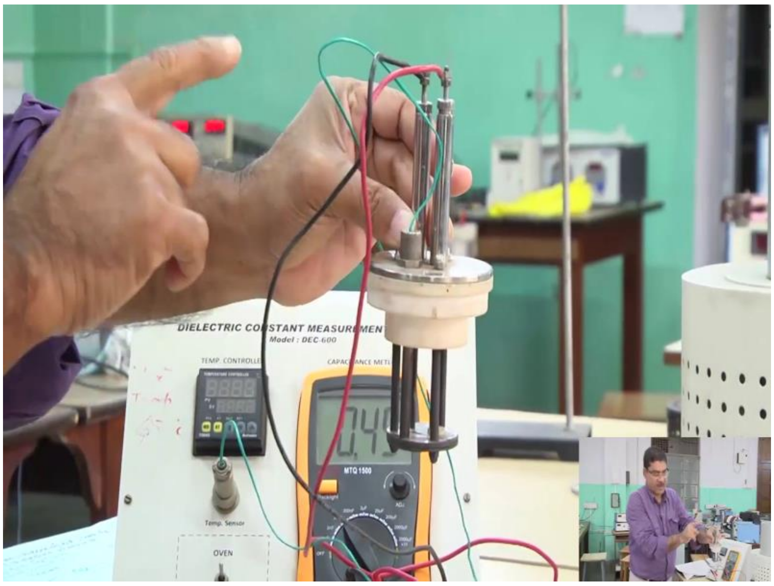

Now we will apply power and here you can see three connection this two for applying electric field as well as for measuring the corresponding capacitance. In addition, these blue line; this one is a temperature sensor, is a thermocouple it is inside this. inside thermocouple is there. This through this wire, we will get the temperature this we will put into this oven. We will put into this oven. I have to put carefully. Yes, I have put inside the oven. Now, we will give power to the oven, from here I switch on this oven will switch on this oven.

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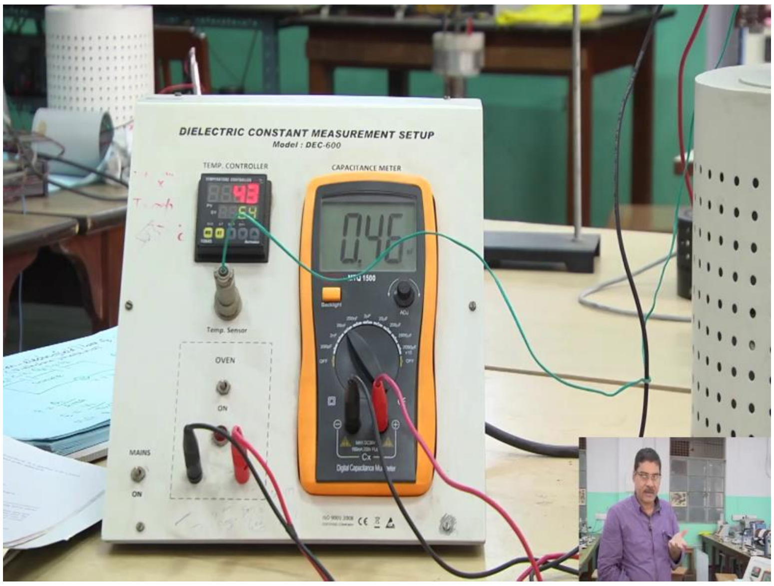

This is the main power and this is the power for oven. I switch on this power and what is the temperature it is showing, it is temperature is 36. We can set here temperature desired temperature what you want. In addition, is the temperature controller if you set temperature? It will automatically take power to reach to the set temperature. you cans design you can set the temperature and for that temperature; we will note down that temperature and we have to wait for reaching that temperature and corresponding whatever the this is the capacitance meter this is the capacitance meter.

Here directly it will give us, it will give us the capacitance of the capacitor with this dielectric at different temperature at present what is the temperature? This 41 temperature and corresponding capacitance it is 0.46. Now, whatever the sample I showed you, it could be barium titanate, it could be lead titanate, and it could be lead zirconate titanate

At present, this sample is lead zirconate titanate. P Z T material we had taken. We are doing experiment for as I told this for barium titanate we will do, but since this material this sample is put there that is P Z T. we can do the experiment using this P Z T.

Its curie temperature is around 320 Kelvin not Kelvin 200 320 degree centigrade that is experiment we have to do here we can give we can heat up to 600 degree centigrade. We will vary that temperature say here you can set the temperature at different value.

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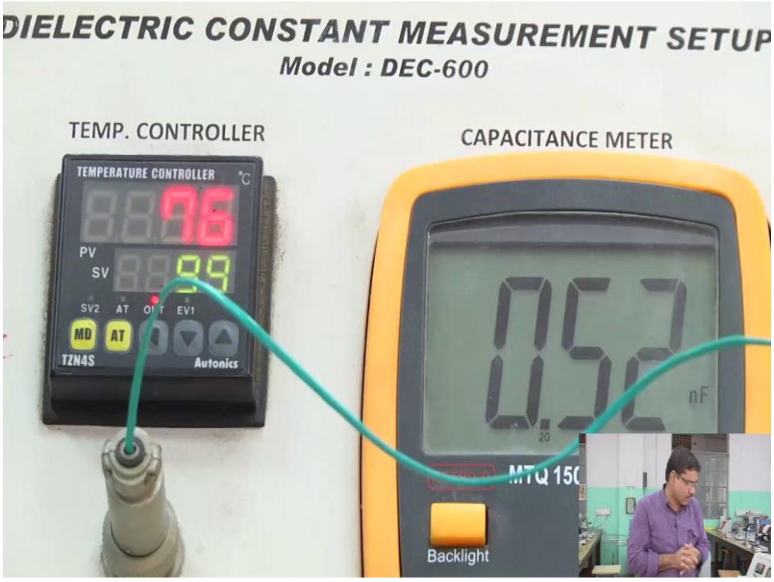

We have set this temperature a higher temperature. generally, one has to put a say 400 degree centigrade. we will do experiment starting from this 50 degree centigrade or 40 degree centigrade It will change the temperature, it will change the temperature; this reading will take and corresponding what is this value that we will note down.

Temperature versus the capacitance C D that we can get from these two reading. Is a very simple experiment it is compared to magnetic material, it is dielectric material it is an easy to characterize. You can see this very simple setup; we need only temperature controller and one oven. This will give the variation of temperature and we need a capacitance meter.

capacitance meter; they are directly, it will give the value of the capacitance in our case this with dielectric P Z T dielectric material for that we are getting you see with temperature it is a 95. Now it is 0.56. This way just reading will change and we have to note down.

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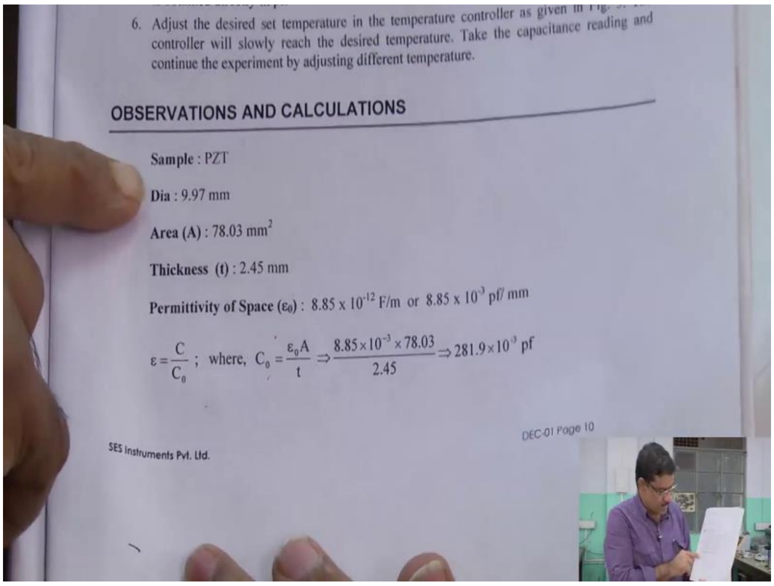

Then you are getting then as I told it is a we have to know the dimension of the we have to know the dimension of this material. here diameter is 9.97 millimeter. company has supplied this sample as well as this diameter one can measure also. Corresponding area will be this. In addition, thickness of the sample, that is an important that is 2.45 millimeter. In addition, epsilon 0 is this one 8.85 into 10 to the power minus 12 farad per meter.

C 0, one can calculate using this supplied data and that is 281.9 into 10 to power minus 3 pico farad C by C 0 whatever C or C d we I have written. That value is this value. Corresponding epsilon this is epsilon r. we will get epsilon r. we will get epsilon r for different temperature.

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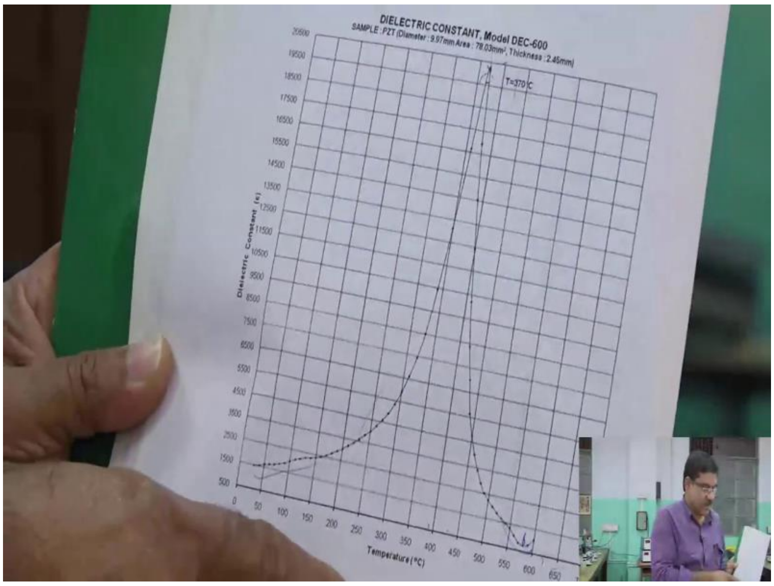

Then we plot it, then we plot it and then if we plot it. This type of graph if we start from 40 degree centigrade. this type of graph you will get. You see it is increasing with temperature, it is increasing it will increase and it is a very huge value you know this dielectric constant it is around 20000 this value and this temperature it is it is not 320 370, 370. It was not put properly. just it is adjusted itself its position.

Here you can see this sharp variation of this dielectric constant as a function of temperature. It is a from 1500 to it is going 20000, 1500 to 20000. Sensitive with temperature and it is going and then again after 370. it is a curie temperature is not 320, it is a 370. 370 then later on it is just again decreasing up to 600.

This experiment one can do from 50 to 600 degree centigrade temperature and we have to; we have to note down this reading and plot it and find out the Curie temperature. In addition, this very nice experiment to see the variation of dielectric constant from 1500 to 20000 ok, between temperature 50 to 370. This the variation of dielectric constant.

Very sensitive to the temperature. and it happened because, this structure is changing; lattice parameter is changing in the metal with temperature. It is a very structure sensitive and this lattice parameter sensitive. that is why this shows how change is observed with temperature. I think one has to continue taking a reading you can see the it is increasing up to 370 it will increase then it will start to decrease. one has to note down.

very simple experiment very simple experimental setup, but it can give very sensitive information that dielectric constant is a function of temperature and in this sample it is the, like magnetic metal ferromagnetic to paramagnetic phase transition one can see.

Here ferroelectric to para electric phase transition one can observe from this simple experiment. this is the; this is the dielectric material. In dielectric, this is the ferroelectric material. It has another very good application this is the it is the piezoelectric material with pressure also this material with pressure with stays this material also very sensitive this its polarization is very sensitive. People use this material as a pizo electric material also.

Now it is 204 and this value is it is a 0.9. it is reading something is happened. I think one has to check. I should not put my hand because this some voltage is there. I think one should change range or something can be done some connection I think some loose connection. One has to change because, things are getting heated and ok.

Some connection contact issue was there. one has to what has to check and do the experiment. I think I will stop here one has to continue the experiment and take the reading let us stop here.

Thank you.