Processing of Semiconducting Materials
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Lecture - 29
Metal Semiconductor Contact - I

One of the important processing technology for the semiconductor is the metal semiconductor junction; and that is very important in the sense that ultimately the semiconductor is used for electronic device fabrication. And to switch on an electronic device, you must connect it to some electrical supply say with the battery or some external bias, and that connections are done through some copper wires so, there must be some contact between the copper wire and the semiconductor. Now, not necessarily that all contacts will be ohmic in nature, because there are some conditions some criteria using which, we can say whether the contact will be ohmic or non ohmic type of contact.

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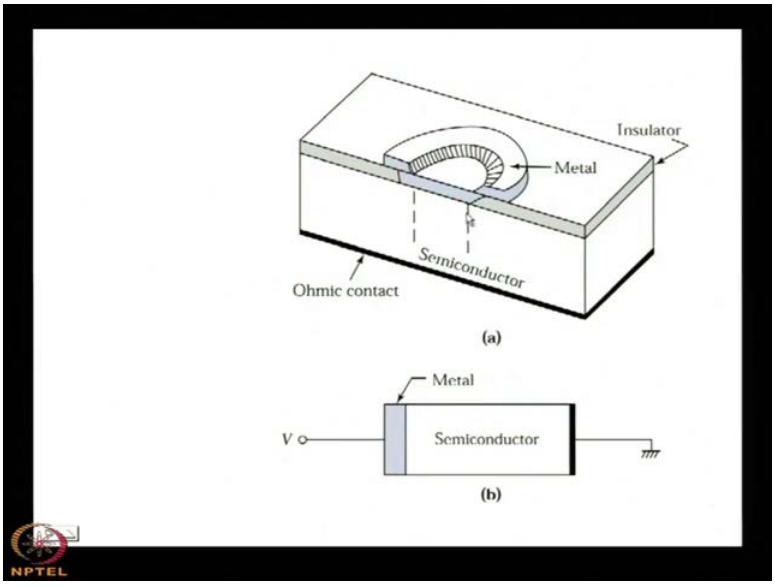

If it is non ohmic type of contact there are many applications of non ohmic type of contact also those contacts are usually known as the Schottky contact or rectifying contacts. As the name implies, the Schottky contact or rectifying contact are the contacts through which current can be passed very easily in one direction, because that is the characteristics of rectifying contact and it will not allow current to flow in the other direction. Now let us see, how the contact is made? Here you see that there is a semiconductor piece and this on the semiconductor piece on the top a metal is deposited

that is the top view a metal is deposited. Now, this metal is deposited means it can be any metal it can be say Aluminum, it can be Gold, it can be Platinum right any metal.

And, depending on the nature of the metal the metal is deposited on the semiconductor by the method of say thermal evaporation or a electron beam evaporation or say r f sputtering because it depends on the melting point of the metal. Because first, you have to melt the metal and then it will be deposited on the semiconductor surface so, that means for melting say Aluminum. Aluminium can be melted easily at say around 300 degree centigrade in vacuum, if you can make a vacuum of say 10 to the power minus 5 or 10 to the power minus 6 Tore then easily at 300 degree centigrade the Aluminum can be evaporated. It is because of the pressure of the vacuum because normally that melting point is higher, but because of 10 to the power minus 6 Tore it can be melted in a lower temperature.

But say Gold or Platinum, that cannot be thermally evaporated because of the high melting point even if you apply some vacuum then also it is not possible. Then you have to use say either electron beam that means to melt by electron beam or by r f sputtering. you make the gold target or platinum target then you sputter the target and then that can be deposited on the semiconductor surface.

So, now by any means you have to deposit the metal on the semiconductor and this is the planner view you see that this is the metal the blue is portion is the metal and it is a semiconductor. So, that is the piece, the piece means which is surrounded by 2 dashed vertical lines you see that there are two dashed vertical lines and in between these 2 vertical lines you can consider that this is the metal semiconductor junction a piece. A piece from this whole thing is cut and is presented here. So, it is a metal semiconductor junction.

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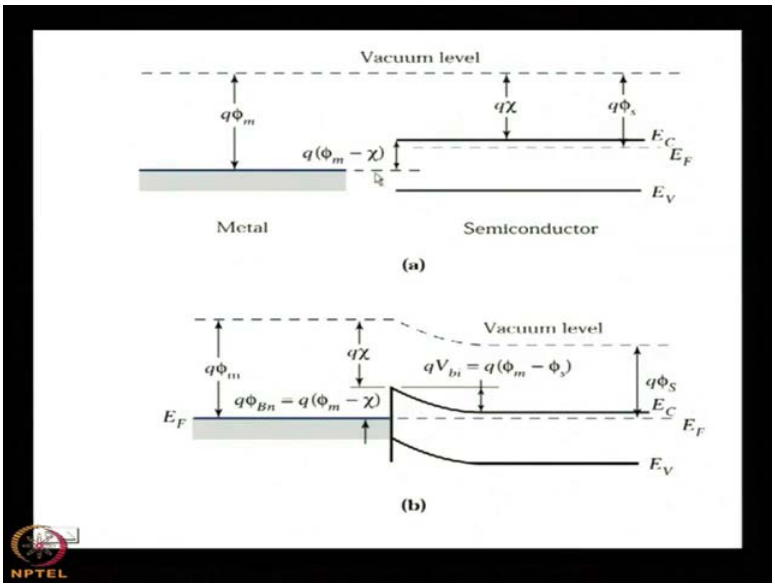

Now this metal semiconductor junction, have some unique properties. One thing is that when you have a metal say this is the metal, you know that the in metal the Fermi level basically is there and because of the overlapping of the conduction band and valence band in metal. So, always you find that there are many electrons even at the surface of the metal you will find many electrons which is not there in case of semiconductor there is a concept of Fermi level and only above Fermi level you can consider that there are some electrons.

So, in metal this is you see that this phi m is the metal work function. When it is multiplied by q the charge of the electron the unit becomes electron volt otherwise if you use just phi m it is in volt, same magnitude. Say phi m is 4 so, phi m can be 4 electron volt if you multiply by q otherwise it is 4 volt if you just use q m phi m. So, this phi m is a metal work function and that is the energy required to emit an electron from the metal surface to the vacuum level that is the energy, which is required to emit an electron from the surface of the metal to the vacuum level now what is the vacuum level?

When in vacuum level means there the electron is free, from the material that particular material it is out of the particular material and where its kinetic energy is 0 that is an imaginary level you have to consider that is some reference level with that reference level we shall discuss the whole thing. Now, this is the n type semiconductor in this n type semiconductor you see that this is the conduction bandage, this is valence bandage

and this is the Fermi level if the dotted line as usual them from the Fermi level to the vacuum level. The energy required to excite an electron from the Fermi level to the vacuum level it is phi s or the semiconductor work function.

So, when we talk about the work function it is the energy which is which is to be supplied to an electron at the Fermi level to excite it from the Fermi level to the Vacuum level. It is true for metal also it is true for semiconductor also the difference here is that only in semiconductor the surface does not have enough electron to emit.

So, we consider the Fermi level to the vacuum level here also you can consider that the it is the difference between the Fermi level to the vacuum level because the Fermi level here it is at the surface in for semiconductor it is always there the free electrons are always available there. Another important parameter is the chi, this chi is known as the electron affinity chi is known as the electron affinity it is the energy required to excite an electron from the conduction bandage of the semiconductor to the vacuum level.

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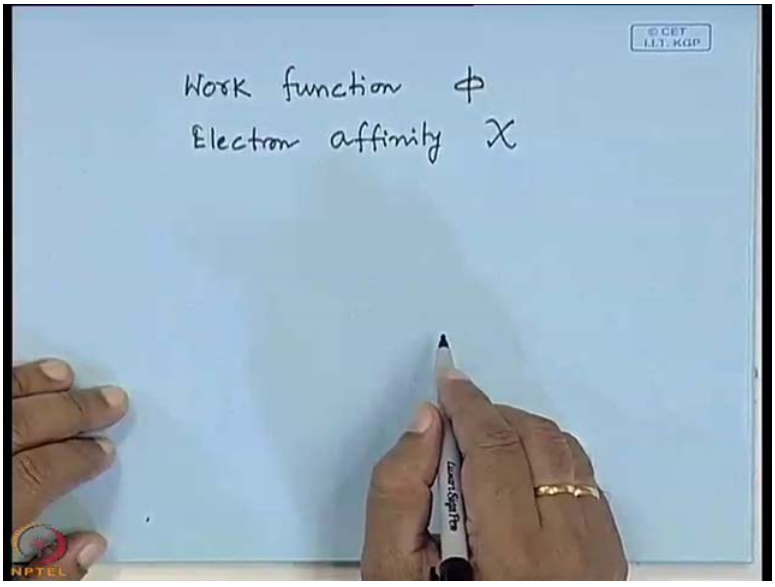

So, we see that one is the work function, which is denoted by phi and that phi can be phi s or phi m depending on whether it is of semiconductor of a metal. Another is the electron affinity, which is known as chi right both are in electron volt if you multiply by q or both are in volt if you do not multiply it by q.

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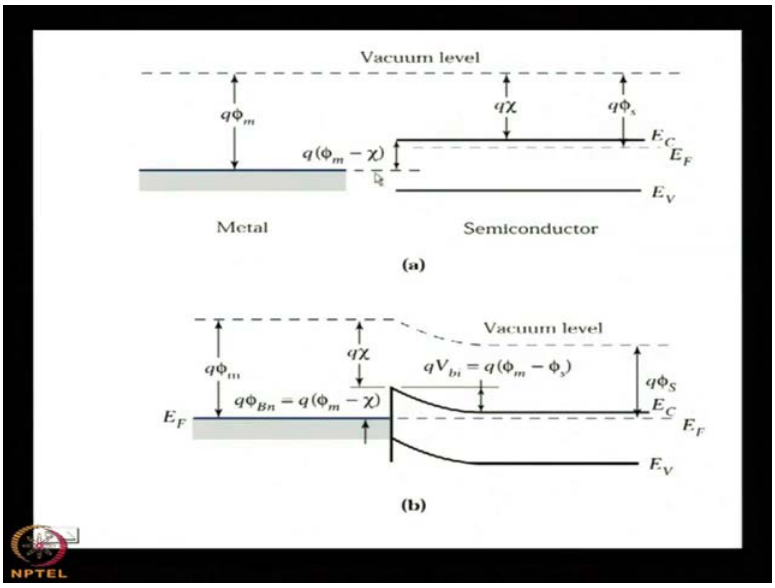

Now, let us take one case where the Fermi level of the metal is greater than the where the work function of the metal is greater than the work function of the semiconductor semiconductor being n type this is case one. There may be several cases what are the cases; it may be phi m less than phi s for n type semiconductor, it can be phi m greater that phi s for p type semiconductor, it can be phi m less than phi s for p type semiconductor that mean four cases are possible.

Either the metal work function can be determine the semiconductor work function or the semiconductor work function can be greater than the metal work function and since two types of semiconductors are involved p type and n type, so it can there are all together there will be 4 cases. So, let us take the first case phi m greater than phi s that means the metal work function is greater than the semiconductor work function for n type material. So, then what will happen this is an isolated metal in contact with an isolated semiconductor just before the joining now when there will be joining then what will happen?

When you join it, electrons will flow from the semiconductor to the metal why because you see that there will be alignment of the Fermi level as well as the vacuum level upper contact. And since, the metal work function is greater than the semiconductor work function so, if you compare with the metal surface there are many more electrons on the conduction band compared to the metal surface. Because it is at a higher energy so, since

the electrons higher energy so, they will come down to the metal side. Why because they will search for the empty levels the electrons will search for the empty levels and there are empty levels above the metal surface. On the metal side there will be empty levels because you see that the there is a difference because of the difference the electrons will come from the semiconductor side through the metal side.

If phi m less than phi s suppose a case where phi m less that phi s then what will happen the reverse thing will happen electrons from the metal will go to the semiconductor because phi m less than phi s means the electrons on the metal side are at higher energy compared to the semiconductor side. So, always the electrons will move from the higher energy side to the lower energy side. And here it is you see that it is higher energy side it is lower energy side so, electrons will move from here to there.

Now during the movement what will happen and how long the movement will continue. It will be like the p n junction case in p n junction case what we have seen, that electrons diffused from n region to p region and holes diffused from p region to n region here you see that there will be no whole diffusion only the electron will move from the semiconductor side to the metal side.

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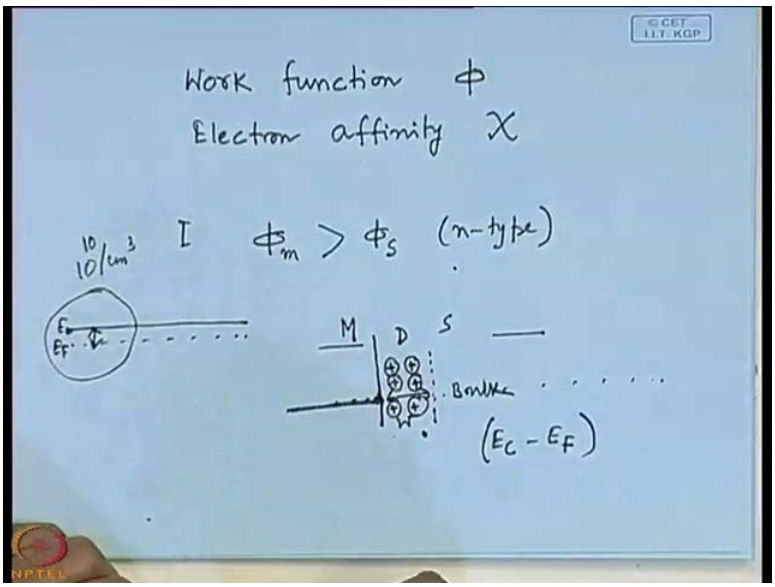

So, that is an interesting difference there will be no charge transportation from the metal side to the semiconductor side only there will be charge transportation from the semiconductor to the metal side, because it is at higher potential. Then as the electrons

move from semiconductor side to the metal side so, the charges will be accumulated on the metal side on the metal surface electrons will be accumulated on the metal surface. And there will be depletion in the semiconductor side because it is losing electron so, only uncompensated donors will be left in the semiconductor side.

So, at this junction say this is semiconductor, this is metal on the metal surface; this is the metal surface electrons will be deposited and on the semiconductor side there we can consider a depletion layer of w width where there will be only uncompensated positively charged donors. And, this is the bulk semiconductor in the bulk semiconductor it is as usual it is n type number of electrons is very high.

So, that means now if the vacuum level and the Fermi level align; that means if we do have a single Fermi level throughout the material then, what will happen; there you can consider three regions. One region is the metal, one region is the semiconductor bulk, another region is the junction between the metal and semiconductor on the side of the semiconductor not on the side of the metal, on the side of the semiconductor where there will be depletion layer. So, that means this is depletion, this is bulk, this is metal so, you can broadly differentiate among the three different regions.

Now, what will happen in the depletion layer in the depletion layer, the number of electrons is very, very less. So, that means E C minus E F will be large; why, because you see that this is E C this is E F when there is a uniform carrier concentration of say 10 to the power 17 per centimeter cube. But if in this region if it is 10 to the power ten per centimeter cube then what you expect that this Fermi level will be far away from the conduction bandage.

Now, if you consider this depletion region this depletion region is nothing, but this encircled region, where the charge carriers are few compared to the metal side compared to the bulk semiconductor side. So that means this is E C minus E V it is E C, sorry it is E C minus E F; this E C minus E F will be large. So that means if E C minus E F is large so, the band will bend.

And you see that the band bends in this manner and you see that the bending is up to W that means the depletion width, just you cross W the depletion width it is again constant. That means E C minus E F is constant only the difference in E C minus E F is in this region in this region. It is because of the depletion layer where the charge carriers are

few compared to the bulk region or the metal region. So, that is very important thing and we have seen this thing for p n junction also, in p n junction also we have seen this thing. But in p n junction on both sides there was this depletion region here only on the semiconductor side there is a depletion region.

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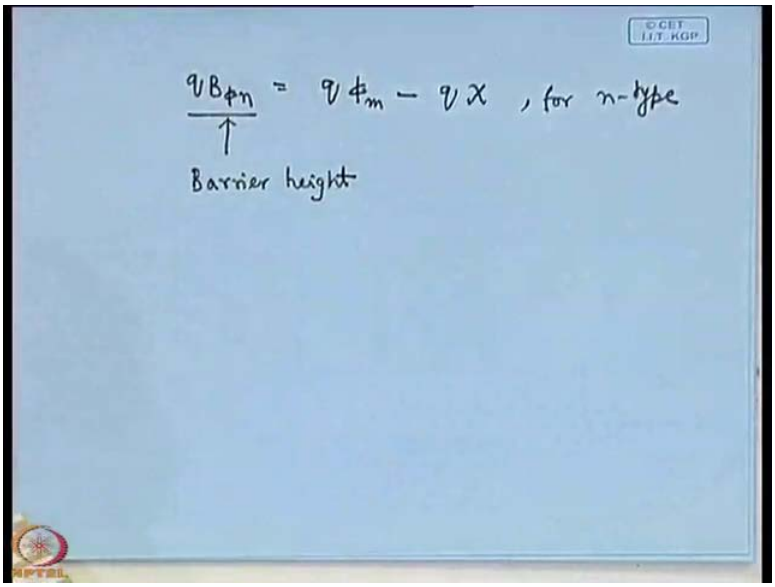

Now, if you now if you consider the band diagram then we can see that q B phi n it is equals to q phi m minus q chi for n type. This phi B n is known as the barrier height, this is you see that this is the barrier height, which one this is the barrier height, barrier height means, the energy height is not here. The distance here it is the energy, which is required to excite an electron from the metal to the semiconductor side, from the metal to the semiconductor side. Suppose, you want to emit an electron from the metal to the semiconductor side then how much is the energy required, it is phi n phi B n that means the barrier height that is known as the barrier height. And if one electron moves from the semiconductor to the metal side how much energy is required it is.

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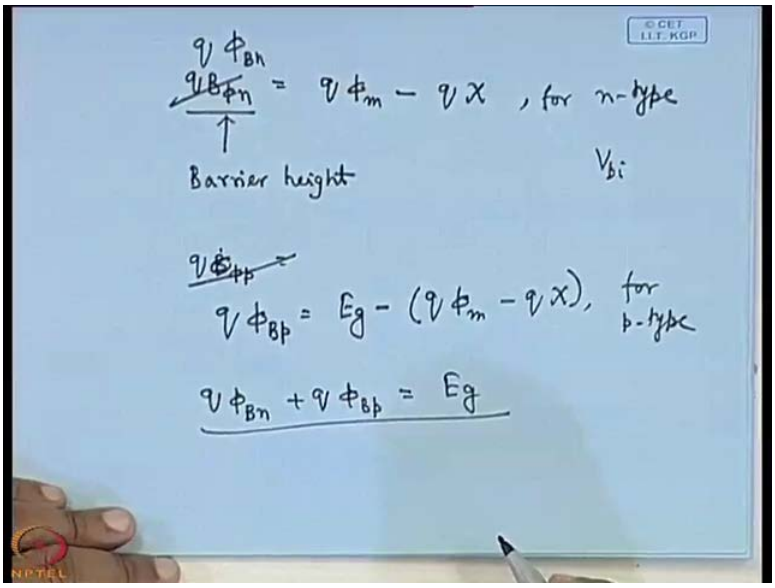

bi that is the built in potential that we have discussed in case of p n junction also. It is the built in potential. So, these are the two things which one which are very important if you want emission of electron or movement of electron from semiconductor to the metal side you need bi phi V bi that means the built in potential. If you want electron to move from the metal to the semiconductor you need barrier height phi v. So, one thing is the barrier height another is the V bi or the built in potential. Now, the barrier height from this diagram you see that it is given by phi m minus chi so, if you know the metal work function and the electron affinity of the semiconductor you can calculate the barrier height for that metal semiconductor contact.

So, what are the parameters you must know one is the metal work function it is readily available in the data sheet for any metal the work function is available and chi is the electron affinity of the semiconductors and this value is also available for the normal semiconductor semiconducting materials. Not very new materials, but people have found out the values for chi also so, you can see whether this phi m minus chi is what is the value of phi m minus chi and that is your barrier height for that metal semiconductor contact

So, this is for n type now for p type this q B phi p that means p means p type and B phi means barrier height. B p that is equals to E g minus q phi m minus q chi it is for p type. For p type it will be this value. Then if you add this 2 thing that means barrier height of a

material for a particular metal for its both p and n type substrate then you will get the band gap, if you add these 2 thing you see that this q phi B n plus q phi Bp this is equals to E g the band gap.

So, that means if you know the band gap and the barrier height for the n type silicon then for p type silicon the barrier height can be easily determined just subtract the value of the barrier height from the band gap of silicon. If the barrier height is say 0.44 and its band gap is 1.12. So, it will be 1.12 minus 0.44, so 0.6 something the barrier height for the p type silicon. For that particular metal that means the barrier height changes from metal to metal for a particular semiconductor and also it changes from semiconductor to semiconductor because the electron affinity is different for different materials.

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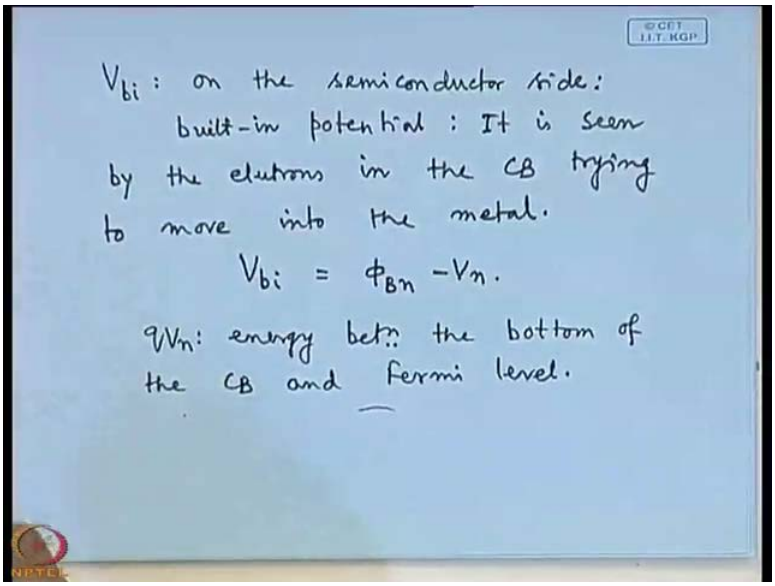

Now, V bi on the semiconductor side this is known as the built in potential. What is this? It is an energy, it is seen by the electrons in the conduction band trying to move into the metal. And this V bi is equals to phi Bn minus V n what is V n? qVn is the energy between the bottom of the conduction band and Fermi level. So, this is you see that this Vbi on the semiconductor side, it is not on the metal side and it is known as the built in potential. It is seen by the electrons in the conduction band trying to move into the metal and its value is given by the barrier height minus Vn, where Vn is the energy between the bottom of the conduction band and the Fermi level so, this is very important consideration that means if you know the metal work function and electron affinity you

can calculate the barrier height and if you know the barrier height and the position of the Fermi level you can calculate the built in potential. So, this is very important relations.

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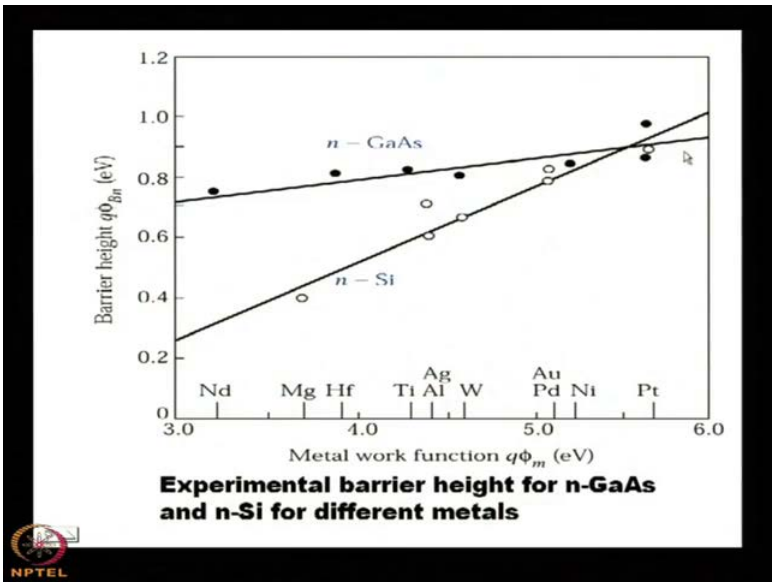

Now, you see that in this view graph we have seen the barrier height as a function of metal work function. For 2 semiconductors 1 is n type silicon another is n type gallium arsenide, if I change it to p type the curve will be different remember it is for n type semiconductor. What we see that, there are several metals which we have used say Platinum, Palladium, Gold, Nickel, Tungsten, Aluminum, Silver, Titanium, Hafnium then Magnesium, Neodymium so different kinds of metals we have used. And it is deposited on n silicon and gallium arsenide then the barrier height was measured and we find the barrier height variation as a function of metal work function.

You see that, for n gallium arsenide it is not very widely varied why it is just above 0.5 to it is 0.8 not very high. The variation is not very it is not stiff the dependence is not very severe it is just 0.5 something to 0.7 something not that it is varied from 0.1 to 0.10 or 0.1 to 1 not that, but for n silicon it is better than n gallium arsenide. So, what you find? You find that, suppose you use Aluminum or Silver the barrier height is almost same either you use aluminum or silver the barrier height is almost same. Similarly, if you use gold or palladium the barrier height is also almost same and if you compare the values between this and this you will find that the value is not very widely differ.

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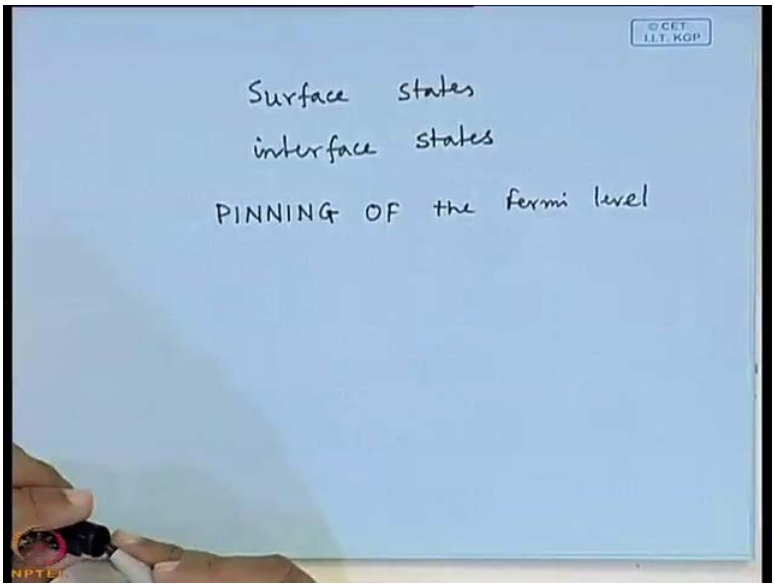

There is no wide variation of the values from this point to that point so, far as the Gallium Arsenide is concerned. Why this thing happened for Gallium Arsenide? Why this is not found in case of n type silicon? Because for n type silicon you see that it is say 0.25 to almost 0.9 or 0.95, but for Gallium Arsenide the variation is not very sharp or stiff. Why this thing happens; it happens because of the surface states one new term I am introducing it is the surface states or the interface states or the interface states. It is either surface states or the interface states the same thing as the name implies states in our subject is the energy levels states means the energy levels.

So, surface or interface states means thus the energy levels which are due to the surface dangling bonds which are due to the surface dangling bonds and those states are found in the band gap of the Gallium Arsenide. It is because of the surface states the surface states are found due to the dangling bonds, that means unsaturated bonds at the surface and it is found in the band gap of Gallium Arsenide. Any states are found in the band gap obviously inside the band gap what those surface states do; they these surface states pin the Fermi level what is pinning of Fermi level? That means, you see that when metal is deposited on the gallium arsenide there will be a change of Fermi level.

But the surface states in gallium arsenide pin the Fermi level, pin means suppose you have used a pin to put it on the board that means you are fixing it on a place pinning means you are fixing it to a position. So, surface states compel the Fermi level to be there

that means Fermi level cannot align itself whatever metal you use because of the pinning of the Fermi level Fermi level. It is pinning of the Fermi level that whatever metal you use for Gallium Arsenide the barrier height is not improved as per your choice that is not possible the barrier height is almost constant. It is because it is not because of the metal it is because of the surface states in the gallium arsenide.

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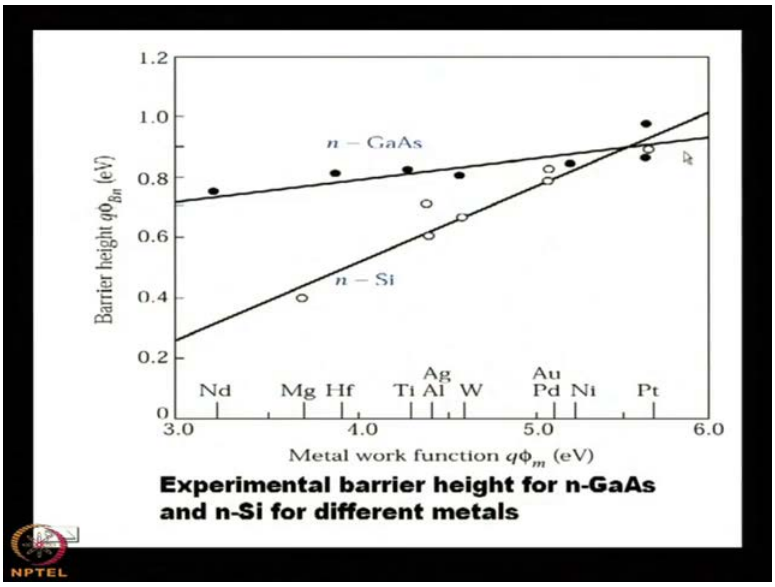

That is a peculiar situation for Gallium Arsenide in many in many semiconductors it is found not that it is only for Gallium Arsenide but, since gallium arsenide and silicon is very well documented material. So, people have seen that for gallium arsenide it happens so, as the for silicon it does not happen and this pinning of the Fermi level is there for Gallium Arsenide that is why the variation is not very severe in case of Gallium Arsenide whatever metal you use? So, that means if you if the variation is not wide then why you will use metals like gold or Platinum because those are very costly.

So, just use aluminum or that type of thing Gold, Germanium or Zinc etcetera that you can use. And another problem is that depositing Gold and Platinum is very difficult also because of the higher melting point of those materials normal thermal evaporation is not possible. So, these are the considerations that means suppose you have fabricated one material you have synthesized one material, that is the new material the material is say x, it is your material you have made it then contact is required. So, you put many metals on it Silver, Gold, Platinum, Aluminum etcetera and you measure the barrier height.

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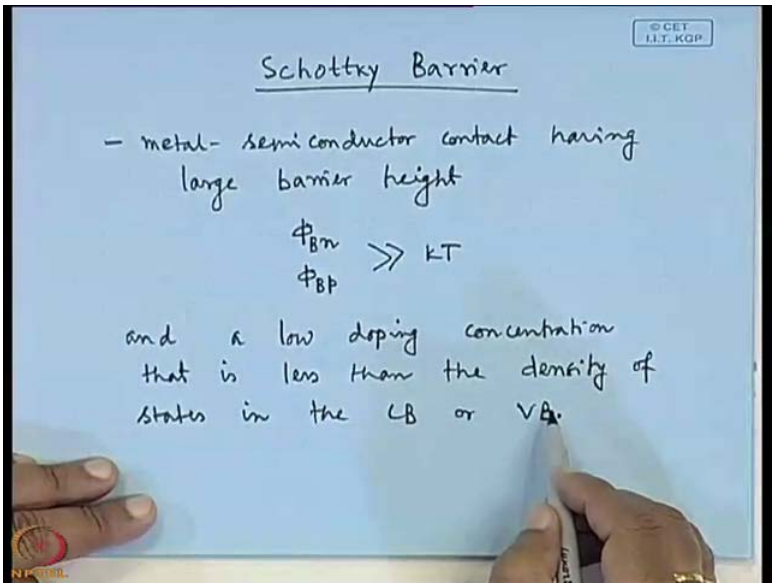

If you find that, the change in barrier height with the metal work function is not very severe then you can consider that for your material x the Fermi level is pinned. Once Fermi level is pinned whatever metal you use the barrier height cannot be changed. Now we have started with our Schottky contact this is Schottky barrier that barrier height is known as the Schottky barrier this barrier height this is the Schottky barrier. Now, it is basically a metal semiconductor contact height having large barrier height large barrier height means what is the meaning of this term? Large barrier height that means phi B n or phi B p very very greater than k T.

When we say that, this is large in comparison with the value of k T at that temperature that means if you work at say room temperature then the value of k T is you know 26 mille electron volt So, but, the barrier height must be very, very greater that 26 mille electron volt. If it is there then you can consider that the barrier is known as the Schottky barrier and a low doping concentration that is less than the density of states in the conduction band or valence band. It is low doping concentration low means less than the density of states in the conduction band or the valence band what is density of states?

Number of empty states per unit volume in the conduction band or in the valence band where the electrons or holes can be accommodated, so if your number of states is high and the doping concentration is low then the Schottky barrier will be there and at the same time the barrier height must be very, very greater than the k t. So, these 2

conditions are there for Schottky barrier now the Schottky barrier it can be determined how the Schottky barrier can be determined? It can be determined either by i v measurements or by c v measurements both the measurements will yield the barrier height. Barrier height means phi b you can calculate from i v you can calculate from c v and sometimes we measure phi b using both the techniques and then we compare and many times we find that the value is different phi b obtained from i v measurements phi b obtained from c v measurements and phi b from the theoretical value what is the theoretical value phi m minus chi theoretical value is phi m minus chi.

All the 3 values are different there are reason, one important reason is that you see that the metal is deposited on the surface of the semiconductor and the surface of the semiconductor is very prone to oxidation. So, before depositing the metal you have to clean the surface very efficiently and the surface must be cleaned in such a manner that between the metal and the semiconductor no defect, no oxides, nothing even minute amount of say dust particles is also not there; if it is there then it will modify the barrier height. So, that is important consideration that sometimes you find that I shall show you an example that where the barrier height measured from theoretical consideration that means phi m minus chi and the barrier height determined from i v or c v is different.

It is because of the modification of the surface before the metal deposition. Now, what are the important differences between p n junction and metal semiconductor junction? What are the major differences? At least one major difference is there it is as follows say in p n junction the current is conducted by both the holes and electrons. Because there will be holes and electrons diffusion and you know that when electron diffused from n region to p region it becomes minority carrier. Similarly, when holes move from p region to n region it is the minority carriers so, you can say that in a p n junction the current is governed by the minority carrier, but in metal semiconductor Schottky junction the current is controlled by the majority carrier, current is controlled by the majority carrier.

No minority carrier is involved. So, that is why it is the uni polar conduction mechanism it is unipolar in nature. So, what is the advantage of uni polarity conduction? Yes the switching time is very less that means it will be very fast. So, that is why i shall show you that a metal semiconductor Schottky junction is used for fast photo conductor photo detector is used for fast photo detector response photo detector. You know that light when falls on the material electron and hole pairs are created and proportional current is

available on the circuit. So, that is known as the photo detector that means current proportional to the amount of light which is incident on the surface of the semiconductor.

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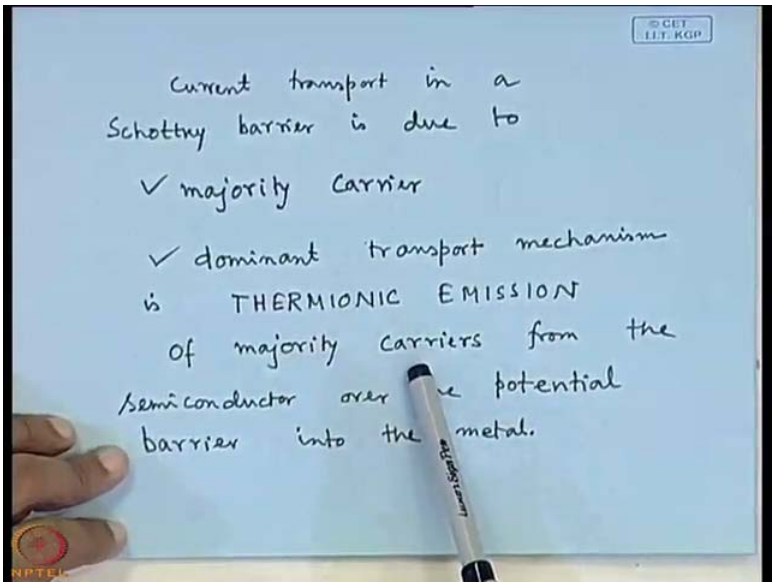

Yes, photodiode so, fast photodiode is obtained from this short key barrier devices. So, one thing is that current transport in a short key barrier is due to majority carrier and dominant transport mechanism is thermionic emission of majority carriers from the semiconductor over the potential barrier into the met also one is the majority carrier current transport is due to majority carrier and what is the mechanism? In p n junction what is the mechanism? drift and diffusion of current transport drift and diffusion in short key barrier. It is the thermionic emission it is we shall prove it that it is a thermionic emission of majority carriers from the semiconductor into the metal over the potential barrier means the vbi now what is thermionic emission?

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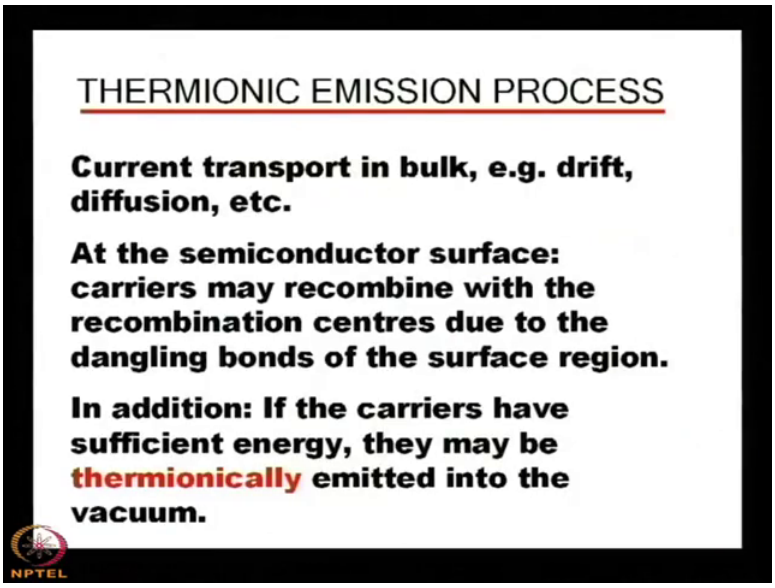

Yes, now if I show you one view graph then it will be clear yes you see that the thermionic emission process current transport can be by means particularly for the bulk material it is drift and diffusion etcetera. And at the semiconductor surface carriers may recombine with the recombination centers due to the dangling bonds of the surface region that also we know in addition to this recombination if the carriers have sufficient energy they may be thermionically emitted into the vacuum if the carriers have sufficient energy where we are considering the surface not the bulk.

So, thermionic emission mechanism is applicable for the surface only when metal and semiconductors are joint it is the phenomena which are same in the surface of the metal and the surface of the semiconductor bulk is not involved that is why diffusion and drift is not there in surface in surface you see that what can be there in surface there can be recombination with recombination centre what is the recombination centre? It is the dangling bonds and additionally apart from recombination there can be emission from the surface if the carriers have sufficient energy so, that is known as the thermionic emission process.

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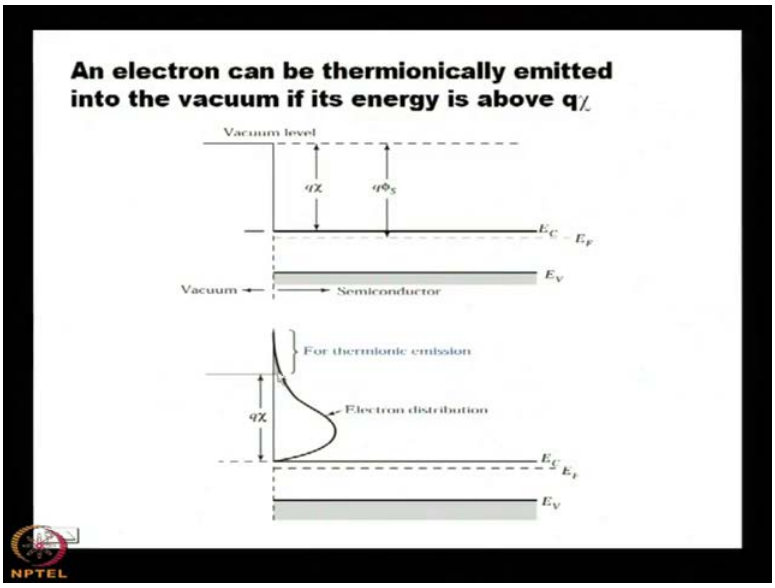

And, you see that suppose this semiconductor it is an n type semiconductor I have seen that chi is the electron affinity and phi is semiconductor work function. So, where the vacuum is above this line this is the vacuum because you know what is chi? Chi is the Energy required from the Conduction band.

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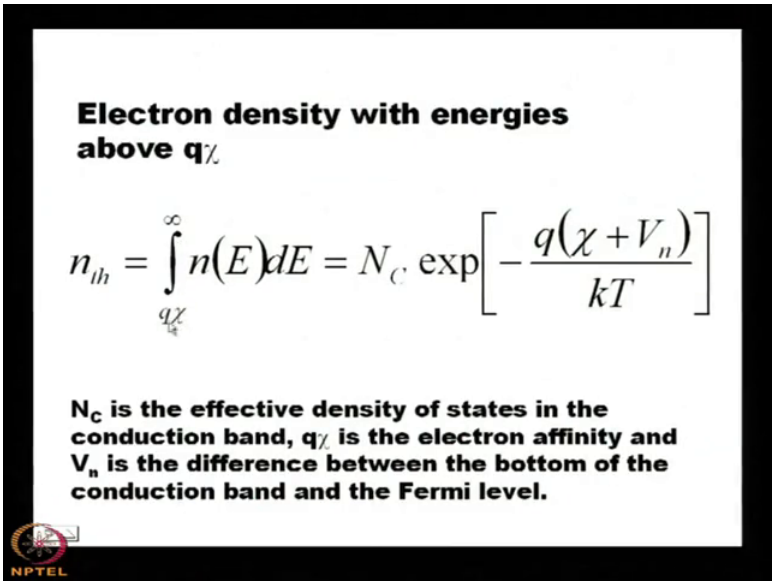

Conduction bandage to the vacuum emit an electron from the E C to the vacuum so, that means if the electron distribution is like this, because we have not calculated the electron distribution in n type semiconductor that is not required in processing class that will be

discussed thoroughly in your physics class. So, you will find that the distribution will be like this it is Gaussian having a tail in the higher energy side. So, now this is the tail you find that there are some electrons which are above chi some electron means those are due to the thermionic emission. So, thermionic emission is possible in n type semiconductor also because of the distribution of electron you see that most of the electrons will be in the outside inside the vacuum level. But there will be some electrons a few not very high you see that this is the tail region and it is the this region is marked with some blue color you see that this blue color region means it is the thermionically emitted electrons.

So, that means when we talk about the thermionic emission it means that some of the electrons are detached from the semiconductor surface to the vacuum. That means chi energy is required, that is the electron affinity if you put chi energy then it is possible and electron density that is we have seen that this is the electron distribution electron density. This electron density can be calculated by this intrigation where the lower limit is chi and the upper limit is infinity why because the lower limit is chi and upper limit is infinity only those electrons will be available.

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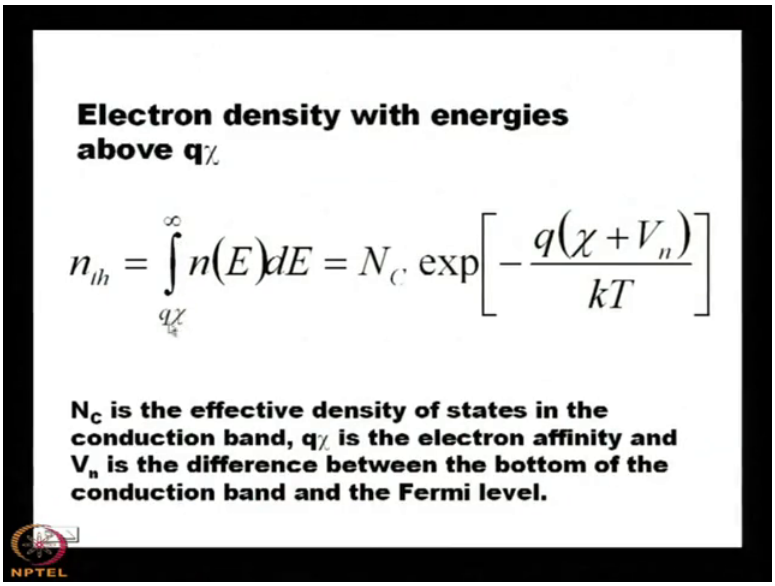

For conduction band what we have put here ec to infinity you can see we have calculated in the at the beginning of the course E C means from the bottom of the conduction band to the infinity. But here not from the bottom of the conduction band because chi energy is the minimum energy required, so chi to infinite infinity and this is the expression for

the thermionically emitted electron density where nc is the effective density of states chi is the electron affinity vn is the difference between the bottom of the conduction band. And the Fermi level kt is the thermal energy k is the Boltzmann constant t is the temperature in Kelvin this is the density of effective density of states in the conduction band because we are considering the electron. So, this say this is the electron density with energies above chi whatever be the small value it will be there now with this expression probably you have write down this expression.

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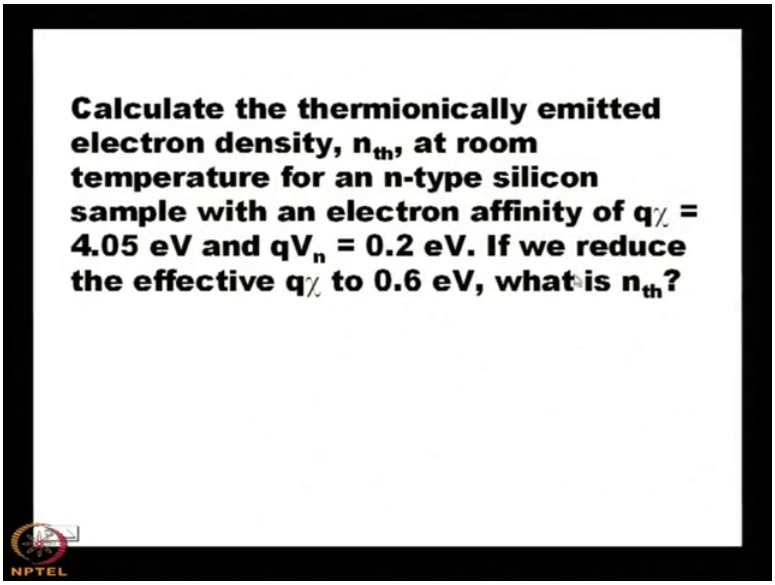

You see that if I try to calculate this thing calculate the thermionically emitted electron density n t h, at room temperature for an n type silicon sample with an electron affinity of chi equals to 4.05 electron volt and v n is 0.2 electron volt if we reduce the effective chi to 0.6 e v what is n t h? Calculate the thermionically emitted electron density at room temperature that means t is 300 k and chi is given v n is given. So, what you need you need n c?

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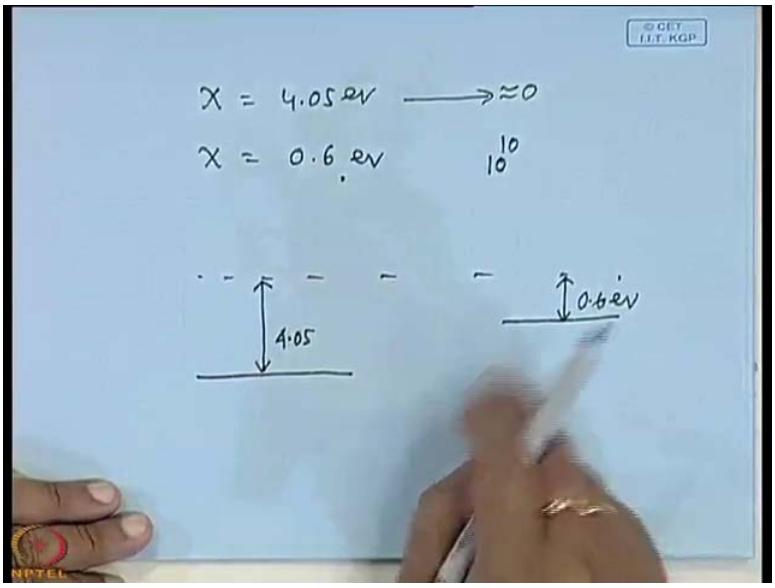

You write down the value of n c it is for n type silicon so, it is 2.86 into 10 to the power 19 2.86 into 10 to the power 19 per centimeter cube. That is n c and you will find that you can try in your room you will find that for chi equals to 4.05 electron volt and chi equals to 0.6 electron volt only 2 cases are given the rest of the things are same n c is same v n is same everything is same t is same k is same what you expect? What should be the electron density for this case where chi is 4.05 it is almost 0 for chi equals to 0.6 electron volt you will find some appreciable amount of electrons moving to the vacuum from the thermionic mechanism.

Why say this value is 10 to the power 10, say an example why it is very simple here the chi is low so, 0.6 e v energy will give you thermionic emission from the semiconductor to the vacuum level here it is very high. 4.05 electron volt energy is very high energy for semiconductor. So, that means it is vacuum level this is 4.05 electron volt and this is 0.6 electron volt which one is favorable for the emission.

This one is favorable because here the energy involvement is very, very less only 0.6 electron volt right here it is very high energy so, at that energy the thermionic emission electron density is almost 0 here it is an appreciable value. So, you try this numerical problem in your room and you must submit it to me today I shall give you one more example numerical problem you have to submit it is a requirement for your assessment exam.

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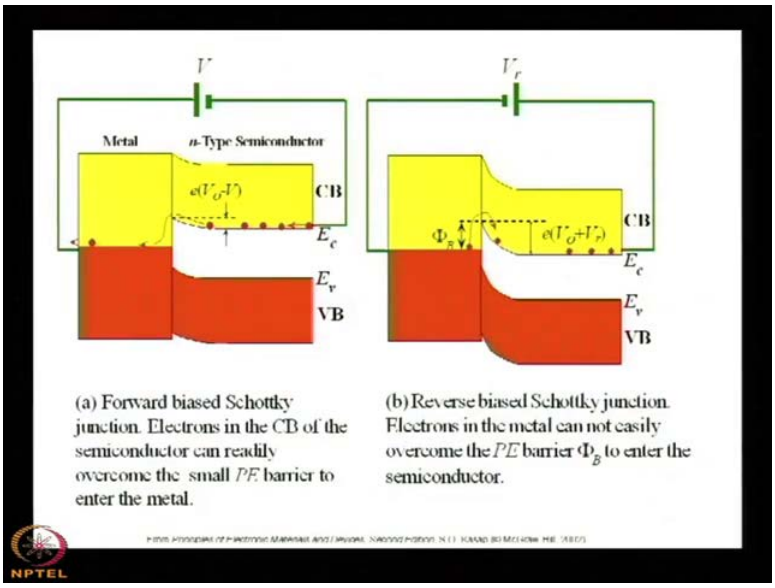

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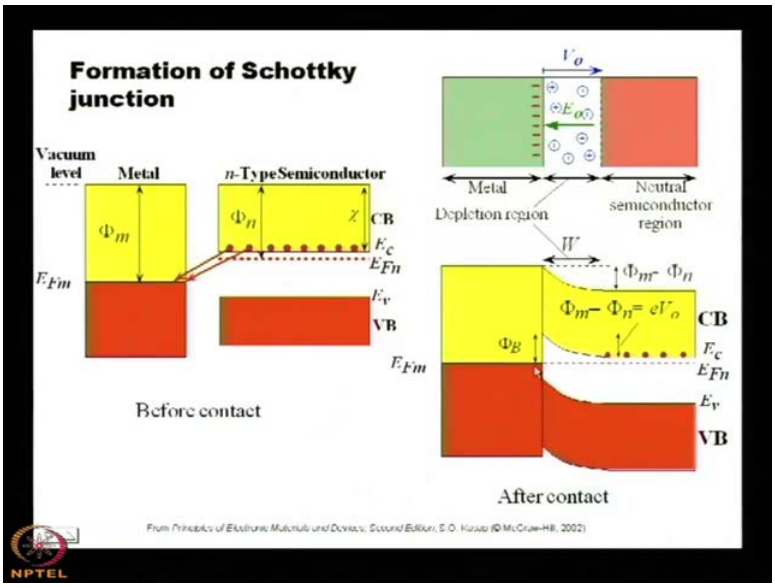

Yes, so what we see that thermionic emission mechanism is the main mechanism for this junction, metal semiconductor junction. Now if thermionic emission mechanism is there; in the next class I shall show you, what are the current components? At thermal equilibrium, what will happen, at thermal equilibrium, the current that the number of electrons, current due to the number of electrons from the semiconductor side to the metal side; here you see that it is the semiconductor side to the metal side. Or yes from semiconductor side to the metal side or from metal side to the semiconductor side by this

phi B, those are equal and opposite so, at thermal equilibrium there will be no current passing through the junction.

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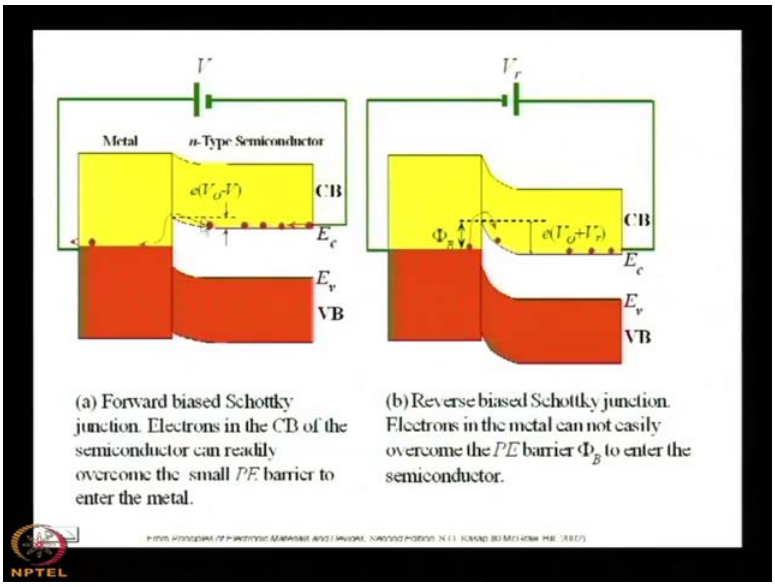

Why one is that e v 0 another is phi b there are 2 barriers and they will resist so, at thermal equilibrium the current from this side to that side or from that side to this side will be same it will be 0. But what will happen if it is made forward bias if it is made forward bias then you see that this v b i reduces what is the forward biasing v b i reduces. So, that means, now the electrons can surmount the barrier and the flow of current will be from the n type semiconductor to the metals. And you see that it is the forward biasing in this junction forward biasing means metal is at a higher potential compared to the semiconductor why because the semiconductor is n type because the semiconductor is n type.

So, you see that there will be positive potential connected to the metal to make it forward bias because semiconductor is n type always the negative terminal of the battery must be connected with the n type semiconductor. So, that means it is reduced earlier it was v b 0 or v b i now it is e v 0 minus b, because we discussed earlier that the voltage will be dropped in the depletion region only because the resistance is high in the depletion region. So, the depletion region will be narrowed down or v b 0 will be less and so, the electrons will move from semiconductor to the metal side and you will get the current so, in the next class we shall consider those things.

Thank you.