Processing of Semiconducting Materials
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Lecture - 24
p – n Junction

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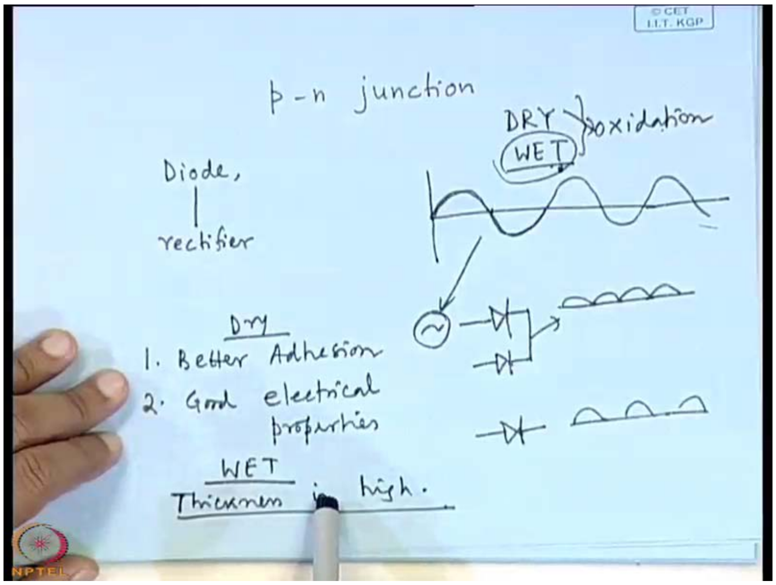

We shall discuss a very important topic today; it is the p-n junction. You know that on the basis of the p-n junction principal, a large number of devices are made in electronic industry and if I give you a few name to you say normal diode. This diode is basically known as the rectifier diode is known as the rectifier. What is rectification?

Student: (( ))

No, no, no. It is the conversion from the a c to d c, not from d c to a c. It is rectifier; that means, you will allow it will allow current to flow in one direction. Normally what happens say, in a c such kind of a wave form is seen; that means on both the positive and negative direction, current flow say or voltage. Then if you use a p-n junction diode and give input, like this. You will get the output as this type of a pulse. To that means, it is not facilitating the flow of current or voltage in both the directions. Only you will find there it is in one direction, but you have to use here two diodes; then only the output will be this type of the thing. Otherwise if you use single diode, the output will be like this. Because only the positive half cycle will conduct; not the negative half cycle.

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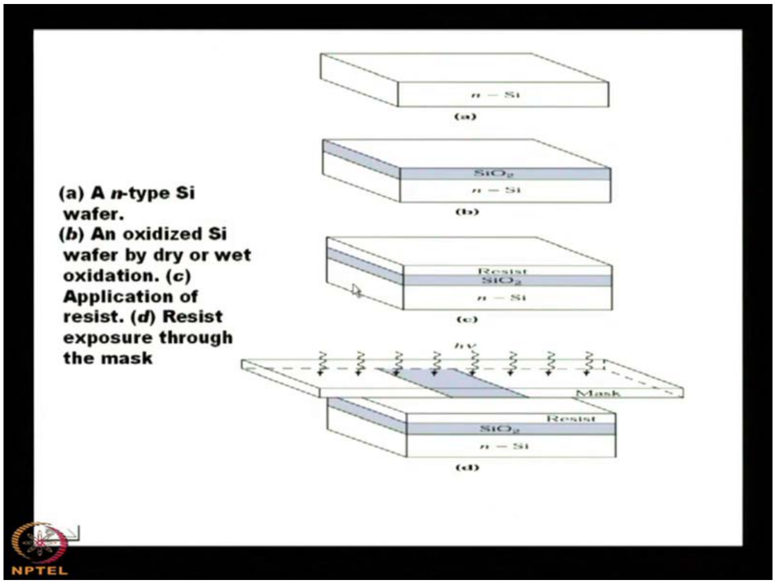

So now if you consider that a p-n junction diode, then the thing is that how this diode is formed, because now we are in a position to fabricate a p-n junction diode from our knowledge which we have gained in last lectures. Let us take a silicon which is n type; this is an n type silicon. Then, we have to make a oxide layer on the silicon. How this oxide layer is done? This is done by oxidation; this is done by normal oxidation process. And in normal oxidation process, generally the material to be oxidize. Say in this case the silicon will be oxidized, so put the sample of silicon in an oven. The temperature required is one thousand to twelve hundred degree centigrade for silicon. Then you have to pass either dry oxygen or paper plus oxygen. Because, oxygen can be of two types oxidation; one is the dry oxidation another is the wet oxidation, oxidation. Dry oxidation means, when you use the dry oxygen gas. And when you use a water vapor or say, with water vapor some dry oxygen, then the oxidation will be an wet oxidation.

Now what is the difference between these two. The difference between these two is that, dry oxidation is very thin and its adhesion with the silicon is better than the wet oxidation. That means, the oxide film which is going to be form using dry oxidation is having better adhesion compare to the wet oxidation film. So, one advantage is better adhesion dry. Good electrical properties. It is the consequence of the better adhesion because the interface is better than the electrical properties will be better because the interface will be free from any kind of defects. So, its scattering will be less.

So, these are, these are the advantages of dry oxidation. And so far as the wet oxidation is concerned, the advantage of wet oxidation is that, thickness is high. That means, if you want to make a thick oxidation layer, then you have to use the wet oxide. Thick; that means, if the thickness is larger, then you have to use the wet oxidation. So, that is the difference between the dry and wet oxidation, for dry oxidation better adhesion is there along with the good electrical property. But for wet oxidation, the thickness can be made larger that means thicker oxide layers can be done. Say, you want to make some 2 micron, 5 micron, 10 micron oxidized oxide layer then you must use wet oxidation. For dry oxidation say, 0.1 micron, 0.2 micron, some nanometers of thickness; then you can use the dry oxidation. So, first step is to make the SiO2 layer on n silicon. Say we have started with an n type silicon. Then, oxidation is done using a furnace.

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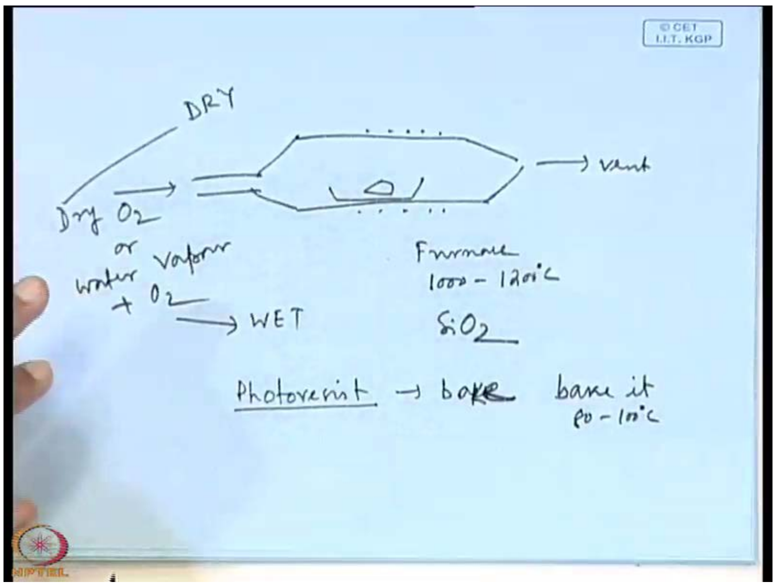

This is the furnace. This is the quad’s boat on which the silicon is placed. Then, this is the vent through which the byproducts will leave from the furnace. This is the temperature heating element which can be control and you send either dry oxygen or water vapor plus oxygen. For dry oxygen, it will be dry oxidation; it is it will be wet oxidation.

So that is the system; that means, just using a simple furnace. The temperature of the furnace will be 1000 to 1200 degree centigrade, for silicon oxidation that means the fabrication of SiO2. Then the next step is to use a photo resist. You see that here, we have written that photo resist must be coated on the SiO2 surface. So first you take the substrate, you make the oxidation n on the surface and above the oxide surface you coat the oxide surface using some photo resist. Right; so if you use a photo resist, then what will happen? It will coat throughout the surface area. Then, you bake it; you bake it at 80 to 100 degree centigrade. Why this baking is required. After coating with the photo resist, this baking is required because yes, for drying; exactly for drying.

Then the next step is you use a mask; you use a mask. Say, this is a mask. What is the mask? There are different types of masks used in semiconductor industry. But generally, it is a glass plate on which a layer of chromium is deposited. Glass plate coated with chromium. Then on that chromium plated glass, there will be the diagram of the circuit which will be transferred from the computer to the glass plate. So that means using a, you first make the circuit diagram on a computer. Say, using CAD tools; Computer Aided Design tools.

Now, these days there are many simulation software's or that type of software's which you can use. First draw the diagram on the computer screen, then transfer the diagram from the computer screen on the glass plate coated with chromium; that means, we have to engrave that is known as the photo graving not engraving. Here, it is done using light. So, photo graving is done. So that is the mask; the mask can be positive the mask can be negative, different kinds of situations can be there. Then you put that mask on the photo resist coated sample. Here you see that this is mask. In this mask, you see that at the mid portion; there is some window type of thing.

Then when ultraviolet light incident on the mask. Then what happens? Depending on the nature of the photo resist, this is the photo resist is an ultraviolet sensitive polymer; ultraviolet sensitive chemical. So when ultraviolet light falls on it, only on the window region it will be in direct contact with the photo resist. On the other parts the ultraviolet light will be blocked. So only in the region of the windows, the photo resist will be polymerized. It will be hardened basically; it will polymerized; it will be hardened. On the rest part of it, it will the photo resist will not be hardening. So, that means this is your photo resist then you put a mask on it. Say that in the mask there is an aperture like this; there is an apeture like this. So that is the mask; that is a mask.

Now, when ultraviolet light falls on it, only when there is the window; the region. The ultraviolet light will come in direct contact with the photo resist. That portion will be hardened; that portion will be polymerized and the rest of the portions the ultraviolet light will blocked by the glass plate. So, it will not be hardened; right. Because our aim is, to open an window on the n silicon; that is the region because when we make a p-n junction; I have to defined the junction area. I have to define the junction geometry whether the junction will be 1 micron by 1 micron whether the junction will be 0.1 micron by 3 micron, that you have to calculate using some equations. That means, when you fabricate a p-n junction, you must know, what should be the carrier concentration; what should be the area of the junction; so how to define that area. You have to define the area by this process. Then the polymerization is complete. Now, it is dipped in a solution. If you did it in a chemical solution so the portion where polymerization did not take place; that means, where the photo resist have not hardened that portion will be washed away east out.

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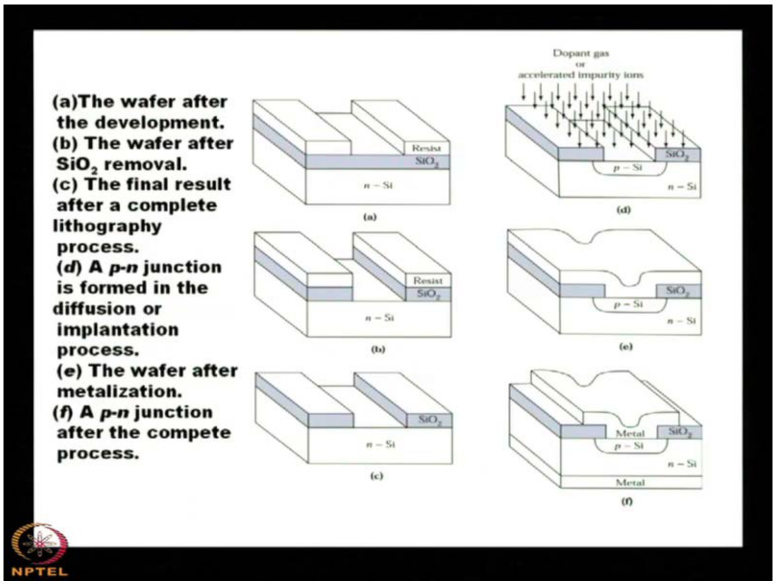

So this is in the next, in this diagram you see that, here this is that region where this is the photo resist coated area and the wafer after the development will look like this. Development means, since ultraviolet light was used; so it is exposed. So, you put the sample in a developer. It is like photography you put it in a developer, so these portion will go out; right.

It depends on whether it is positive or negative photo resist; it depend on it is positive or negative photo resist, it is like photography. It is like photography. Then the this is the pictorial diagram where the wafer after SiO2 removable, you see that in this region there is SiO2 throughout the surface. Here, you see that, only this window is defined, where there is no SiO2. Only SiO2 are there on the left and right parts of the substrate. So that means, I have defined one window having length and breadth of this type, for the deposition of p type doping to form a p-n junction; why? Because, I have started with an n type silicon; I have started with an n type silicon. So for p-n junction n, you have to dope it with p. Without masking the whole region will be p type.

So that means, the complete surface will be a p-n junction. You do not have any control on it but as soon as you used this type of a masking, so that means, only on this portion there will be p type doping and the area of the device will be, if the diameter is say 4 centimeter then the radius is 2 centimeter, so it will be pie R square. That means pie into 2 square area will be the p-n junction; not the whole p-n junction.

Say, it is 10 centimeter by 10 centimeter or say 100 centimeter by 100 centimeter. Only you defined the area where the p-n junction will take place. And that will be your effective area of the device, because in many applications, in many calculations, you will find that there is a term a area. So area of what; area is not the surface area, area is the device of the area. Yes you have to you have any question.

After beginning the solution (( ))

First you coat it, then your job is to wash out the photo resist material which have not hardened or if you use a negative photo resist then which is hardened; right? So, there will be 3 area. First area there will be say no hardening. Then on the middle portion there will be hardening and on the third portion right side there will be no hardening. See, it is hardened; it is not hardened; sorry it is not hardened; it is hardened; it is also not hardened. So there will be 3 regions of this penal geometry. This is known as the panel geometry. Then what you have done? Then this portion you have ached out; that means, the middle portion you have ached out; yes, right? But it depends on the it can be other way round also. So depending on the nature of the photo resist, because photo resist can be negative can be positive and depending on the developer solution, the it is possible that only the hardened region can be washed away or the non hardened region can be washed away

It exclusively depends on the type of the photo resist which we are not going to discuss in this class. So now, this portion is see ached out. So this is after the development, development means we have used some developer which is used in photography. Then you see that this portion is having SiO_2. So, if you want to dope silicon, if you dope want if you want to dope it by p type, then you have to remove silicon oxide; why? Otherwise the dopents will not be able to penetrate through the SiO_2. Because the diffusivity through SiO_2 of Phosphorus, Arsenic, Aluminum, Boron, etcetera it is very, very small. So it will not defuse. Then you remove SiO_2. The wafer after SiO_2 removal; this is the wafer after SiO_2 removal. Then you see that here the photo resist square removed. In this diagram what is difference between b and c. See first, what is the difference between a and b. In b SiO_2 is removed.

Student: Figure a that is no SiO_2 in the right age I mean there it is there it a region.

Where? Yes, if it is full of SiO_2.

Student: (( ))

Upper portion means?

Student: It is age of resistance the junction second junction it is no SiO_2

No. It is full of SiO_2. The whole surface is coated with SiO_2. Then the photo resist is covered is spread on the surface. So the difference between A and B is only one difference is there. Here there is no SiO_2 on the mid region. Otherwise there is no difference. Only from the mid region the SiO_2 is removed. Then the difference between B and C you see, that one C there is no photo resist on SiO_2. There is no photo resist on SiO_2.

Student: Where is the hardened photo resist?

Where is the?

Student: Hardened photo resist.

It is gone.

Student: In the first step or.

It depends on the photo resist nature weather it is negative or positive. Suppose, the hardened was on the mid portion, suppose, so it is gone in the first step or if you think that the hardened region is on the side portions then now it is gone, on c it is gone. So, it depends on the nature of the photo resist.

Student: What is the significant of the hardened region?

No, it is, that is no significant except that it is the chemical property. For that particular type of hardening or softening, you will have to use different kinds of chemical achenes to ache it out. Like in many cases, that we have discussed, say you would like to clean a silicon substrate. So there can be an achante of acidic base or there can be an achante of alkaline base. both acidic and alkaline base achants can be use to remove the oxides layers from the silicon.

Different kinds of solutions and achants are possible. Similarly, different kinds of photo resister also available in the market. So consider that if the mid portion is hardened, so it has gone on the first stage. Now if you consider that the mid portion, the soft portion has now run. So now what will see that on n silicon we have defined one region at the mid portion say 1 centimeter by 2 centimeter. Example in this case and on the left and right of it, it is full of SiO2. Now when it is defused some species defused on it say, Boron is we would like to defuse Boron on it, then what will happen? The boron will not be able to defuse on the SiO2. Only it will defuse at the mid region. So this p silicon you see that p silicon is from here only. The p silicon is from here only. Though there is some extension of the junction below the SiO2 that we have discussed during our discussion on diffusion and ion implantation why such thing happens.

So that means, you have restricted the diffusion or ion implantation of the p type material on the SiO2 regions, so that means, through SiO2 nothing will be penetrated, only there is no SiO2, there will be penetration of the dopent gas and p-n junction will be formed. So this is the formation of p-n junction and on the rest of the figures basically there is metallization. Because without metal contact the current will not be able to pass through the junction, so on the top and on the bottom there will be metallization. And that is basically Aluminum in nature and now this what is the size of this p-n junction. Say the size is 1 centimeter by 1 centimeter or say 10 centimeter by 10 centimeter that means length and width. Then we have to cut it into small pieces to form one device; that means, one device is some micron square. So if it is 10 centimeter by 10 centimeter then 100 centimeter square area so divided by say 0.1 micron square. So you can assumed that how many devices will be formed using a 10 centimeter by 10 centimeter junction. So that is yes your question.

Student: Sir, the penetration of charged.

Not charge the penetration of the dopent gas through Si. No that is not possible even ion implantation is not possible, even ion implantation is not possible.

Student: Any chance?

No, not possible.

Student: (( ))

Then no then you have to yes then you have to thickened the layer SiO2; you have to thickened the layer SiO2. But a moss principal is different; moss principal is not this principal.

Student: In that case the (( ))…

Yes yes no no that is a different story. Moss principal we are not going to teach here no? That is a different kind of principal. That is a parallel plate capacitor.

Student: But on term of the how the content for the capacitor.

That is the electron is penetrating here arsenic actomoiel have to penetrate. No, arsenic atom is a not a charge pieces unless it is ionized; unless it is ionized; unless it is ionized. Generally, generally for n type doping you used arsenic. Say arsenic atom is defused. And these diffusion is basically due to carrier concentration different. Diffusion is basically the carrier concentration different. Yes.

Student: Sir what type of contact is in between the…

What type of?

Student: Contacting between metals and semiconductor.

Yes, metal and semiconductor contact will be a different will be a discussed separately. There can be two types of contact, one is the omic contact another is the sotki contact. So those things will be discussed separately possibly within next three four classes. Yes.

Student: I get that thing in any doping the p then pushing the main doping.

No no it is not pushing. Because you know that the mechanism of doping is that it is, it is taking inside the crystal lattice. So there is no pushing or pulling in case of semiconductor doping. It is their forming a bond and where they go? We have discussed this thing earlier also; vacancy. So if there is vacancy there will be, diffusion. Yes, if there no vacancy there will be no diffusion. But fortunately there will be sufficient vacancy in the crystal and so if see, if your stomach is empty, you can consume. If your stomach is not empty and if you try to consume something, then there will be some pushing type of thing. Otherwise, why there will be pushing or pulling. Yes, yes please tell.

Student: My point is the already in (( ))

Yes,

Student: Then here putting p type.

No, no though where it is going the atoms are going on the vacancy; so if their sufficient number of vacancy. It will go their if there is no vacancy it will not go. Then there will be you have to energize for creating the vacancy and those things we have all calculated also, how much energy is required? Yes.

Student: Sir, first we have directorate photo resistance photo resistance yes finally (( )).

No, because you have you have defined a junction for for defining and a window you have use that type of a thing, that is I reason that you have use the photo resist. Otherwise how you will define these junction without photo resist. Actually the photo resist was given to remove silicon oxide SiO2 from a certain portion which we have done and then we have doped.

Now, super is contact as concern generally the whole surface is given the metallization, it is done by thermal evaporation technique we shall discuss separately and what type of metal we choose; why Aluminum is chosen for silicon; why the if you use gold it will or platinum it will be sotki type of contact; why those things happen that we shall discuss separately.

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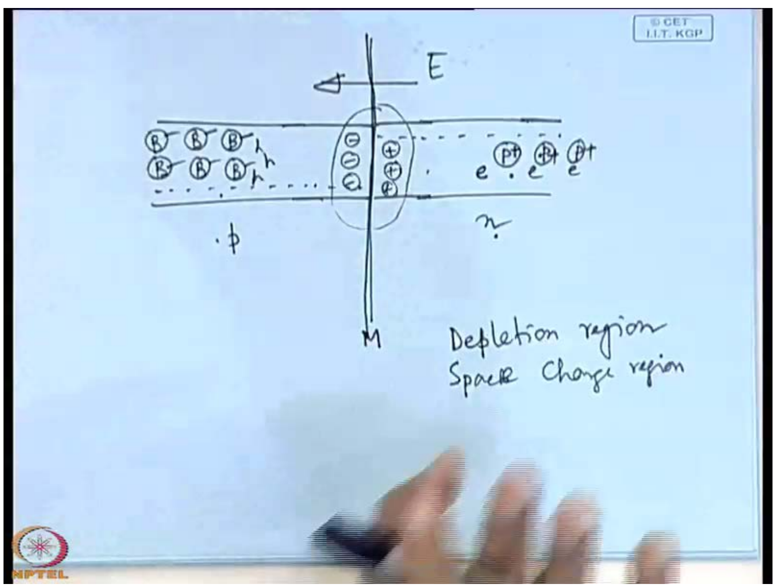

Now, in our p-n junction device, you know that on the principal of p-n junction, many devices have formed. Say this is a p and this is n. For p, where is the formulable? The formulable will be here. For n where will be the formulable? And say this is the metallurgical junction. It is the metallurgical junction. That means, this side p this side n; it is before contact. Now when you make the contact, what will happen? When you make the contact what will happen? (( )). Formulable will…

Student: Constant.

Why?

Student: There is a clock that (( )).

Yes, formulable is constant but why?

Student: There is not constant we just take the formulable (( )).

But why you take?

Student: Because no contact was (( ))…

Exactly, exactly. So now, what will first happen? Here, in p side say Boron atoms are there. You have doped p side with boron atoms. So there will be many Boron atoms and on the n side, say it is Phosphorus atoms.

Student: Sir, we cannot dope Boron and Phosphorus.

You cannot (( )).

Student: Boron is for p type and Phosphorus is for n type (( ))

Student: Boron Aluminum.

I think we cannot dope Phosphorus for n type

Student: Why? why you cannot dope? phosphorus is pentathlon type of atom.

Yeah.

You can; you can. So in this case due to ionization of phosphorus a phosphorus atom will be ionized and one electron will be donated to the crystal lattice and the phosphorus atom will be positively charged ionized pieces; why? Because leaving of electron or absence of electron is considered as the positive. So, it will be positively charged. It will be positively charged. It will be positively charged. Similarly Boron, it will be negatively charged.

Why? Because positively charged particles holes will be donated to the crystal lattice. So in this diagram you see that, the electrons are the majority carrier on the n side and holes are the majority carrier on the p side, so what you have suggested, that there will be diffusion if charges from the higher concentration region to the lower concentration region. So that means, electrons will move from n side to p side and holes will move from p side to n side and very near to this metallurgical junction they will recombine they will recombine.

So that means, on the vicinity of the metallurgical junction, on the region close to the metallurgical junction, there will be depleted of charge carrier. Depleted of charge carrier means?

Student: (( ))

No, no not neutral. Depletion means very few, depleted of hair means some hair are left but almost there is no hair. Depletion. So, this region is known as the depletion region. This region is known as the depletion region. Why because this region is depleted of free carriers. Here, there are free carriers; electrons are the free carriers. Here there are free carriers holes are the free carriers. But, near the vicinity of the metallurgical junction, it is depleted of free carriers. That is why this region is known as the depletion region or space charge region. Space charge region; why? Because when there will be recombination only the ionized donor or acceptor will be there. Because, it is also here on the both side of metallurgical junction, there will be the ionized dopents and acceptor. Not only here, it will be here also.

So, just at the adjacent to the metallurgical junction, there will be two column of charges, on the n side it is the positively charges donor, on the p side it is the negatively charged acceptors. So that means, two column of charges will be there, so since two column of charges are there, so that will give to a raise to an electric field. Because under this circumstance field is there; uncovered charges are there; so electric field will be generated.

So, this electric field, what will be the direction of electric field? Why it will be directed always from positive to negative? It will be directed always from positive to negative. So, the electric field will be generated and that electric field will prevent for the diffusion of charge, carriers from n type to p n region to p region or from p region to n region. So that means when the electric field will be generated, that we shall see that a build in potential will be generated also, because of that field. So, diffusion will be stopped. You take a p type material; you take an n type material; you join it there will be diffusion, how long the diffusion will take place? So long as the electric field will not be there. When sufficient electric field will be generated for the diffusion will be stopped.

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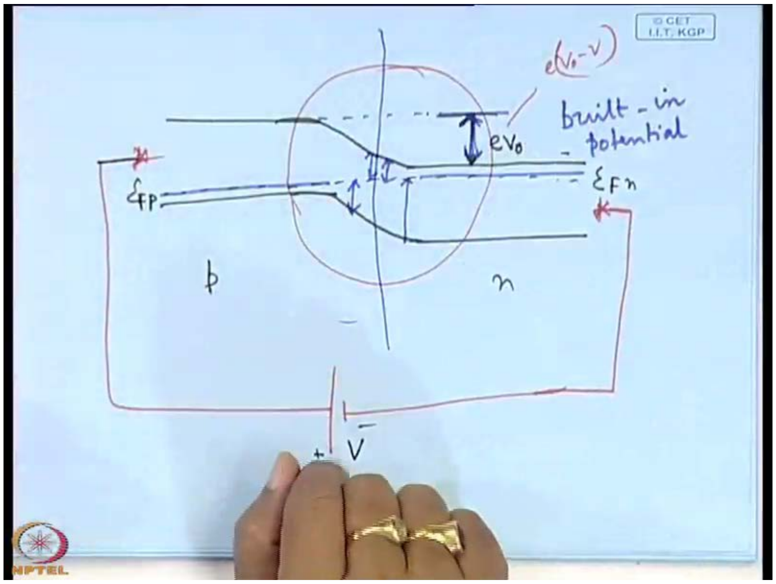

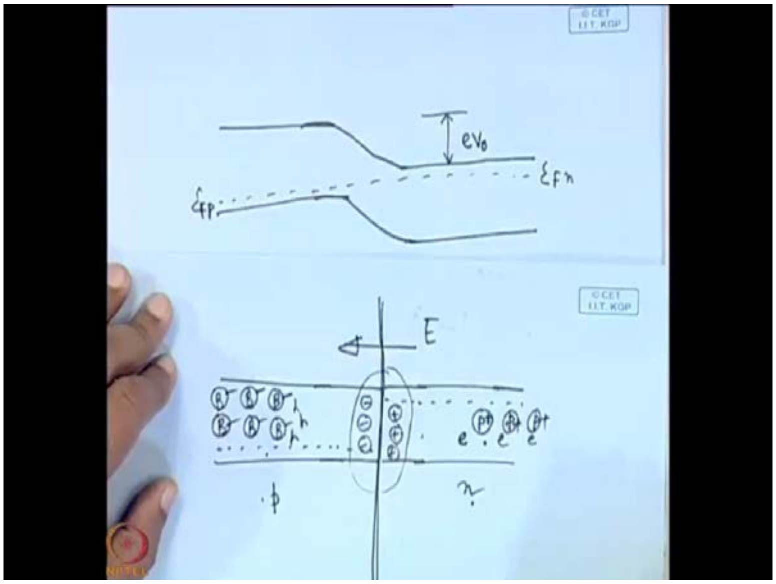

Now the question comes then how the band diagram will look like. The band diagram of a p-n junction, how to draw it? The band diagram of p-n junction will be like this. What is the difference between this one and that one. Here you see that throughout the material, there is only one formulable. There in one formulable throughout the material. It is aligned. Single formulable. Here there are two formulabel. Here, this is E F N which was just below the conduction band of the n type and it is E F P which was just above the balance band of the p region. There are two formulabels were there two different regions. Here, the formulable is aligned and that thing you have suggested also, he has suggested also, because if there is any discontinuity of the formulable; that means, they are change of energy is associated. But without doing any work such change of energy is not possible. So, the formulabel will align itself, when it will be in equilibrium.

When it is in equilibrium? When the electric field is sufficient to stop for the diffusion. Then we can say that the junction is in equilibrium, when the junction is going to be formed or during diffusion, it is not an equilibrium, because there is movement of charges from one region to another region. So, equilibrium is reached, at that time, at that point of time, when there is no further diffusion. During equilibrium the formulabel will align itself throughout the length of the material. And you see that the there is a band bending. Have you seen the band bending? You see that this is the band bending. In this region band bends; band bends; why band bends? Why band bends? Yes, it is because of the concentration of free carriers you see that when there is a depletion region the free carriers are very small.

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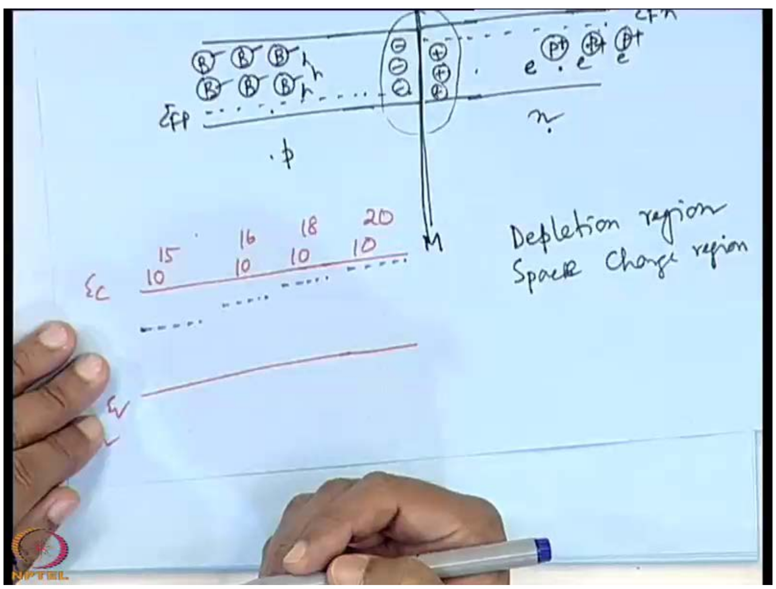

So, let us consider this case that here the charge carrier is 10 to the power 15; here charge carrier is 10 to the power 16; here charge carrier is 10 to the power 18; here charge carrier is 10 to the power 20. Say it is n type material; it is conduction bandage; it is valence bandage. So, what should be the formulable. For 10 to the power 15, say it is here 10 to the power 16, 10 to the power 18, more close; 10 to the power 20 sufficiently close. That means, formulable changes as the carrier concentration changes. Since, near the depletion region or inside the depletion region, the charge carriers are less. So this will be more. That means, the difference of the formulable with the conduction band will be more. So, that is the reason that since to align the formulable, the band will bend itself. Formulable will not bend; formulabel will be in thermal equilibrium; it will be constant throughout the material.

So to denote the change in carrier concentration in the material, what is the option? Band will be bend; right. So that means, you see this is the metallurgical junction on both side of the metallurgical junction you see that, the band bends. So that, the carrier, here it is n type material. So, carrier you see that the formulable is very close to the conduction band. Here it is p type material. It is very close to the balance band but on the depletion region, what is the difference? You see the difference is more.

The difference is more; the difference is more; the difference is more, compare to this region. Why? Because the charge carrier concentration is different, so that is the reason band bends in thermal equilibrium. Whenever we would like to draw a band diagram in semiconductor, in metal semiconductor contact we shall also again draw the band diagram. In fact, mosfet every time in transistor you can draw the band diagram. In hetero junction of junction between two dissimilar semiconductors, you will draw the band diagram. Care must be taken when it will bend, where it will not bend, where will be the formulable. So that means, all those parameters you must know. To draw a band diagram, what are the parameters you must know? 1) the band gap 2) is the carrier concentration

Student: (( ))

That means, the band gap you know if you the band gap you can know the type because it will be not unknown. Suppose, you have grown gallium arsenide on silicon so you know that, you have use the p type silicon on n type gallium arsenide you have grown. So, what should be the band diagram for p silicon and n gallium arsenide? Because the carrier movement inside the material will be govern by the band diagram unless you do not have any knowledge about the band diagram. You cannot think where will be the electron at what moment whether electron will be movement will be there or not.

So, now this you see that this is the difference between the bottom of the conduction band in n side to the bottom of the conduction band in the p side. This is known as the built in potential, built in potential; that means as soon as the thermal equilibrium is reached. Then what you find? As soon as thermal equilibrium reached, the electrons movement will not be possible. Why? Because there is a wall there is a barrier. Now if, electron moves from here to here, what will have to do? You will have to cross a barrier of energy e v 0. Unless the electrons are energized with e v 0 amount of energy, electrons will not be able to escalate the barrier to reach the barrier, sorry to cross the barrier. This is known as the built in potential and why there is a built in potential? It is because of the electric field generated because of the uncovered charge in the depletion region which stopped further diffusion from n side to p side or from p side to n side. So that is very important consideration for p-n junction.

Now, if you forward bios it; make it forward bios. What is forward biosing?

It is positive resistance (( )) higher potential (( )) p type at higher potential (( ))

Yes. So, that means, it is forward bios; why it is forward bios? Because p is connected with the positive terminal of the battery and n side is connected with the negative terminal of the battery. When the positive terminal of the battery is connected to the p side and negative terminal of the battery is connected to the n side then it is known as the forward bios. Under such a circumstances suppose the bios is V. V volt is applied. Then, what will happen? What will happen? What will happen? The (( )) coming inside. No. What will be happen to the band diagram?

Student: The replacement take will be (( ))

Yes

Student: (( ))

Wight, wight will decrease

Student: (( ))

That means e v 0 will now be e v 0 minus v. e v 0 will now be e v 0 minus v. Why? Why such thing will happen?

Student: Push the carrier through the (( ))

No. Actually physical significance is not that thing. The whole voltage V amount of voltage would be dropped at the depletion region only. Why? Because away from the depletion region in the bulk region, basically on this side or that side, it is conducting in nature. It is conducting in nature. So the drop of voltage drop will not be there; where there is a voltage drop.

Student; Resistance

Yes. When there is a resistance. Forget about depletion; depletion the term we are using for p-n junction. But normally where the voltage drop when there is a resistance. So here the depletion regions since it is the depleted of free carriers, so that means resistance must be higher than the bulk regions.

So the whole voltage will be dropped on the depletion region. So it will be e v 0 minus V. So, this thing will be.

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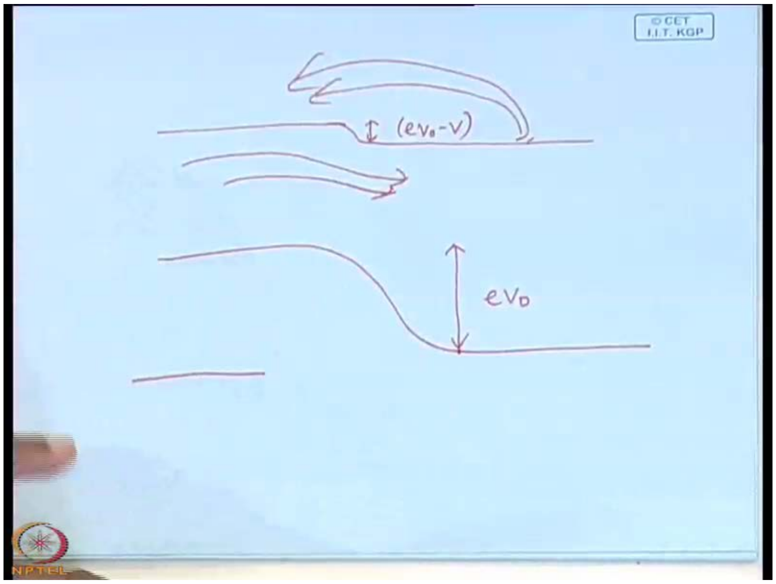

Now the band diagram will be like this. This is e v 0 minus v. Earlier it was like this; earlier it was e v 0; earlier it was e v 0. Now it is e v 0 minus v. That means, now the electrons will be able to surmount the barrier and there will be movement of electrons from this side to that side. And similarly the holes from this side to that side, here remember that this is also again diffusion of electrons; again this is diffusion of electrons. Because on the n side the electrons are larger in numbers and also since we have connected the negative terminal of the battery with the n side. So that means, the electrons which are getting out from n region is been compensated by the negative terminal of the battery; that means, at the cost of the battery at the cost of the energy, from where the energy is coming, from the battery.

So, basically you are losing energy of the battery to compensate the charges which are defusing from n to p. Because, how many charges are there on n region. Say, x amount of charges are there. So, x amount of charges will go on moving moving. So, after x amount of charges leap inside, from where the charges will come? From the battery. So that is the whole physics behind this p-n junction, that when you put a forward bios, voltage of amount v, it will act on the depletion region and it will be e v 0 minus v again the diffusion of electrons will be there or holes from there.

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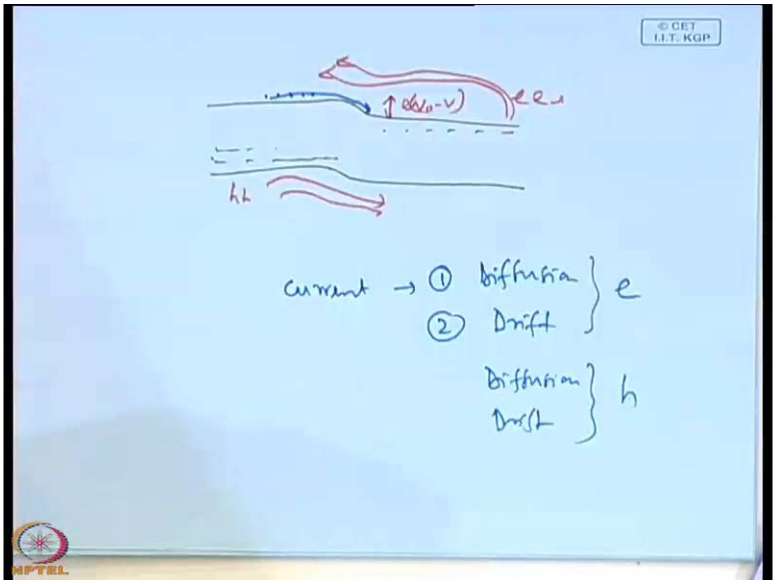

That means, now the band diagram will look like this. Remember that, now there will be no alignment of the formulable; why? You have broken the equilibrium because you have connected a voltage source. So, you have broken the equilibrium. Only during equilibrium that will be alignment of formulable. Now this amount is e v 0 minus v. So, diffusion of electrons will take place and holes will defuse from this side to that side. This is diffusion; so because of the diffusion of carriers you will have a current which is known as the diffusion current.

Similarly, there will be drifting as well. What is the drifting? Drifting is here there will be electron that electron drift from this side to that side. You can ask me sir why there will be electron? Minority carriers will be there and some minority carriers will be thermally generated also on the p region. So electrons will move from there will be diffusion a drifting of electrons from p region to n region will also be there. In thermal equilibrium drift current equal to diffusion current. So, there will be no resultant current available from the device from the junction.

Student: (( ))

No

Student: In forward bios

No.

Student: Diffusion (( ))

Diffusion from that to that side, drifting from the other side. Now…

Student: Sir, current direction is from p to n

See we are, I know everything. Problem is also I know. We are discussing the drift and diffusion. We are not considering the whole device right now. That we shall discuss in my next class. Where I shall show you a mathematical calculation what is the value of drift current; what is the value of diffusion current and what is the total current that we shall discuss. Now, the so the current will have 2 component one component is diffusion and one component is drift. In thermal equilibrium the drift and diffusion current are equal and opposite. So there will be no resultant or total current in the junction. But, as soon as you will put the voltage, source, so then there will be different amount of current and drifting will be larger than the diffusion current.

So, similarly it will be for electrons; similarly for holes also. There will be diffusion and there will be drift. So, electron will have 2 components one is diffusion current and another is drift. Similarly holes will have 2 component diffusion and drift. In our next lecture, we shall derive the expressions for the diffusion and drift current for electrons and holes and we shall see, the total current through a p-n junction with some forward bios or if we connect some reverse bios. In reverse bios the opposite thing will happened; that means, p type and negative (( )) Yes, yes in that case the depletion region will be widened so there will be no current, only there will be reverse saturation current or current due to minority carriers. We shall discuss that thing.

Thank you.