Experimental Physics - III
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Lecture - 32
Superconductivity (contd.)

Before I start to demonstrate the experiment in the laboratory, let me discuss about the Experimental arrangement or doing experiment on Superconductivity. Therefore, we will measure we want to demonstrate how to find out the critical temperatures of a superconductor. Therefore, for that we have to do I-V measurement I-V characteristics of superconductor.

These. one should have very clear knowledge about the transport measurement. Let me discuss about the transport measurement I-V measurement as a function of temperature, as a function of magnetic field or as a function of current density although in our laboratory only one parameter will vary that is the temperature and we will find out the critical temperature.

However, whatever the case whatever the experiment related to superconductivity. This I-V characteristic is the important measurement. K this is the transport measurement.

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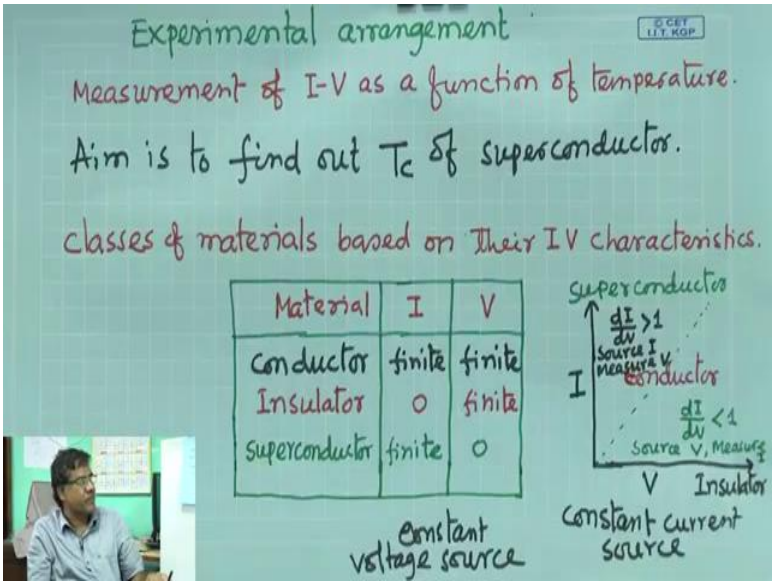

Transport measurement you can see here the depending on transport measurement I-V characteristics materials can be classified into three types; one is conductor if it is conductor. Current would be finite and voltage also will be finite if it is insulator material then current will be 0 and voltage will be finite. If it is, superconductor then current will be finite and voltage will be 0.

This way one can classify material based on their I-V characteristics. Here I and V. now, question is that what you will vary allow what you will keep constant? Generally between I and V in transport measurement one of them we keep constant in the circuit, we keep constant in the circuit and measure the variation of the other one because we are in transport measurement we are measuring the resistivity or resistance of the sample.

Resistance of the sample if varies, then if one parameter either I or V remain constant then other parameter will change depending on the following the change of the resistance. To know the variation of the resistance we have to keep in the circuit we have to keep one parameter constant. See it can be current or it can be voltage ok. Now, here as I told this one of them I and V one of them will keep in circuit constant.

For that, we need source. That is the two type sources are available it has a one is current source constant current source and another is constant voltage source. I think this meaning of constant current source or constant voltage source is clear because the source we will use in our circuit where that current or that voltage will remain constant. That source will supply the constant current or constant voltage in the circuit although there will be change of the resistance in the circuit. That is the specialty of constant current source or constant voltage source ok.

Now, which one we should keep constant and which one we should measure? if I want to keep current constant. I will use constant current source in the circuit current is constant. I will note down the current ok, but I have to measure voltage. That voltage variation of that voltage is that is that that indicates the variation of the resistance of the sample. other way if I keep this voltage constant voltage source. In the circuit this or across the sample this voltage remain constant.

Then I have to measure the current. current will vary if resistance of the sample varies for some reason as a function of temperature or magnetic field whatever. Now, question is when we should use constant current source and when we should use constant voltage

source. there is a here I have shown here you see this is the these the current axis and this is the voltage axis.

If it is conductor, if it is conductor this conductor one can use here I have shown dotted line; I have shown dotted line. See its conductor if d I by d V d I by dV is less than 1; this is I-V I plot. if d I by dV the slope if slope is 45 degree it's a then it is 1 if slope is less than 45 degree then it will be less than 1 d I by dV less than 1. For that sample; less than one means d I by dV. This resistance is higher d I d I by dV is less than 1 means the resistance of the sample is higher.

In that case, one should use constant voltage source and measure the current measure the current. If d I by dV is greater than 1 for small change of volt voltage for unit change of voltage current change is higher, see it is the more conductor it is conductive. In that cases resistance is lower in that case; in that case constant current source is used and measure voltage ok.

Therefore; that means, in case of superconductivity superconductor experiment one should use constant current source and measure the voltage variation voltage drop across the sample ok. In this case, it will be 0; in this case, this voltage will be 0. We will get current variation. that one should measure. In addition, in case of insulator as I told higher resistance, source constant voltage source. one should use and measure the current. when insulating material in that case one should use constant voltage source and measure the current; measure the current because here in case of insulators this current is in case of insulator current is almost 0 ok.

In addition, voltage is finite in case of voltage is finite current is 0. in this case we are telling constant current voltage source and measure the current. However, current is almost 0. If possible, it has an it's an ideal case if there is a very high resistance. Practically current will be 0. One cannot it is an in ideal case one cannot measure. Anyway, insulator here whatever we are trying to see it is very high. in that case a constant current source one cannot use one should use constant voltage source and do the current measurement.

Here, this is the general rule for transport measurement. When one should use current source constant current source, when one should use constant voltage source. This are nicely explained in this slide.

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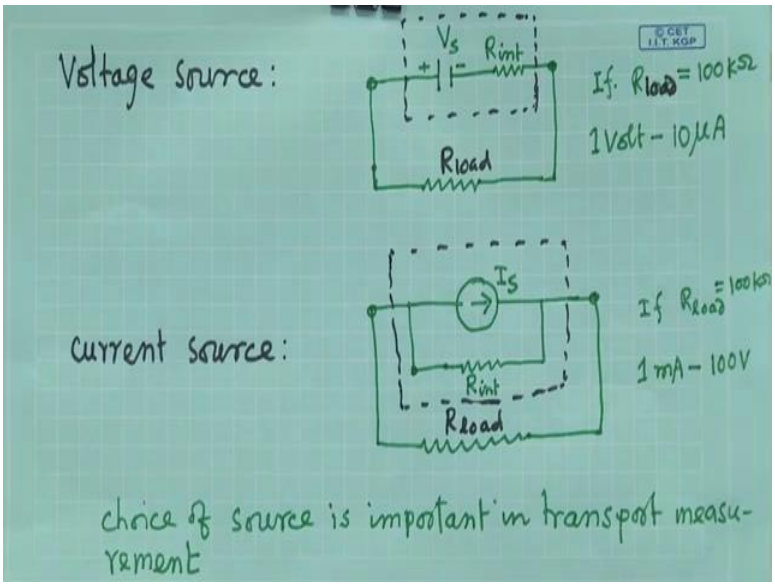

What is the constant voltage source? What is the constant voltage source? What is the constant current source? Constant voltage source you see there is an it is a like a battery kind of things and there is a battery constant voltage source you know.

1.5-volt ever-ready battery or other battery from market we buy and this we use in our circuit. we use in our circuit as a constant voltage source. Because the voltage in the circuit always remain the same 1.5 volt ok. for any battery you know these there is a internal resistance internal resistance now that battery. The as a whole this one is a constant current constant voltage source and there are there will be option; there will be option for connecting our sample until load R resistance R load.

It is connected with our sample. then in the circuit the voltage will remain same; will remain same now we measure the current which will tell you that is whether this load is changing or not as a function of something. Similarly, for current source is like; this current source is like this. A current source having internal resistance in parallel and a source one can use or connect with the load.

Now, why I showed you here? Because it is a very in case of in case of constant current source say you are telling that I need 10 ampere current. I should buy a power supply constant current source; I should buy a constant current source, which will be able to give maximum 10 ampere current.

we do not need to buy 20 ampere current because if current is higher than this price of the power supply will be higher see if you need maximum 10 ampere. you will buy this a source which can get the maximum 10 ampere current. Now, that is not enough that is not enough.

voltage also in that specification if you just decide the current it is not enough, you have to decide the voltage also Because the power supply constant current source the power supply how it can keep current constant in the circuit? In the circuit there is there will be load. Now, if that load very varies; if that load varies means resistance varies in the circuit then there will be change of current.

Now, to neutralize this change of current then these power supply should be should have ability to increase the voltage in the circuit that the current will remain constant. Although we are interested for constant current, but the voltage in specification voltage also important that how much maximum voltage the power supply can use that is called compliance voltage that is called compliance voltage ok. That is the internal voltage in this power supply, which will have a maximum capacity. wherever necessary it can use this that internal higher voltage.

A compliance voltage that also although this current is important, but one has to decide the compliance voltage depending on the depending on the load of your experiment. that is why I just discuss more on this issue that similarly for voltage source if I need say 100 volt maximum 100 volt that is good enough. Now, again that it question if load changes; if load changes, then voltage will change; voltage will change.

To keep voltage constant; to keep voltage constant in built there will be arrangement which can increase the current which can increase the current that the across the load the voltage will remain constant ok. This is called how much current maximum current that constant voltage source supply this is called compliance current ok. These compliance current that specification alone has to tell this 100 volt if voltage is higher generally current is lower. when voltage is say a 100 volt. This current rating will be in milli ampere. 100-volt 1 milli ampere or a 100-volt 1-microampere ok.

This is also important depending on your experiment depending on your load. load on the power supply constant power supply look. Depending on the load one has to decide not only the constant current maximum current or constant maximum voltage, we need

to decide the corresponding compliance voltage or compliance current. that is why I want to mean and it is really very important to decide during the transport measurement. Now, we have current source and you have constant voltage source, you have volt meters you have ammeters ok.

Depending on the experiment you have to use one of them it can constant current source or constant voltage source as I told in case of super conductivity, we will use constant current source.

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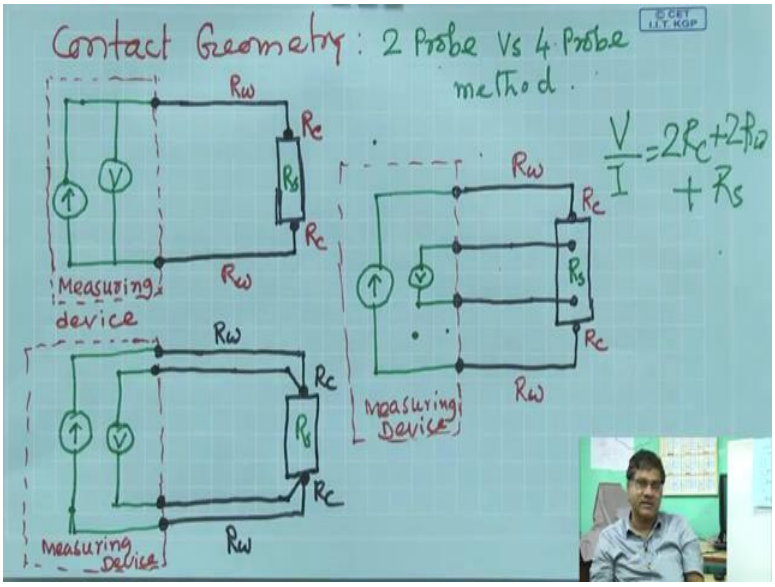

Now this these power supply we have to connect. for I-V measurement this clear that it is clear that this type of connection we are habituated to be to make in our in our laboratory. This is the sample; this is the sample arrays its resistance is arrays now either this these two contact will take either solder the say copper wire solder with the sample.

There will be contact at the sample of this copper wire. there will be resistance small resistance at this contact also that I have written Rc. now, this wire also will have some small resistance, but there will be resistance there is a R w wire resistance ok. Now if your constant current source if you say here I have taken constant current source. You are connecting like this and there is a voltmeter there is a voltmeter which will measure the will measure the voltage drop across the resistance.

you will be able to find out the resistance of this sample, now here whatever voltage you are getting whatever voltage you are getting that is the reading you are getting that is voltage drop across the resistance when current passing through the resistance. Now, this you see current passing through this R w if constant current i passing through this I will say i R w that will be voltage drop, i R c that will be voltage drop, i R s that will be voltage drop across your sample and also again i Rc i R w.

If you measure this with this voltage, actually it is not measuring the voltage drop across the sample only. it is measuring voltage whatever reading it will give that is 2 Rc plus 2 or R w plus R s into i ok. P by i equal to 2 R c plus 2 R c V by I will be equal to 2 R c plus 2 R w plus R s ok. it is not only the resistance of the sample there are two other resistance alit is there. This way if the sample resistance is very small it is comparable to the resistance of the contact resistance R c and the R w, then you can see this error is huge in this measurement.

If R s is very high and then R c and R w is negligible in that case this type of correction whatever in laboratory, we are we used to connect use. This type of correction measurement is otherwise when you are going to very small resistance as like superconductor ok. In that case, this contact resistance and wire resistance will be factor. We have to eliminate this this resistance contact resistance and wire resistance, but contact is without contact and without wire we cannot do transport measurement we have to use them.

What is the remedy; what is the remedy? here. Other way people also can use like this your sample. from this contact itself. This is a constant current source is connected with this and directly from the sample the voltage is connected. in that case the voltage drop whatever it is noting down. That voltage drop is noting down this you see voltage drop across this. here this r w will not come wire resistance that voltage drop across the wire resistance that this volt meter will not see, but it will see voltage drop across this R c as well has R s.

Still there will be error in the measurement if R s is very small. Still in this type of arrangement you can eliminate R w, but you cannot eliminate R c. this third configuration here you can see if it is connection is like this. from this two contact this constant current source is connected and from two other contact from the sample

separate contact from the sample. We have connected this voltage. Now, here we are telling that this volt meter only it will decode the data or give the data reading that that voltage drop across this across the sample between these two contact you know it is not the whole sample now, it is the between these two contact voltage drop between these two contact.

Also though here there is a contact, but this contact voltage drop across these contact will not will not come in this measurement why. this is the slightly confusing, but try to understand that you see voltage drop you have resistance, but voltage drop only possible only occur when the current pass through that resistance, if it does not pass through that resistance, then there will not be any voltage drop and that will not be recorded . Here you see that current is flowing through this. this contact flowing through this contact, but this contact is not included in this in the volt meter connection that will not come this resistance of the wire also will not come, but here when it is current will come here.

there will be two path one is this through the sample and another is this some portion may go through this volt meter connection wire, but volt meter resistance series resistance of volt meter is high practically no current flow through this through this wire towards the volt meter ok. there is no current flowing through this contact towards the volt meter. There will not be any voltage drop.

Whole current will pass through this R s, whatever voltage drop across this length of the sample between these two contacts that voltage reading we will get from this voltmeter. Now, here you see there which sample this in this case two contact in this case also from the sample two contact, but in this case from the sample this four contact. 4 probe 2 probe contact with the sample through the two contact. this called 2 probe method and this called 4 probe method ok. And 4 probe method it exclude the contact resistance and the wire resistance in the measurement only we will get the resistance of the sample. That is thus this 4 probe method is superior to this 2 probe method.

When the sample resistance is very small. One must use these 4 probe method not two probe method in case of superconductor we will use constant current source. Why we will use constant current source, I try to explain we will use 4 probe method or I-V measurement ok. I will stop here.

Thank you.