Electronic Packaging And Manufacturing.

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Lecture - 05
Semiconductors and Components-II

Welcome back to the course on Electronic Packaging and Manufacturing and we will continue from where we left off. Last time we were talking about Semiconductors and devices and or Components ok. So, if you recall this we were these are the topics that we are going to cover conductors insulators and semiconductors and eccentric semi extrinsic semiconductors.

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So, these two was covered in the last lecture and today we are going to take off from there and we will talk about what is a P N junction what is a diode and then we will we will end this lecture looking at the steps of how we can make or fabricate a diode. So, with that what we will do is we will go ahead to the place where we stopped last time.

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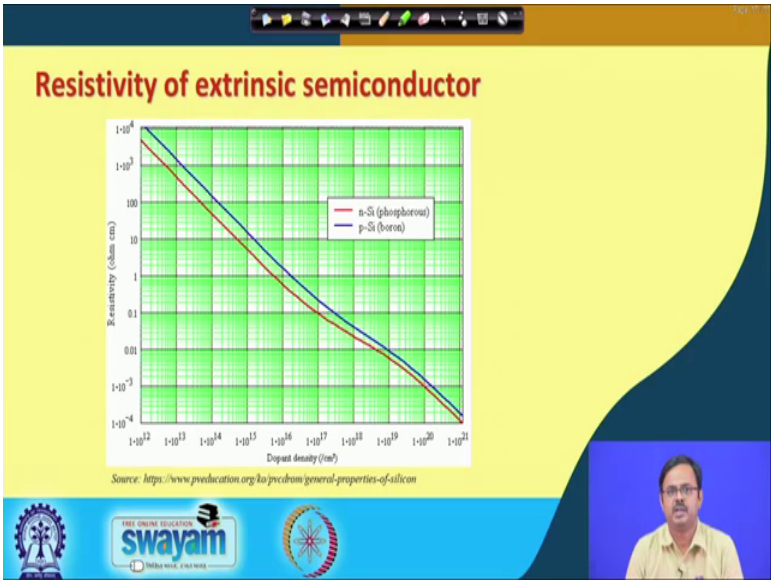

And this is where we where we had discussed about N type semiconductors we have discussed about P type semiconductors and we saw that in a P type semiconductor we have charge carriers in the form of electron holes whereas, in N type semiconductors we have charge carriers in the form of electrons ok. Now, what can we do if we have a P type semiconductor and an N type semiconductor what can we do ok?

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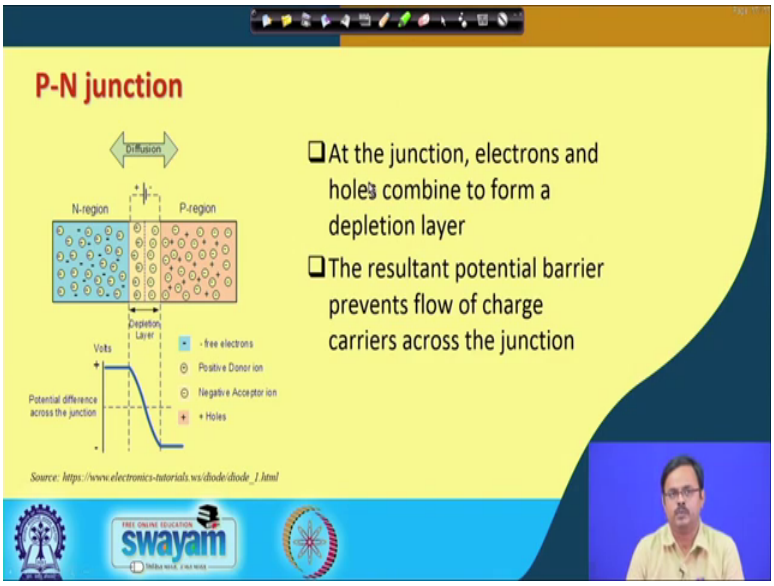

So, that brings us to the concept of what is called a P N junction ok. As the name suggests a P N junction is a P type semiconductor and an N type semiconductor which are joined together which are placed next to each other. Now, recall what happens in N type semiconductors you have free electrons, in P type semiconductors you have holes which can accept electrons. Now, if you place them side by side make a junction of a P type and N type together what will happen? Very close to the to the junction as we see here.

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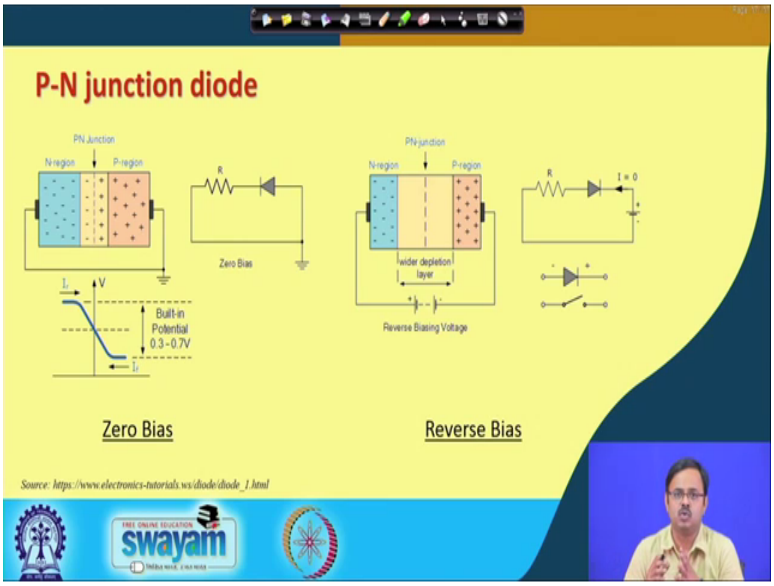

This region the one that I am circling what happens is the free electrons and the holes they recombine to form a region of what is called a you know it is a neutral region it is a region that is devoid of any free charge carriers whether it is electrons for there is a hole because the hole and the electron recombine ok. But; however, as they recombine what happens if you look to the right you have a P region which has lot of positive charge carriers on the left you have the N region with lot of negative charge carriers ok.

In the middle we have what is known as this depletion region. So, the depletion region what happens as a result is I am sorry I jumped a little bit sorry in this depletion region what happens over here is there is a potential difference as a result that is created ok. So, here you have no free charge carriers because the holes and the electrons have combined on the left side you have free electrons on the right side you have free holes or not free holes you have holes which can accept electrons. But, because of this depletion layer in the middle it forms a barrier and the electrons from this side cannot jump to the holes on the other side. Because, if I if it has to do so, it has to go through we go back it has to go through what is known as this potential barrier because, which is a potential difference across the junction caused by the depletion layer ok.

So, this is what a P N junction is, but what can I do with this one, it is a P N junction with a depletion layer in the middle which is preventing which has caused a potential barrier and preventing electrons from flowing from one end to the other. So, can I make it flow or can I do something else? If I do not do anything what happens ok. So, if I do not do anything and just leave it the way it is I am calling that a reverse bias ok. Reverse bias nothing will happen we have connected the two ends, but we have not given it anything ok. So, it is a sorry I am sorry I I take my word back it is called a 0 bias I have not biased with anything we have not applied any potential difference across or external potential difference across the two ends. So, it remains the way it is.

Now, let us say I do this where what I do is I apply an external voltage or external potential difference, but I connect the positive terminal to the N side and the negative terminal to the P side ok. So, what will happen what will happen is the fact that this electrons from the N side is going to be attracted away from the depletion from the junction and same for the holes. And the and therefore, the potential barrier will further increase the depletion region will widen the potential barrier will further increase and there will be no current flow from the P side to the N side. Because, for current to flow the holes have to flow from right to left and electrons from left to right, but here it is just the reverse is happening ok. So, this is known as reverse bias so, in the reverse bias what happens there is no current flow clear.

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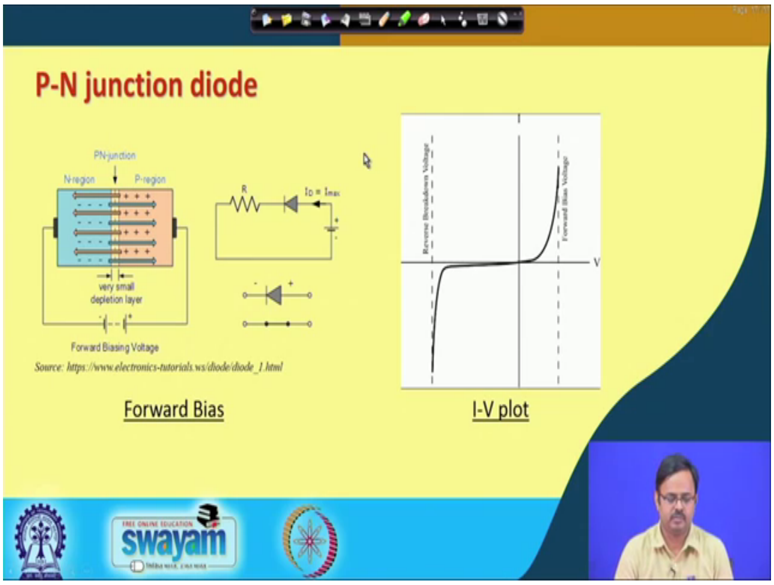

But, however if you apply the voltage if you reverse the direction of the applied voltage or in other words you connect the positive terminal of your external voltage source to the P side and the negative terminal to the N side then what happens? Then what happens is the holes are going to be attracted towards from the P side to the N side and the electrons are going to be conducted from the N side to the P side. As a result what is going to happen? As a result what will happen is the depletion region is going to reduce further and further and the potential you know the potential difference the potential barrier that we saw is going to reduce let us try to sketch that a little bit and see what happens ok.

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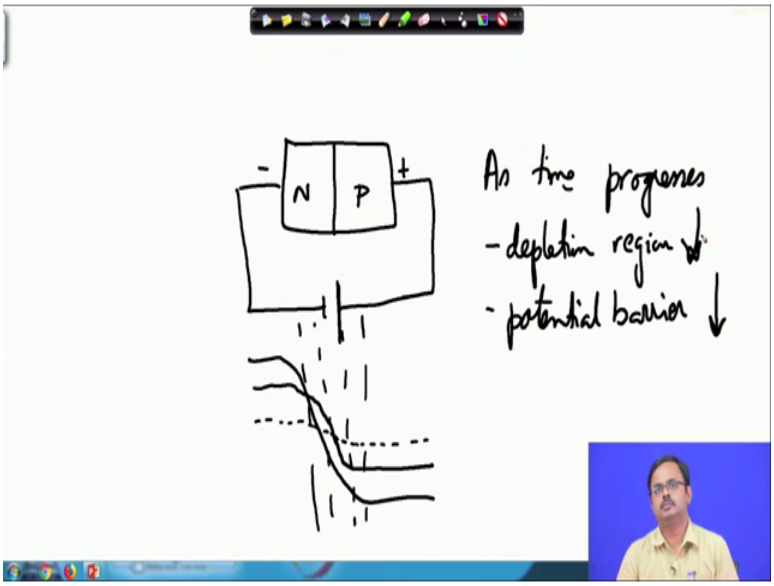

So, let us do this ok. So, I have attached the positive side to P and the negative terminal to N. So, earlier what did I have if I had to draw the potential barrier it was something like this was my depletion region. Now, what happens slowly is with time what happens the depletion layer also reduces in size and the potent depletion layer reduces in size and the potential barrier also reduces ok. And slowly we are finally, going to reach a stage where it is going to be like this ok. So, what I am saying is as time progresses and when I say time these are like minuscule very very small time frame time steps I am talking about depletion region goes down potential barrier also goes down ok. So, finally, what happens?

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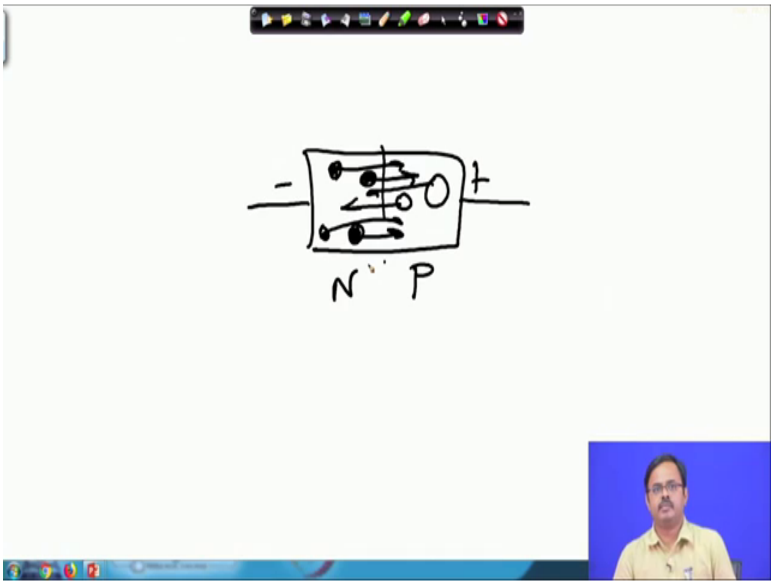

You reach a stage where you will have migration of electrons these electrons are darkened. So, they will migrate and then you have holes which are going to migrate from the P side to the N side ok.

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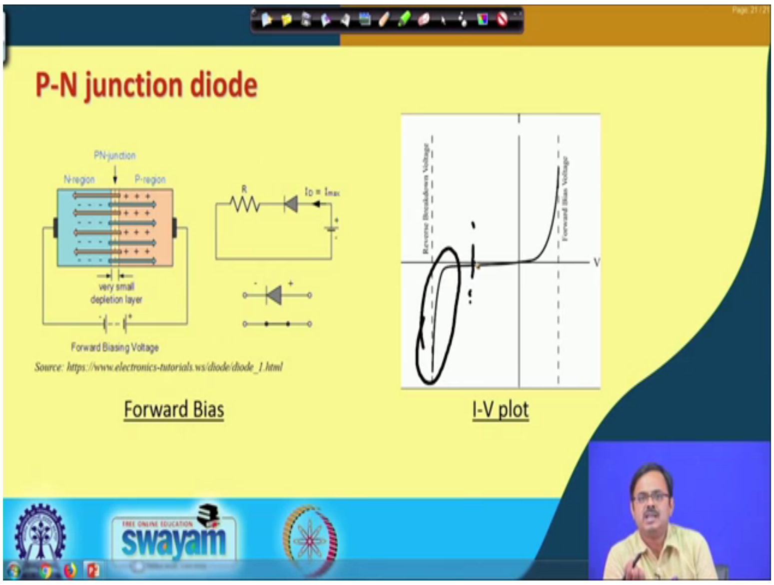

So, that is what is shown in this figure as well the depletion layer gets reduced. So, now, if I do that then what happens there is a current flow from the right to left or the P side to the N side because, which is opposite to the direction of flow of electrons and in the direction of the flow of the electron holes ok.

So, therefore, we have now discussed what is forward bias? This is known as forward bias and we also discussed what is pre reverse bias? In the previous in the previous slide. So, now, what happens as I keep on increasing the voltage whether it is forward or reverse what will happen if I measure the current across this P N junction. So, at the beginning what happens is if you consider over here at the beginning I am talking about forward bias voltage.

As I increase the voltage there is some threshold after which I start measuring the current what is this threshold because this is a threshold that is required to overcome the potential barrier that was there initially ok. So, for certain voltage range we will not be able to measure a current, but thereafter we will see an increase in the current value clear and then as I keep on increasing the forward bias voltage my current value is going to be higher and higher.

But, if you look at the reverse bias what happens in the reverse bias there is hardly if you keep on increasing the voltage, but in the opposite direction we do not see current flow except at very high value over here this is known as an avalanche effect we are not going to talk about that. But, practically for all purposes you do not see any current flow in the reverse direction except some very small leakage intrinsic leakage currents ok. So, that is a diode a diode is often denoted in by this symbol over here what it shows is and what it means is it allows current to flow in one direction, but not in the reverse direction.

It is like a valve like a mechanical valve a valve allows flow across an orifice in one direction, but closes it in the other direction a diode is the equivalent in the electronics world it is a component which allows current to flow in one direction, but not in the other direction ok. So, that is a P N junction diode there are many other types of diodes by the way. So, I have I have given a you know one of the sources in the references if you go through that you will be able to see a lot of other types of diodes, but this is the most simple case of a P N junction diode ok.

So, this was more of a refresher maybe probably you have already studied this as part of basic electronics or maybe even class 12 physics high school physics, but this was more of a recap of what we had already learned. So, now, that we know how a diode works at least the P N junction diode works let us see how we can make one and that brings us to the world of electronic packaging and manufacturing. Especially, now this is about micro fabrication technique how do I fabricate a diode how do I make a diode alright. So, let us before doing that what I am going to do is I am going to talk about a technique which is known as lithography.

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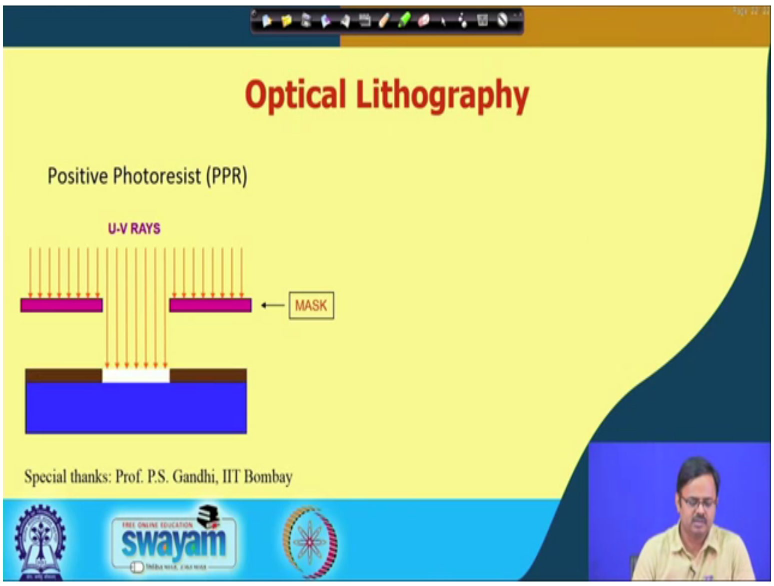

But, this is essential to understand before we go on to see the fabrication steps of a diode. Now, this is something we are again going to see later when we talk about 1st level packaging 2nd level packaging particularly motherboard fabrication lithography will be extensively used. But, in this case, but let us first talk about what is lithography ok? So, a lithography a photo lithography as we talk about is when you have a substrate the substrate can be some material some metal some layer let us forget right now what it is. On top of that you put in a material which is known as a photoresist it is a material these are certain materials for example, PDMS it is a very common photoresist material.

Photoresist what does it mean that what it means is as the name suggests that in the presence of light or optical energy particularly U V light it undergoes certain change in properties either it resists or gets hardened or something else happens we will come to that. So, positive photoresist what happens you put you had as you had a substrate you put in a photoresist material and smear it and form a layer then photoresist what happens is we have what is called a mask or an optical mask what is an optical mask optical mask what it means is just like a mask you know face mask what does it have?

It is some you know it is some kind of a pattern with certain holes through which I mean for example, a face mask we have holes. So, that we can see and breathe and sometimes even talk. So, similarly a photo mask will have some openings some may be holes orifices slits etcetera through which if you shine light the light will be able to pass through those holes or slits ok. So, that is a mask.

So, this is a photo mask for example, I am showing a 2 D structure a 2 D cross section now let us put U V rays ok. So, where this mask material is it is going to block the U V rays from passing through it, but where I have a cut out then the U V rays pass through that cut out whether it is a hole whether it is an orifice whether it is a slit and then falls on this photoresist material. And as the U V rays fall on the photoresist material it undergoes certain changes in properties and which later can be removed ok. Now, what is the change in property etcetera that depends on the photoresist material, but it is something some change locally which you know can be used to remove or to; or to remove that material later and not remove the rest of it which has not been subjected to the U V light ok.

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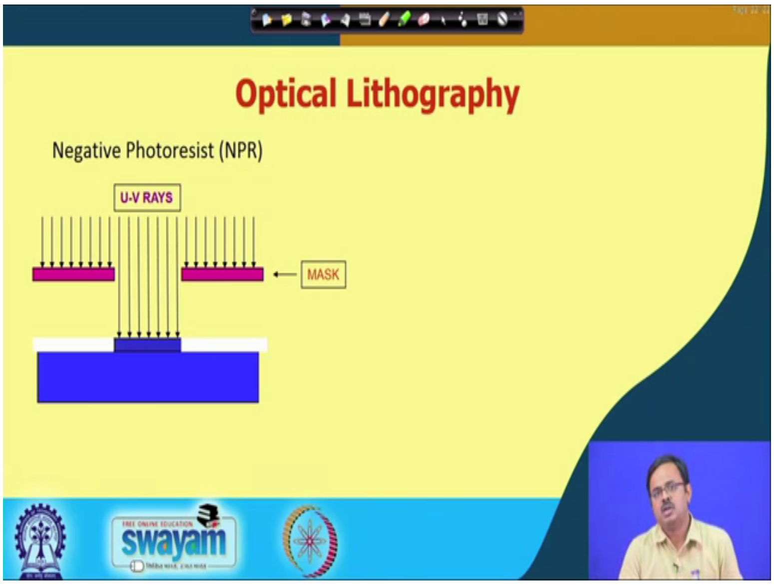

So, similarly so, this is positive photoresist negative photoresist on the other hand is just the reverse same thing you have a substrate you have a photoresist which is smeared on that then you bring a mask you put U V rays. But, here what happens is the change in properties is such that the exposed part gets undergoes some change which prevents it from being removed through that treatment that we are going to do later. And so, we do some other kind of treatment by which we can remove the part which was not exposed to U V light clear. So, again the whole point of photolithography is that I am able to locally change the properties of a certain surface. So, that later on if I make that surface undergo some chemical treatment preferentially material from those localized areas can be either removed or retained depending on the whether it was for positive photoresist or a negative photoresist ok. All right so, with that now let us look into or let us look at sorry the steps of fabrication of a diode.

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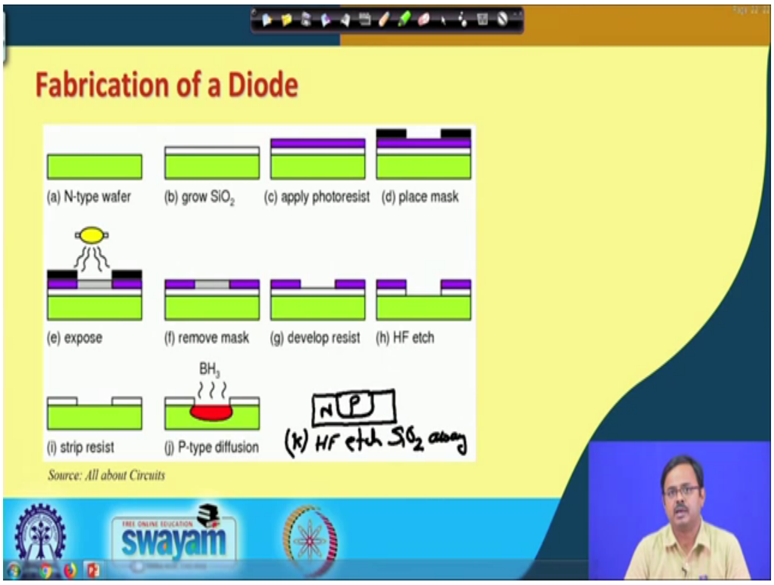

So, I am going to go very slow on this one. So, that you understand what is happening? The step a we will start with an N type wafer. So, the substrate is an N type semiconductor alright. So, what do I need therefore, to make a junction I need to have a P type material impregnated into this N type wafer ok. See the way we were discussing before it was a hypothetical situation you have N type your P type you bring them and join them together in reality that does not happen how do you join them together how do you make that junction ok?

So, in real life to making that fabricating that is a very complex process ok. So, what do we do is we start with an N type wafer and on top of that we grow a silicon dioxide layer ok. Once again I repeat we start with an N type semiconductor and then what we do is we add a layer of silicon dioxide. So, the surface of the silicon is oxidized then we add a layer of photoresist as is shown in step c ok.

So, if we add a layer of photoresist then they put masks and this is positive photoresist where we will put this mask and then shine U V light so, that the part of the photoresist which was exposed to U V light can be removed all right. So, it undergoes a change in property and then later on what we do is we can remove that photoresist from that x from the from the area which was exposed to the U V light ok. I repeat once again on the silicon which is N type to start with we put a layer of silicon dioxide and on top of that we apply a photoresist then we undergo a positive photolithography process where we have an optical mask through which we shine U V light in step e.

And as a result the exposed part undergoes some chemical change and can be removed. So, what do I have now? I have a device which is an N type silicon still with a silicon dioxide layer and then a layer of photoresist at certain locations next what we do is we take hydrofluoric acid and use it for etching if you use it for etching what happens is the silicon dioxide layer will be removed will be etched away. So, that is the step h as is shown over here.

So, the silicon dioxide is removed and next what we do is there is something called a strip resist method or so, basically you strip off the photoresist that is that was still remaining over here these violet or purple bands are then stripped off and what we have. Now, therefore, is an N type wafer still covered with a silicon dioxide layer, but at certain locations thanks to the photoresist method follow or the photolithography method followed by etching chemical etching we have certain parts of this N type silicon which is now exposed ok.

So, there after what we do is we diffuse what is called we diffuse a P type or boron into this ok. So, we diffuse boron into the N type semiconductor sometimes it is in boron hydride sometimes in the form of boron hydride, but what happens is therefore, boron atoms get diffused inside into this N type semiconductor ok. And therefore, what is this boron when it is refused in the N type semiconductor this becomes a P type and then the final step which is not shown is maybe if I say this is step k sorry if this is step k I would say we still now we will again HF etch the silicon dioxide layer

So, what am I left with I am therefore, left with my N type semiconductor, but now with a P doped region inside and that my friends is a diode we have made a diode. This is how an actual diode looks like it is not you know rectangular P type and rectangular N type joined together this is how a diode is made ok. So, once again just let us spend a few seconds of maybe half a minute. On the steps started with a silicon N type silicon substrate and then used oxidation followed by photolithography and chemical etching and followed by you know diffusion of boron into it to form a P N junction.

Now, think about it can you do this again now you have a P N junction can I have another you know can I have in this region inside the P region another N region why not.

We will again go exactly by the same process except the my mask dimensions and mask pattern has to be different, but everything else is just the same and instead of you know instead of diffusing in boron or a compound of boron we are going to diffuse a compound of phosphorous.

And what we are going to end up through that is an N followed by a P and again an N N P N and that is a transistor ok. So, this is a micro fabrication technique by which we have fabricated a diode using micro fabrication processes ok. And the same process as I said can be this is this micro fabrication process is very commonly used and can be used to make a bunch of components or semiconductor components like this diode and transistor are just two examples ok.

So, therefore, let us now quickly wrap up and go through what we have just discussed as part of this entire module or as part of this lecture. Remember in the last lecture we had left off we had introduced the concept of semiconductor eccentric semiconductor extrinsic semiconductor and the concept of doping. In this lecture we started off from there and talked about what is the P N junction and the P N junction by application of an external voltage can be made to act as what is called a diode what is a diode? It allows electric current to flow from one direction to another, but prevents it in the from flowing in the reverse direction that is the diode.

And the way that can be done is you take a P N junction and you apply voltage in one direction by which electrons will flow from the N to P and holes will go from P to N or there will mobility of holes from P to N. But, if you change the polarity of the external voltage then the current flow does not happen anymore. So, that is a diode very basic diode which a P N junction diode and then what we did was we went ahead and said we understand what is a diode?

Now, let us see how we can make one and that introduced us to a micro fabrication technique by which we started in this example that we discussed we started with an N type semiconductor substrate and then we kind of impregnated a P type or P doped semiconductor into it and thus form an P N junction ok.

So, that kind of ends our discussion here and in the next class what we will do is we will go straight into what is called the 1st level of packaging where we are going to see how you know these devices with their input output can communicate with the rest of a system. So, that is 1st level packaging we are going to talk about that.

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So, what we discussed the references for the materials that we have discussed. So, far again our two textbooks Packaging of Electronic Systems by Dally and Fundamentals of Microsystems Packaging by Tummala and then also this is a very good resource electronics tutorials dot w s ok. Here if you want to just go through the fundamentals and brush up some of your basic electronics this is a very good resource.

There is another website where I showed a picture from there all about circuits that is also a very good website a little bit crowded and therefore, a little bit at least I thought a little little harder to navigate through, but still a wealth of information available over there ok. So, if you want to brush up your basic electronics I think these are two very good resources that you can go to. And with that thank you very much for your attention and what we will do is in the next class we are going to go straight into the 1st level packaging of electronic components ok.

Thank you very much have a very good day.