Experimental Physics - III

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Lecture - 17
To Study the Variation of Resistivity of Metal and Semiconductor at Low Temperature Region

today I will demonstrate the Resistivity measurement of Metal and Semiconductor as a function of Temperature. how resistance of a metal and semiconductor changes with temperature? this is one fundamental experiment in the sense that how to distinguish a metal from a semiconductor; from this experiment we can distinguish between the metal and semiconductors.

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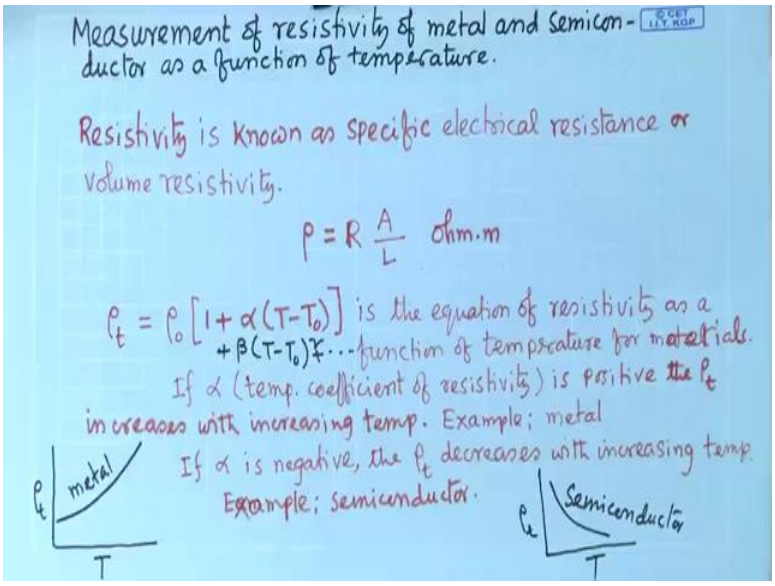

in that sense this experiment is very important. resistivity is known as specific electrical resistance or volume resistivity. resistivity rho is equal to R A by L ohm meter. R is resistance of the sample, A is the area of the sample and L is the length of the sample, then rho is the resistivity.

resistance and resistivity the difference is that resistance depends on the dimension of the sample, but resistivity is independent of the dimension of the sample. resistivity is resistance of a sample of the cube having of a cube having unit length, unit breadth and unit thickness if that is why it is here R is resistance ohm R is resistance in ohm and if an area is 1 and length is 1 this say meter square and this is the meter. it will be meter for unit that is why it is called volume resist volume resistivity. It is the for unit volume of a material what is the resistance. that is the; that is called the resistivity.

now, resistivity depends on temperature. Generally, we write the expression of resistivity as a function of temperature rho t is equal to rho 0 1 plus alpha T minus T 0 plus beta T minus T 0 square plus. higher terms will be there; it is a polynomial.

ah. in for different range of temperature it is the one will take up to first order or second order or third order terms that one has to resize. that is why it's it is not a state for a linear function. it depends on higher terms also somewhat in general one can write this polynomial.

here you see if we take just only this first order term one plus alpha T minus T 0, then T is the temperature present temperature and T 0 is the initial temperatures. it can be room temperature or it can be some other temperature. at initial temperature what is the resistivity. that is the rho 0 and that that temperature is T 0 and now I am changing the temperatures from T 0. it means is T it is it can be higher temperature lower temperature. generally, if we increase the temperature T minus T 0 this term will give the change of temperature delta T.

for this change of temperature ok, what will be the resistivity? rho 0 that is the initial resistivity plus alpha rho 0 and this delta t. that part is the change of resistivity due to the change of temperature delta t

now, here alpha is the temperature coefficient of resistivity. temperature coefficient of resistivity; if it is positive; if it is positive then you can see this. this term will be added will be added with this with this rho 0 term.

So; that means, this term will be positive this term will be positive and resistivity will increase with them temperature. If this alpha, it may happen that alpha is negative; temperature coefficient is negative, then this term will be for increasing temperature by delta t this term will be this term will be negative. resistance will decrease. with increasing of temperature resistance will decrease with temperature resistance is decreasing or with temperature resistance is increasing. that will depend on the alpha the temperature coefficient of the resistivity.

in case of metal in case of metal, this alpha is positive and in case of semiconductor, this alpha is negative but this is this is a polynomial you know it is not just it does not depend only this this this up to first order up; there is the effect of other terms also its a polynomial. it comes in various form; in some cases, it is a logarithmic form, it can be exponential form so.

here just this expression I am using just to tell you that from this expression in some extent considering the main terms one can decide whether temperature will increase or temperature will decrease that will depend on the material that will depend on the temperature coefficient of the resistivity of that material. And if it is positive generally in case of metal it is positive it will temperature with increase in temperature the resistivity will increase. In case of semiconductor, this alpha term is negative temperature coefficient is negative. the resistivity will decrease with increase in temperature.

that is how we can conclude, but exact form when you will do experiment; it will decrease and other one is will increase, but in which form it will increase or which in which form it will decrease that we cannot get from here as long as. we can feed this experimental data and find out find out the heating parameters how it depends on temperatures. it will depend on the other higher terms also depending on the range of the temperature. this form will be different. temperature dependence will be in different form that we can find out from the heating the experimental data of resistivity versus the temperature curve so.

we are why we are doing the showing the experiment using the metal as well as the semiconductor because from this experiment, one can easily distinguish metal and semiconductor. In case of metal as I told, these it will increase resistivity will increase with temperature; in case of semiconductor, resistivity will decrease with temperature.

this is the fundamental inherent phenomena of the resistivity of metal and semiconductor and one can distinguish them seeing the response to the temperature. now, question is that in case of metal resistivity or resistance of the sample increases with temperature and for semiconductor it decreases with the temperature.

why this opposite phenomenon we see? reason is that the metal; metal have the free electrons carrier are available in the metal. Now, this carrier when we apply voltage. carrier will move carrier will move. Now, when it is moving, carrier will move in a particular direction in which direction? The direction of the electric field direction of the applied voltage.

Now, when the electrons are moving towards the following the electric field, then it will collide; it will collide with other electrons; it will collide with the impurities if any impurities in the metal, it will collide with the with the ions. generally, we do not tell ions. we here major contribution comes from the scattering this electron phonon scattering from electron photon scattering, this resistivity arises in case of metal.

what is phonon? Actually when you increase the temperature change the temperature the lattice it vibrates there will be lattice vibration; there will be lattice vibration. this quantized form of the lattice vibration is phonon is phonon. as if this in metal there will be phonon which is the equivalent which generates from the lattice vibration.

Now, electron will be scattered will be scattered from the phonons. instead of we are we have instead of telling that this electron will scatter from the ions instead of that we tell that electron will scatter from the phonon.

phonon is nothing, but the quantization of the lattice vibration and this lattice vibration is become prominent or it changes with the temperature. scattering will be higher and higher when temperature will be higher and higher because you will get you will get the phonons higher number of phonons from the lattice vibration and there will be more scattering and there will be more resistance.

that is the reason for the for the resistivity or change of resistivity or resistance of metal with temperature. in case of metal why we why these free electrons are available? Why we tell these free carriers that are available?

Because if we consider the band structures of the material you have conduction band, then you have valence band and these other bands are there all other bands are filled up. Only this conduction band in case of in case of conduction bands are free. valence bands also filled Now, in case of metal this conduction band and valence band they overlap.

carriers available in conduction band electrons available in conduction band, then then we tell it is free; there is no morally if it is free to move in case of metal the conduction band and valence band they overlap that is why this or whatever the electrons are in the valence band, they are in the conduction band. they are free to move that is why in case of metal we tell that is the free electrons are available.

now in case of semiconductor, the conduction band is empty and valence band is filled there is a gap between these two. there is no carrier available for the for the conduction there is there are no carrier free to participate in conduction now at low temperature T 0 initial temperature if it is small if it is less than room temperatures or it is say yeah it is the close to the close to the 0 temperature 0 degree kelvin then it is a just perfectly insulator. When you increase the temperature of the semiconductor what happens? The carriers the electrons from the valence band. it will break the bonds covalent bonds due to this thermal energy and it will jump to the conduction band.

now, carrier is available in conduction band to participate in conduction if we increase the temperature, the carrier density carrier density in the valence band in the valence band and the conduction band electrons in conduction band and hole in valence band. two types of carrier will be generated and both carrier will participate in the conduction with temperature, we are increasing the density of carrier’s free carriers that is why and that carrier if we apply the voltage it will move; it will move.

increasing the temperature, you are generating more number of carriers. conduction will be higher and higher. resistivity or resistors will decrease in case of semiconductor temperature is changing the electron and hole density carrier density in the metal it is increasing. that is a conductivity is increasing; resistivity decreasing resistance decreasing. that is why in case of semiconductor, we see that the resistivity decreases with temperature

that is the change of resistance change of resistivity of a metal and semiconductors as a function of temperature. this concept is simple, but these are intrinsic property of the material and experimentally we can easily verify. I will show I will demonstrate this experiment in our lab.

Thank you.