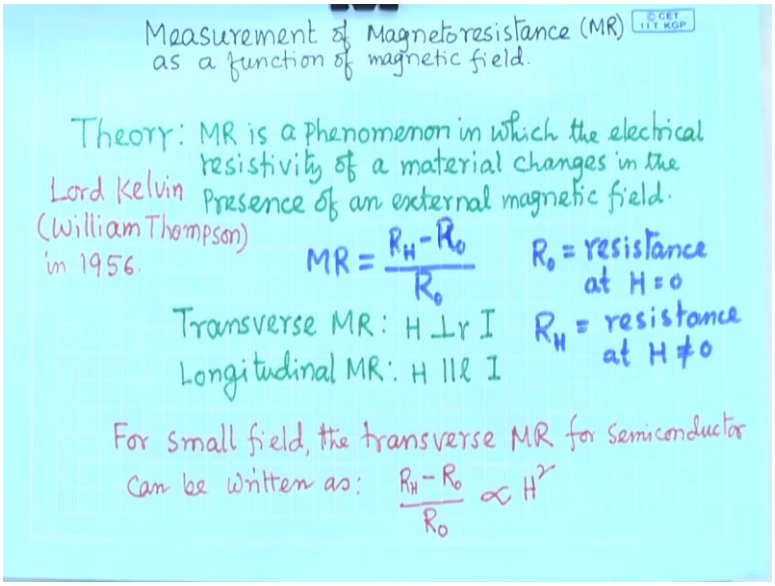
Experimental Physics - III
Prof. Amal Kumar Das
Department of Physics
Indian Institute of Technology, Kharagpur

Lecture - 12
Topic - Measurement of magneto resistance

Today, I will demonstrate about the experiment how to Measure the magneto resistance of a sample? resistance of a sample, we are used to measure how to measure yes is an Ohms law, verification ohms law you know, if we take a register now we pass current through the sample and measure the voltage drop across the sample.

resistance is the voltage drop across the sample divided by current passing through the sample. now, this resistance it responds, it varies with external parameter like magnetic field temperature, pressure. today we would like to see how resistance depends on the magnetic field. that resistance depends on the magnetic field that we express in terms of magneto resistance.

(Refer Slide Time: 01:59)



magneto resistance is a phenomenon in which the electrical resistivity of a material changes in the presence of external magnetic field. this phenomenon was observed or discovered in 1956 by Lord Kelvin, he is also his name is William Thompson, but he is known to us as a Lord Kelvin. magneto resistance is defined; is defined by this R H

minus R 0 divided by R 0. R H is resistance at R 0 is resistance at H equal to 0 magnetic field when magnetic field 0.

And, R H is resistance at H is not equal to 0 means in presence of magnetic field. to know the magneto resistance we have to measure the resistance of the sample without magnetic field, and then resistance of the sample in presence of magnetic field. And, then using this formula we can calculate the magneto resistance.

now two we defined the magneto resistance in two ways; one is called transverse magneto resistance, another is called longitudinal magneto resistance. When magnetic field is applied perpendicular to the current, sample current, then that is called transverse magneto resistance. When magnetic field is applied parallel to the current, then the magneto resistance is called longitudinal magneto resistance.

Now, for small field, the transverse magneto resistance for semiconductor can be written as this magneto resistance R H minus R 0 divided by R 0 is proportional to H square theoretically one can find out these that is for small field and for semiconductor. The magneto resistance depends on magnetic field, how it depends whether it is linearly proportional or it is proportional to the square of the magnetic field for metal it will not be this dependency will not be this it will be different.

our task is in this laboratory we will use semiconductor, germanium semiconductor and N type germanium semiconductor. And, we will measure the magneto resistance of that sample at different magnetic field, then we will plot the magneto resistance as a function of magnetic field and we will verify the dependence of this magneto resistance on magnetic field.

that data we will get, whether we can fit; whether we can fit this with this expression. that curve is should be it should be parabolic curve, because y equal to x square kind of formula expression here. if we are expecting that this data if we plot that graph it should be; it should be parabolic theoretically this found that, this type of dependence of magneto resistance or magnetic field for semiconductor in transverse mode. from that, from this experiment in this laboratory, we will verify this, we will verify this expression.

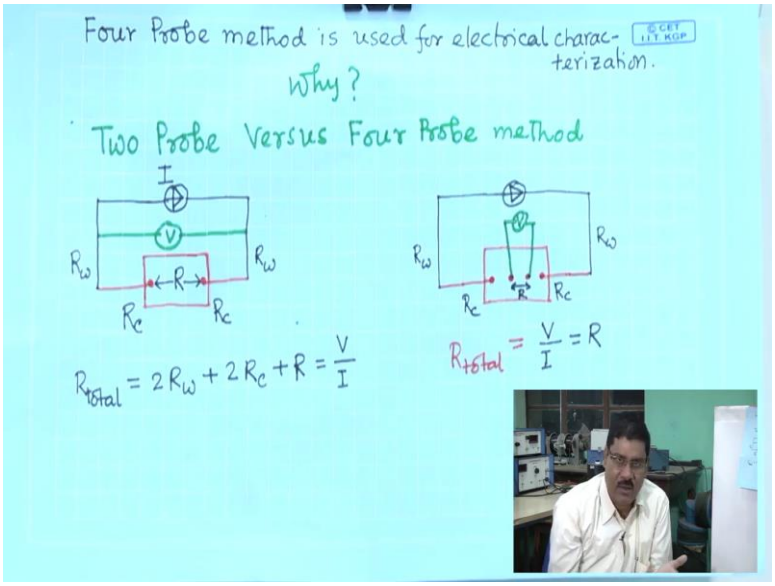
for this experiment what we need we need constant current source, for sample current we will apply constant current in the sample and, then we will measure the voltage drop across the sample. we need voltmeter, we will use Nano voltmeter or micro voltmeter, then we need magnetic field.

how to generate magnetic field in laboratory viewing the electromagnet that I have discussed, then we need gauss meters to measure the magnetic field. And, we need connection, or applying, or passing, current through the sample we need connection with the sample also we need connection with the sample for measuring the voltage drop across the sample.

we are used to make connection for electrical measurement we use wire and just we connect different component using the wire. sample and we have different meter volt meter, or ammeter, or gauss meter.

what I would like to tell you that, for electrical measurement generally whatever the way we measure in the laboratory. that we call the 2 probe method or 2 connection method, but for this experiment we will use 4 probe method. what is 2 probe method and what is 4 probe method? Why we will use 4 probe method, whether 4 probe method is better than the 2 probe method? that one should know that let me discuss this 4 probe versus 2 probe method.

(Refer Slide Time: 10:19)



this 4 probe method we use for electrical character, characterization for this experiment. why, why we will use 4 probe method? Why not conventional 2 probe method or 2 connection method we will use?

let me tell you what is the difference between these 2 method and how this 4 probe method is better than the 2 probe method. this is this red one, this is your sample, this is your sample. with sample, you need to connection 2 electrode ok, for passing current through the sample.

let me take this; we asked you have to take 2 contact with the sample. this the 2 lines. with some wire you have to make contact, either using silver paste or whatever the way. you have to electrically make connection with this sample. these 2 point from where this wire is either one can shoulder also. So these two wire we are taking out. we have connection; we have connection with the sample at this 2 point.

Now, this is the constant current source. Now, this constant current source is connected with these two contact. And, for measuring the voltage again the voltmeter we have connected across this the sample. using this same connection using the same connection, we can connect the voltmeter like this.

here with sample there are two, two contact; one is here another is here using these two contact, we are connecting the constant current source as well as the voltmeter now, we will apply constant current some current. current will pass through it, either this in this direction or this direction. it will pass through the sample. since it is constant current source. constant current will pass through these sample file.

Now, this voltmeter will give me reading voltage, which drop across the; across the resistance, across the resistance between these between these 2 point, because current is flowing. when current is flowing. wherever it will see the resistance there will be voltage drop.

here R w I have written that is this wire resistance this wire resistance from. voltmeter it will it will give the reading the voltage drop across the resistance wherever present in the in this circuit present in this circuit it will see the voltage drop across this resistance, then R c this contact resistance, similarly the other side also R c and R w.

And, these sample resistance is R between these 2 point. this voltmeter whatever the reading it will give that voltage drop, voltage drop, across the total resistance. what will be the total resistance 2 R w plus 2 R c plus R ok? that will be the total resistance and voltmeter will give the voltage, the reading, that is V, divided by this constant current will give us this reading of current passing through the resistance. that is I.

we just connect and we take reading of voltmeter and ammeter or from current source. now, just we divided this V voltmeter reading divided by these current reading from the constant current source. V by I is resistance, so that resistance is R total. In R total what is there, this contact resistance as well as the wire resistance both are present along with the sample resistance.

using these we tell generally 2 probe method; means, we are using 2 contact; we are using 2 contact for the for the electrical measurement. And, in this measurement you can see, we cannot get the only R value, this R value along with the other contact in wire resistance.

Now, when the sample resistance is very high; sample resistance is very high, then this contact resistance and wire resistance maybe negligible. in that case one can use this 2 probe method, but if sample resistance is not very high if it is small value, if you use metal semiconductor n type semiconductor we will use in our laboratory. their resistance is not very high. in that case this contact resistance and the wire resistance may be comparable to the sample resistance. 2 probe method we cannot use in this space. to avoid 2 whether there is any way out to this contact resistance in the measurement.

let us see; that is the purpose. how it is done in the using the 4 probe method? here we tell linear 4 probe method this contact this 4 contact will be taken from the sample and they are linear. that is why it is called linear 4 probe method, there are other method Van der Waal method that I will not discuss.

here same sample; only here 4 contact, we have taken from the sample. this outer 2 this outer 2 contact is used for the current, for applying current passing current through the sample and middle 2 contact is used to connect the voltmeter. in this method we are telling that you can avoid you can avoid the contact and wire resistance only in this case you can measure the sample resistance.

how? here people can think that, in this case two contact whereas, here it is 4 contact. there will be contact there will be more contact resistance. how it is better? How it is better than these two probe method? here you see that constant current is passing through this wire and then contact, then sample same way as it is happening here.

now look at the measurement of voltage, we have taken the connection between these two point. Now, voltage drop across the resistance here what is the resistance wire resistance? there will be voltage drop across this resistance, across the contact this contact resistance, but it will not be because this voltmeter now it is not connected this way, it is directly connected to the sample this wire resistance and this contact resistance will not come in this voltage drop.

but there are two more contact are there here from where we are taking the connection for the voltmeter. Now, here if there is no current passing through the contact, then there will not be voltage drop and it will not be included. If current passes through the contact, then there will be voltage drop.

Now, when current is coming here, current has two path one is; one is this path through the voltmeter and another is through the sample through the sample. Now, here voltmeter that we know the resistance is very high current no current pass through the voltmeter it is a very high resistance of these voltmeter. when it will come here no current will pass through the voltmeter. whole current will pass through this sample.

if there is any current passing through the voltmeter. it has to go through this contact; it has to go through this contact, but current passing through the sample do not need to go through this contact, it will go through the sample. no current will pass through the voltmeter or negligible current will pass through the voltmeter.

voltage drop, there will not be voltage drop or negligible voltage drop due to this contact or this wire. that is that one can neglected because of very high resistance of the voltmeter compared to the sample resistance.

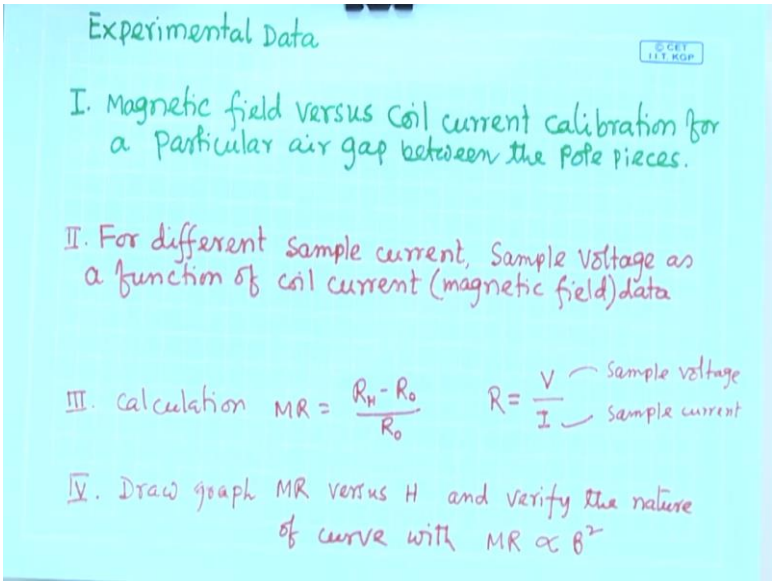
it is expected that whole current I will pass through the sample. voltage drop across the resistance between these 2 point of the sample that is R. you will measure the resistance of this using this formula whatever voltmeter reading, you are getting V and whatever

current you are getting from your constant current source. V by I equal to whatever resistance, you will get that is purely sample resistance.

this is the 4 probe method and which is superior to the 2 probe method. And, this method has to be used when you are going to measure the resistance of metal or semiconductor. If, any insulating material in that case or resistance is very large in that case 2 probe method is used generally. far you have use this probably 2 probe method for different electrical ah characterization.

in case of ohms law verification in class 12 11 12 or class 10 you have done that experiment. there are these the way you have measured that is called 2 probe method, but in this case we will use 4 probe method and 4 probe method, it is superior to the 2 probe method. one should understand this method clearly we will use this 4 probe method for measuring the electrical characterization in this laboratory.

(Refer Slide Time: 24:57)



what we have to do? experimental data collection. first magnetic field versus coil current calibration for a particular air gap between the pole pieces. magnet electromagnet you know already I have discussed. there is pole between pole piece, there is there is an air gap and in that air gap we will place our sample for magnetic field.

Now, this magnetic field strongly depends on the air gap. we have to fix the air gap, that air gap it should be such that you can you have to place sample in that gap. gap should be

sufficiently large or it should be comparable to the to the size of the sample with the probe connection.

you have to fix the air gap between the pole pieces of the electromagnet. And, now in this condition we have to calibrate the magnetic field versus coil current. Coil current means, the current we are passing through the coil of the electromagnet. for different current what is the magnetic field, that we will measure using the gauss meter, hall probe, and that that will plot in graph paper magnetic field versus the current.

And, that graph we will use as a calibration earth for magnetic field, because when we will do experiment we have to put sample between the pole piece. there we will not put the hall probe for knowing the magnetic field, because it can disturb it can affect the measurement of the resistance.

we will not use the hall probe or gauss meter during the electrical measurement. that is why before starting this resistance measurement even the 4 probe, we will calibrate the magnetic field or calibrate the magnet; that means, magnetic field for different magnetic, this coil current for a particular air gap. that is the first job task we have to do and for that I have not shown here table.

one has to make table, we have provided what is the air gap that we should note down and then for that air gap what is the current versus magnetic field for different current will take and this for different magnetic field, we will note down on the gauss meter and then that table will be used for drawing the curve graph and that is the calibration graph.

Now, after calibration we will we will place our sample, we will make core connection during the 4 probe method and with this 4 probe connection, we will place the sample between the pole piece, and then we will do experiment we will take data. What data we will take? That sample current at different sample current we will do the experiment. we will fix the particular current, sample current. Now, for that sample current, now we will apply we will vary the coil current means, we will vary the magnetic field. for 0 magnetic field what is the voltage, then how voltage will vary with the coil current?

we will take data for a particular sample current, what is the voltage across the sample for different coil current that we will note down. And, we can keep another column after the coil current, that is magnetic field from that calibration curve one can find out the

magnetic field from this from this current. you are getting data magnetic field versus voltage ok.

Now, current for that current different voltage you will get for different magnetic field corresponding resistance you can calculate V by I, V by I, you can calculate the resistance for 0 magnetic field that is R 0 I. now, that you will get R H for different magnetic field, now you can calculate the Mr Magneto resistance for different magnetic field.

now we will draw graph, next we will draw graph, magneto resistance versus magnetic field and, then we will verify whether we are getting the curve this parabolic curve or not. If, you get parabolic curve whether you are getting linear curve or parabolic curve or it is splitting with some other parameters.

here we will verify MR is proportional to here I have written B. one can write B also, but as I told H. I will write H square or B square also, when I have to write at all places B. that is the experiment I will demonstrate after this discussion. let me stop here and then go to the experimental setup to do the experiment.

Thank you.