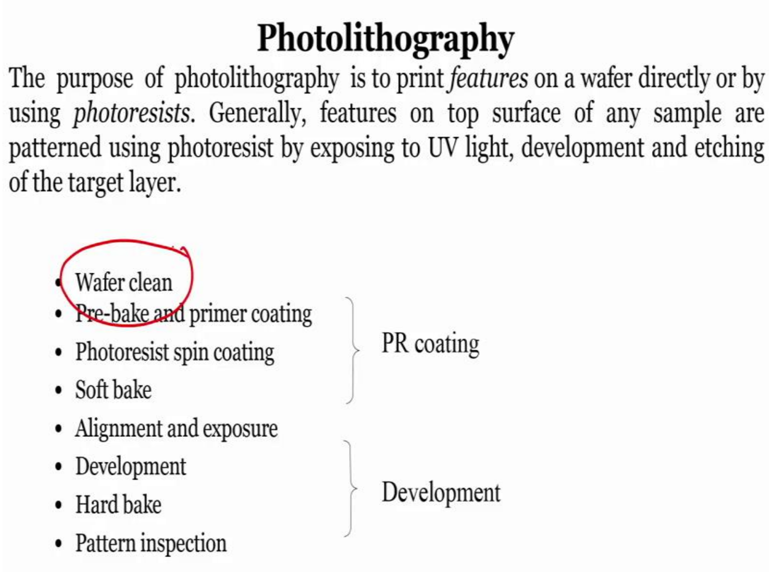
Introductory Neuroscience and Neuro-Instrumentation
Indian Institute of Science, Bengaluru
Lecture 63
Photolithography with Example

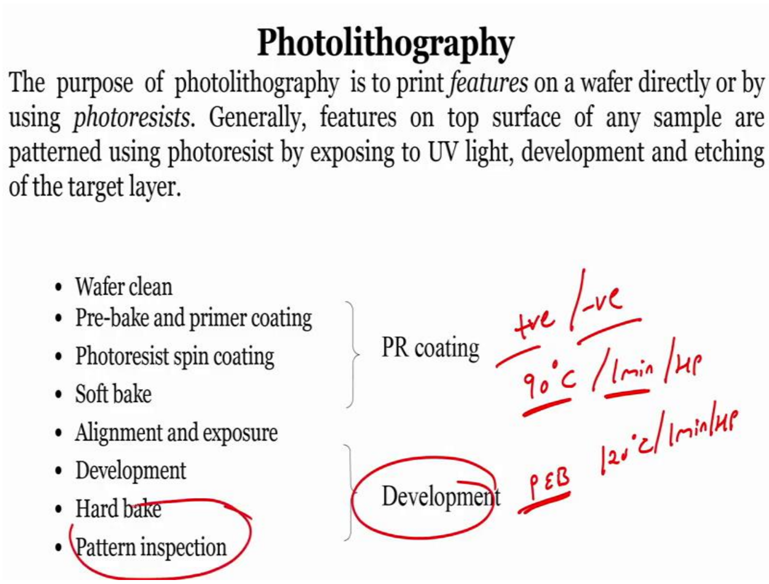
Hi, welcome to this module. In this module we will be discussing about how to pattern a metal which is deposited on an oxidised silicon substrate. We will also see if it is not an oxidised silicon substrate, if it is a glass substrate then also how can we pattern the metal on it and the applications would be for a patch electrode that you can attach and you can get the signals out of it, having said that we will also have one module which was already you have seen which is on Comsol simulation.

We have recorded that and in that you will be able to see how much pressure one has to give on the skin so that it will not harm either the sensor or it will not poke the skin. So, if you take the EEG electrodes then there are several kinds of electrodes that as you have as you know now, there are spike electrodes that are wet electrodes there are dry electrodes.

So, for the spike electrodes in particular and for further electrodes also once you place on the scalp, the pressure should be not that much that it will start poking your scalp or skin. So, that how we will know when you design a band how much pressure should be given you can design you can understand by performing simulation using Comsol which one of the TA has already taken in this particular class.

(Refer Slide Time: 01:43)



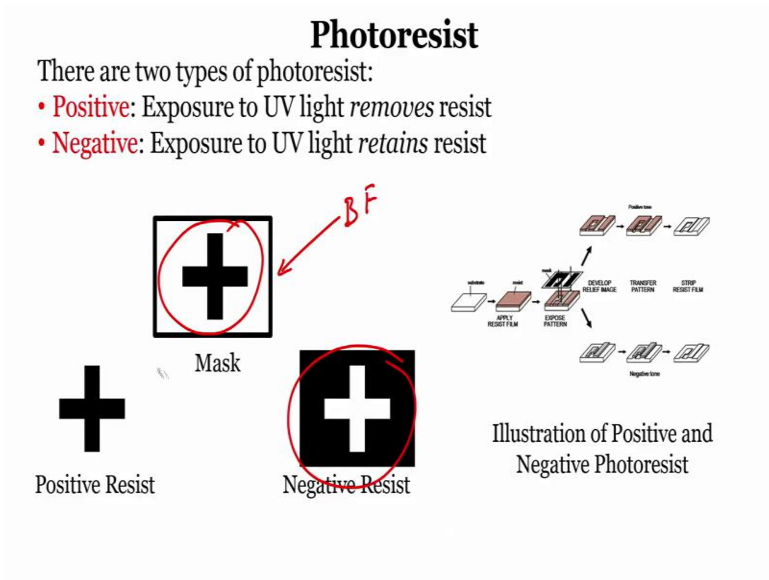


So, let us come to this module and as you already know about lithography earlier in we had discussed this thing earlier module that when you want to perform a lithography, you had to start with a wafer which is which you have to wafer cleaning. There are two types of cleaning RCA1 and RCA2 and it is called piranha cleaning, then you do go for pre-bake to remove any kind of moisture from the wafer.

Go for photoresist spin coating photoresist can be two types as you know positive and negative photoresist. Then you go for soft-bakes; if you use positive or negative photoresist generally soft bake is done at 90 degrees centigrade for 1 minute on a hotplate. If it is not hotplate and if it is oven then the temperature would be temperature would be same but the time would be different. Then you have to take a mask align and expose you already know finally you have to develop the photoresist and perform a hard-bake hard bake also called post exposure bake now you also know that particular term post exposure bake is done as 120 degrees centigrade for one minute on hotplate.

After that, you can develop the metal or whatever the material is on the top of the wafer anyway you can understand there the part has been patterned perfectly or not using the pattern inspection method. So, these are the steps in lithography.

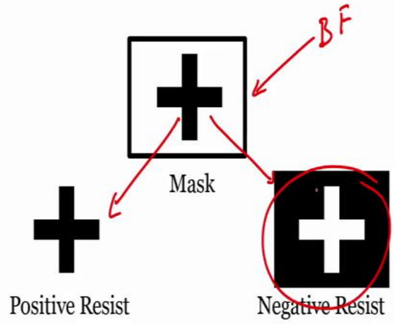
(Refer Slide Time: 03:09)



Photoresist

There are two types of photoresist:

- Positive: Exposure to UV light *removes* resist
- Negative: Exposure to UV light *retains* resist



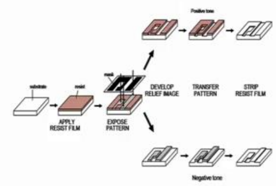
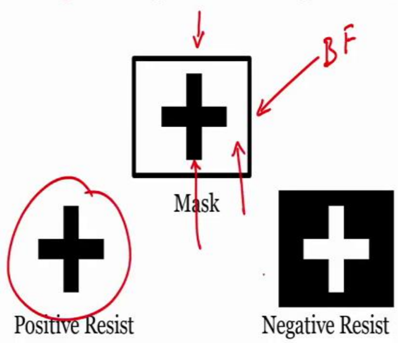


Illustration of Positive and Negative Photoresist

Photoresist

There are two types of photoresist:

- Positive: Exposure to UV light *removes* resist
- Negative: Exposure to UV light *retains* resist



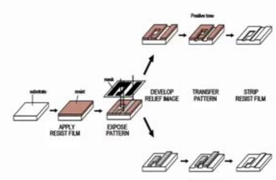
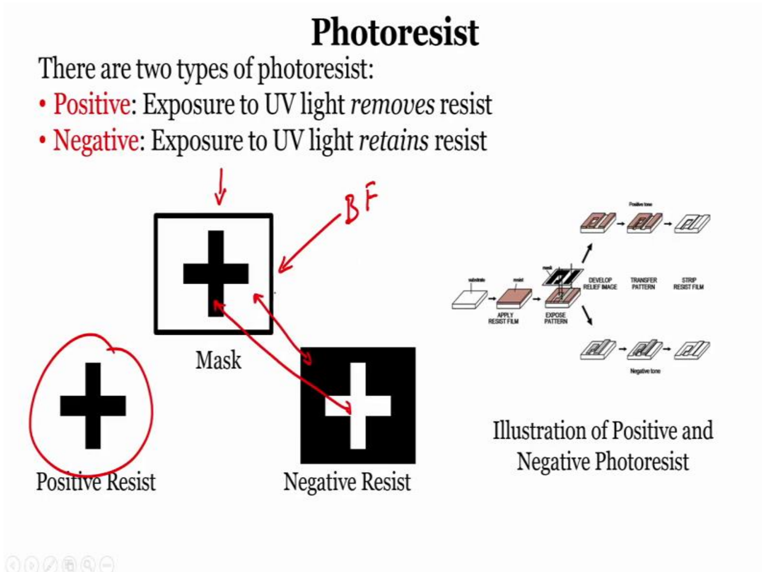


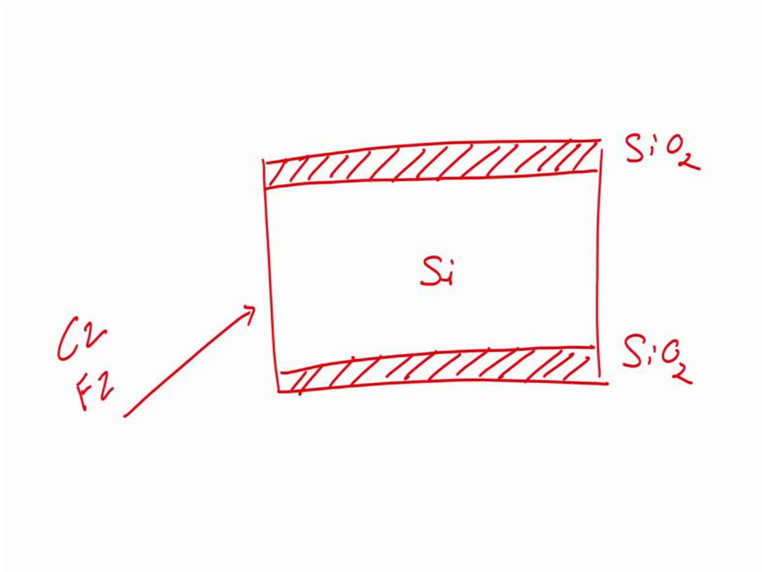
Illustration of Positive and Negative Photoresist



I am just before I start giving you the process I wanted to just help you to recall what photolithography steps are involve what are the steps. In case of photoresist you had to photoresist and as you already know that if this is a mask which is your bright fill mask, bright filled mask, if I use positive photoresist I can replicate the pattern if I use negative photoresist I would have replicate of that pattern, English is little bit funny.

So, you can replicate the same pattern here, but this is the opposite of the pattern that you are getting in the negative photoresist. In another terms or in as per the book terms what you will read is now when you use a positive photoresist the unexposed region would be stronger and the exposed region would be weaker. If you take a negative photoresist the unexposed region would be weaker and the exposed region would be stronger. So, this is how positive negative photoresist works that also you know.

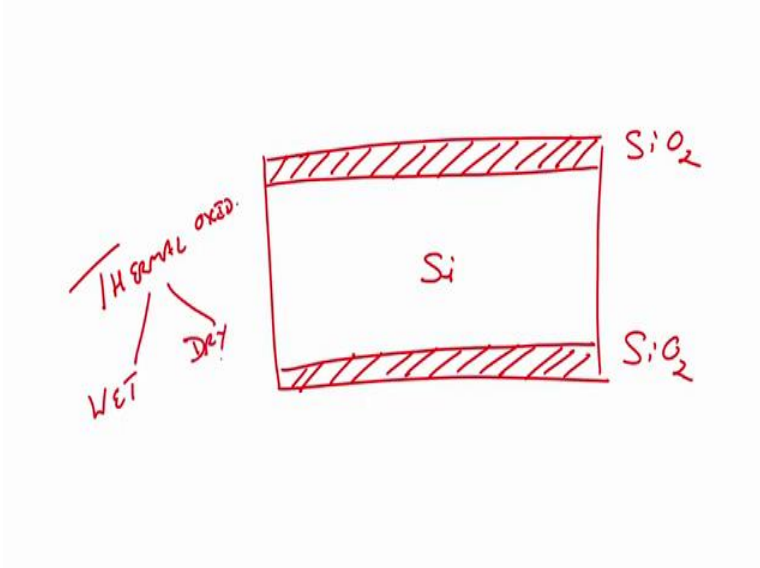
(Refer Slide Time: 04:25)



Now, let us take an example of patterning a metal on an oxidised silicon substrate. So, I will take So, what I want finally, first we had to understand finally, we want oxidised silicon substrate that means you should have oxide lead us pattern oxide when you say oxide it is silicon dioxide. Why you use silicon dioxide and how grow silicon dioxide on silicon wafer?

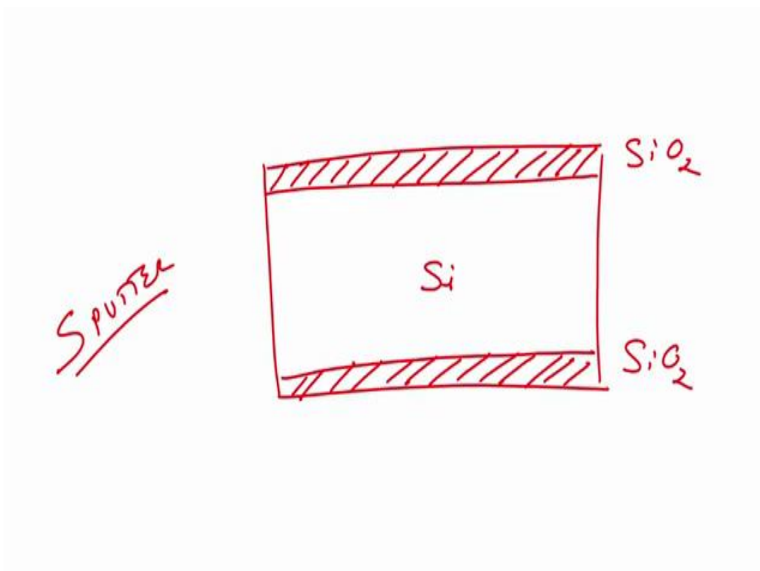
Now, you know that process as well. First is how silicon came into existence, that means that how we are we are developing a wafer that you know the process Cz process and Fz process. So, Czochralski or Float zone technique we have seen from the send, how the silicon wafers are fabricated and once you have silicon wafer, you have a single side polysilicon wafer and double side polysilicon wafer here we are using single side polysilicon wafer. Single side ploy silicon wafer is less costly compared to the double side silicon wafer.

(Refer Slide Time: 05:20)



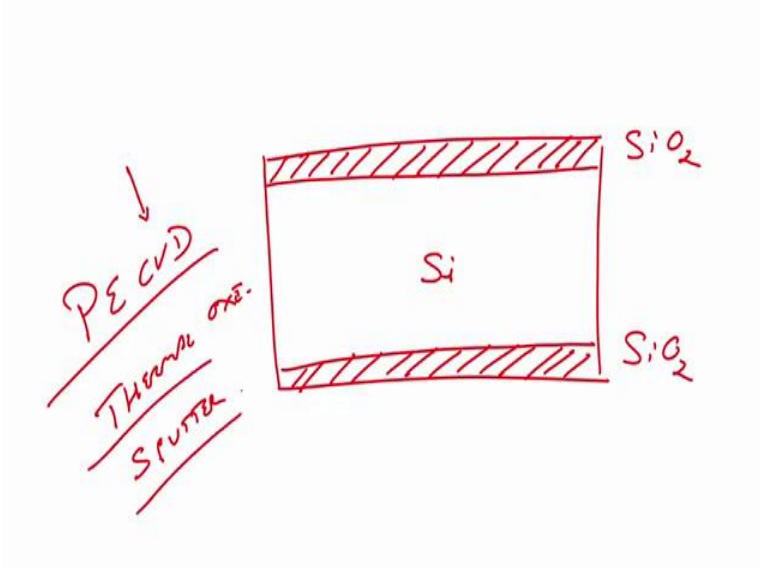
Now, when you talk about silicon dioxide on silicon, you again know that there are process several process one is your thermal oxidation, oxidation thermal oxidation you can grow silicon dioxide if you talk about thermal oxidation again you know from our previous lectures that there can be wet oxidation and there can be dry oxidation.

(Refer Slide Time: 05:42)



Other way of grow depositing oxide instead of growing oxide would be using sputtering, you can sputter the silicon dioxide on to silicon wafer.

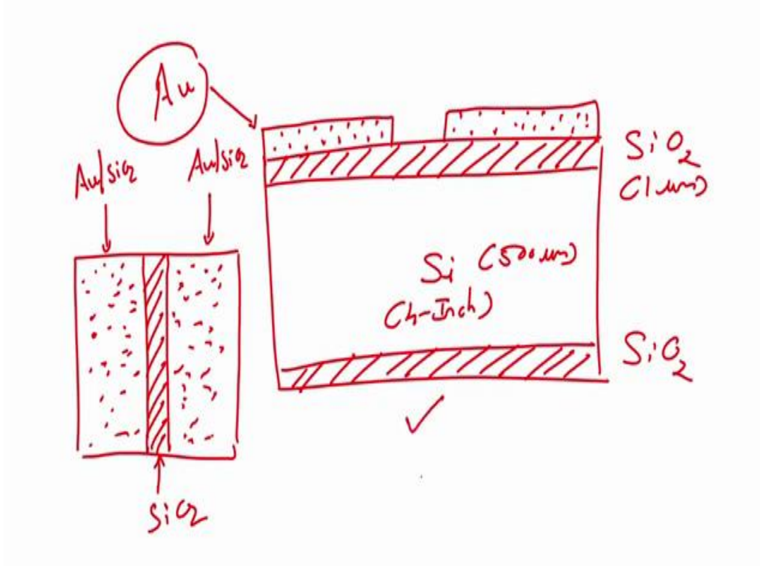
(Refer Slide Time: 05:59)



Another way of growing silicon dioxide depositing would be PECVD, we have not taken in this particular course the details about CVD techniques, but just to help you out that there are different methods to grow silicon dioxide this method is called plasma-enhanced chemical vapour deposition.

So, plasma-enhanced chemical vapour deposition, thermal oxidation and sputtering are three known methods there can be other methods as well, but this is these are three answers. If a question is there that, what kind of method you can use for depositing silicon dioxide on the silicon wafer.

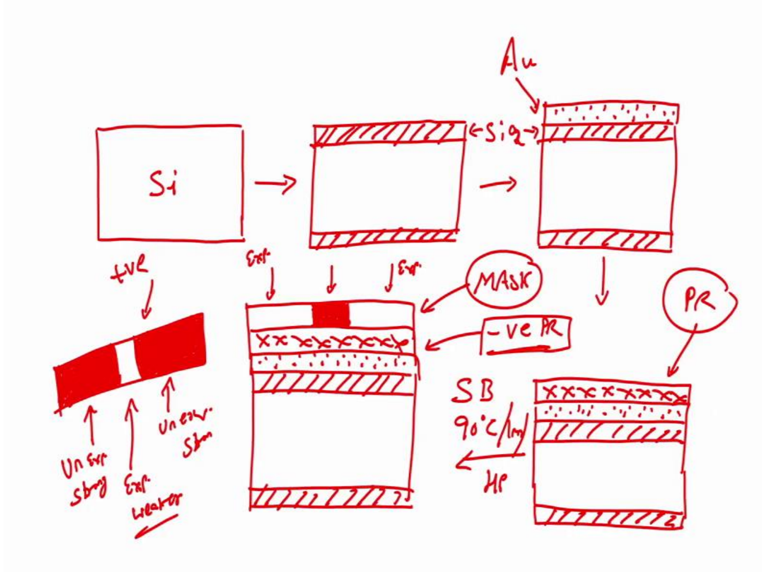
(Refer Slide Time: 06:40)

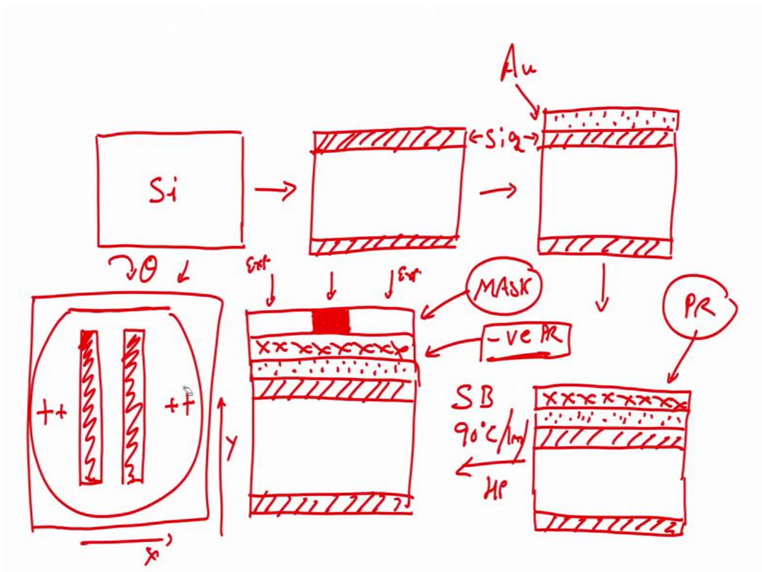


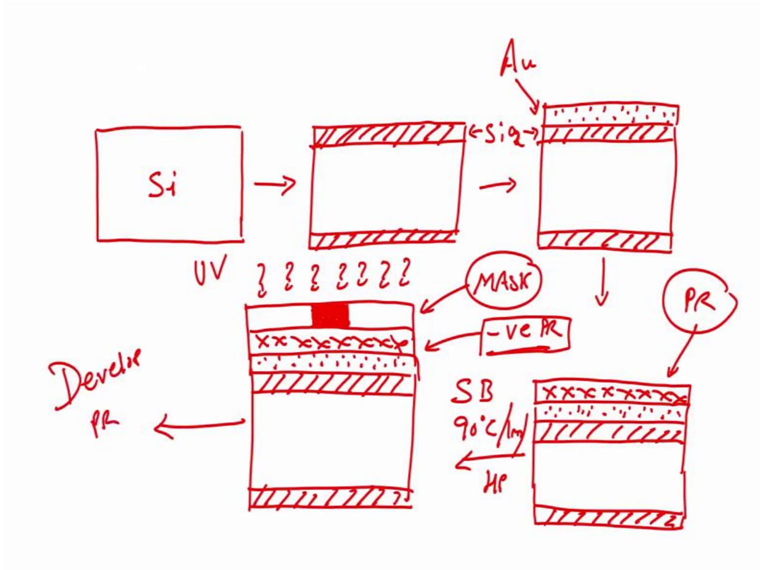
Now, having said that so we have a silicon dioxide and our thickness of silicon dioxide is about 1 micrometre, silicon wafer is 4 inch silicon wafer if you have 4 inch silicon wafer the thickness would be 450 micrometre to 500 micrometre, 450 to 500 micrometre. Now, on the silicon dioxide we want a patch that looks like this and this would be our metal, this will be our metal let us say gold, gold is there.

So, if you see the top view it will look like, so the dotted region is your metal this is your gold and this one will be our silicon dioxide this is gold on silicon dioxide and this is your silicon dioxide. You want to use this it can be used for a lot of applications one can be patched but there are other applications right now what we are interested in how can we design our pattern the gold on silicon dioxide.

(Refer Slide Time: 08:35)







So, let us start the process. The first step as you already know, we draw it, this is a cross section of a silicon wafer in case if somebody asked you in interview or under exam, you have silicon wafer you grow silicon dioxide then you deposit metal on silicon dioxide, then you spin code photoresist on silicon dioxide, spin code photoresist, photoresist let us say is represented by x, what is this? Photoresist; what is this material? Let us say metal, this one you know, it is a Sio2 this one.

Now, after you spin code photoresist, what is the next step? Come on, you should know by now. Next step would be soft bake exactly that is correct 90 degrees centigrade 1 minute on hotplate after that, what is the next step? You should have been answering the question while I am talking to you guys that the next step would be to load the mask silicon dioxide, silicon dioxide metal photoresist and your mask, how should mask look like? Mask will look like this.

If I am using positive photoresist then a mask will look like this. But let us say in this case just to make it easier, I am going to use negative photoresist I am using negative photoresist mask should look like the one that I am drawing right now, if I would this is a mask if it is negative photoresist but if it was positive photoresist guys then our mask should look like dark fill mask, it should it will look like a dark fill mask.

Because you know that if it is positive photoresist then the area which is not exposed by UV light will be stronger. So, if I want to use positive photoresist my mask should be similar to what I am right now drawing, but if I am using negative photoresist mask can be bright fill mask. So, understand this thing if somebody writes that with positive photoresist we had to use a bright fill mask with negative photoresist we had to use dark fill mask that is not correct. It is not correct. If you have a mask then you have to understand which photoresist you can use so to the pattern or if you have photoresist you can design a mask accordingly.

So, in this case, if you see the slide that if I use negative photoresist but if I want to use a positive photoresist then my masks should be the one that I am showing it to you hear. So, why because in negative photoresist if I am using then the unexposed region which is here would be weaker and the exposed region would be stronger. In case a positive photoresist they unexposed region would be weaker and the exposed region would be stronger, sorry, is it correct or not? No is not correct.

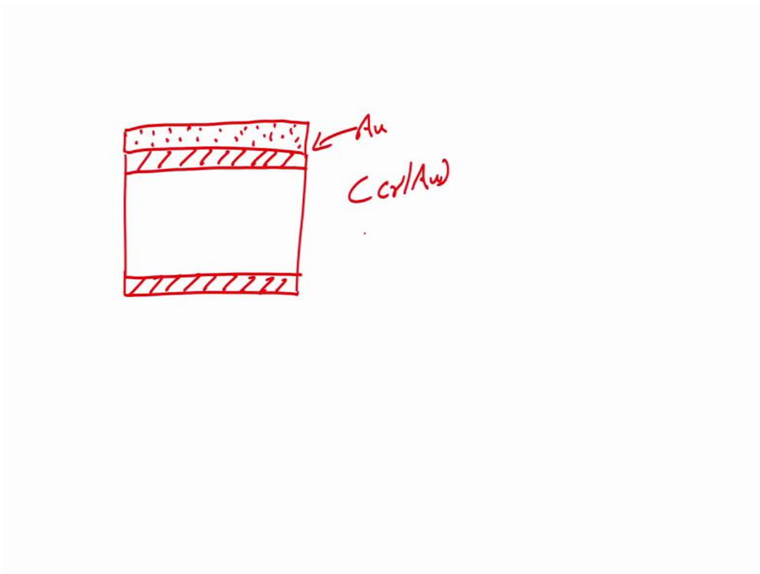
The unexposed region would be stronger and the exposed region would be weaker in case of positive photoresist. In case of negative photoresist the exposed region would be stronger and the unexposed region would be weaker. So, depending on the negative photoresist positive photoresist you can change the mask.

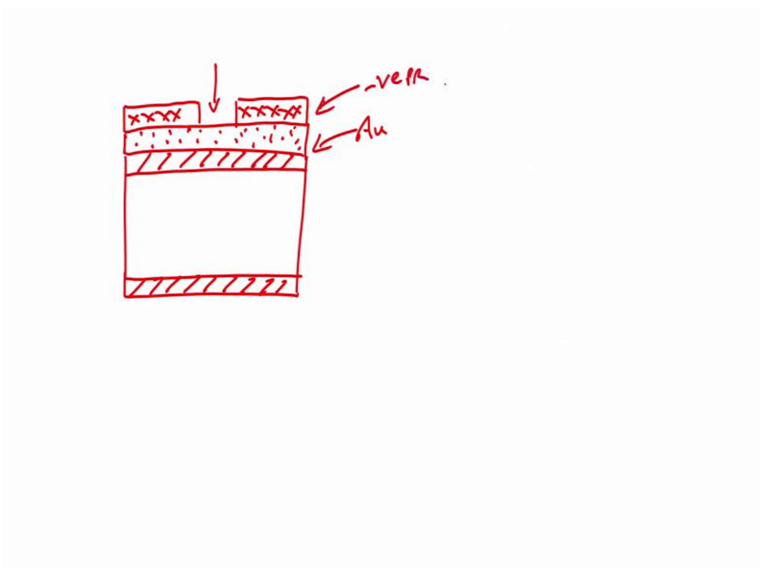
Now, once we have the mask, then what is the next step you have to load the mask and align it with the wafer. Now, every time we use this word aligning, what does aligning means? You have a mask here and these are alignment marks, this is the pattern on the mask all is a pattern on the mask you assume that this is entire thing is dark these two patterns.

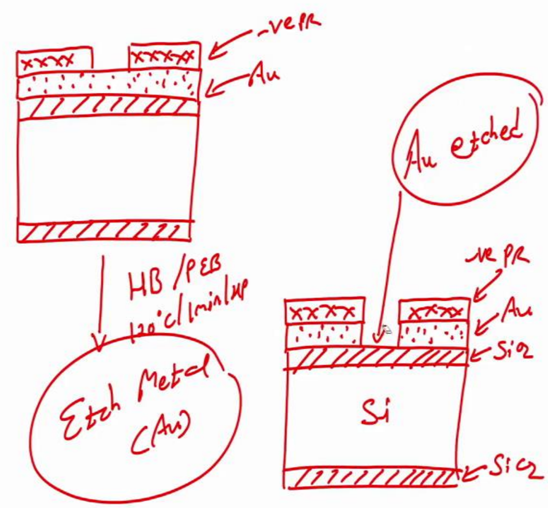
So, now you had to make sure that the alignment of the wafer is correct with respect to mask it is not tilted. Second thing is it should be in a centre of the wafer since is a first mask process one single mask process. So, it should be in the centre of the wafer, it should not be tilted it should not be towards too much towards one direction, not towards too much towards other direction that is why this is x and tilt is our theta.

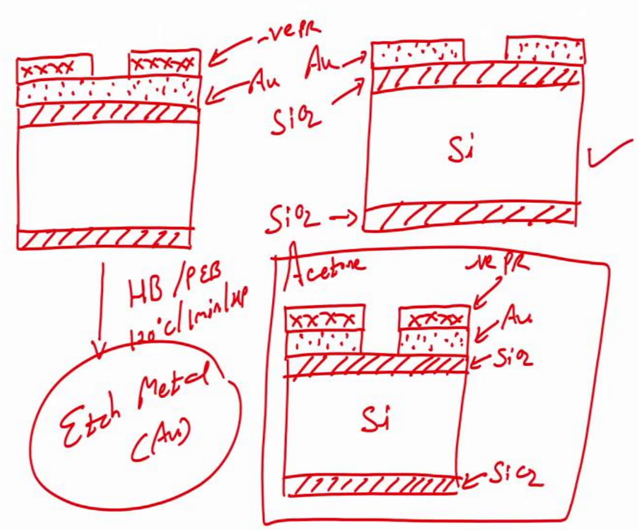
So, we can that is why if you recall about mask aligner we can move the mask in x direction or we can move the wafer in x direction, y direction or theta, you have option of either moving the wafer or you can option of either moving the mask. So, this is the alignment. So, once you perform the alignment, what is the next step after the alignment you have to expose the wafer and exposure is done using UV light. So, you will have UV light exposure of this wafer UV light. After that you have to unload the mask and develop photoresist unload the mask and develop photoresist.

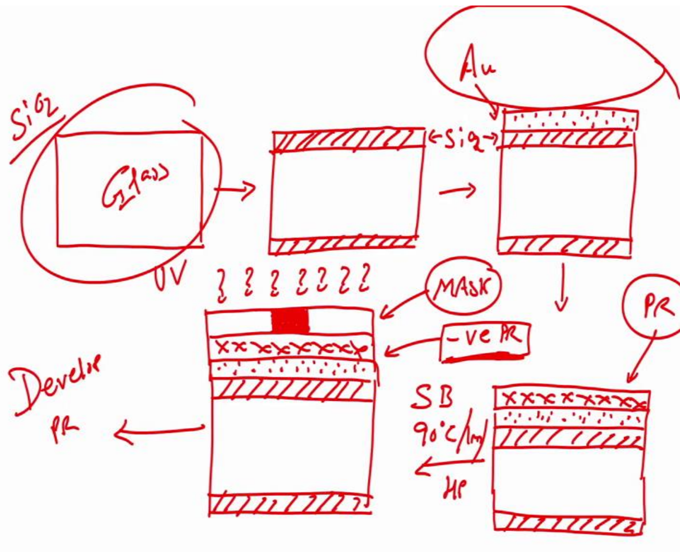
(Refer Slide Time: 15:55)



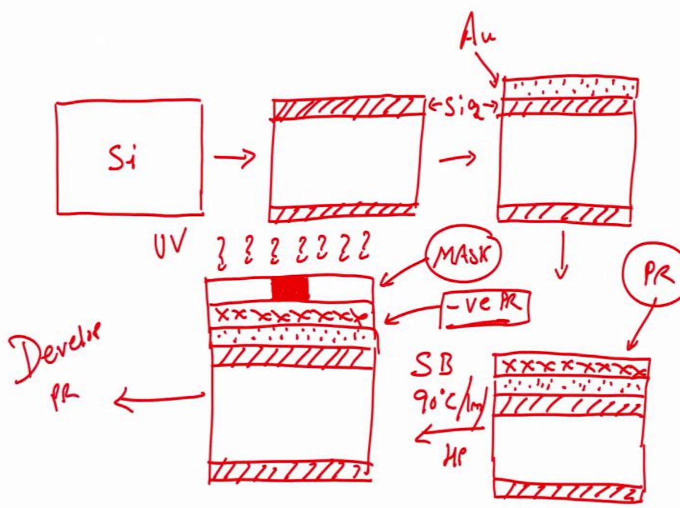



-ve PR
Au
HB / PEB
120°c/1min/HP
Etch Metal (Au)
Au etched
ve PR
Au
SiO2
Si
SiO2

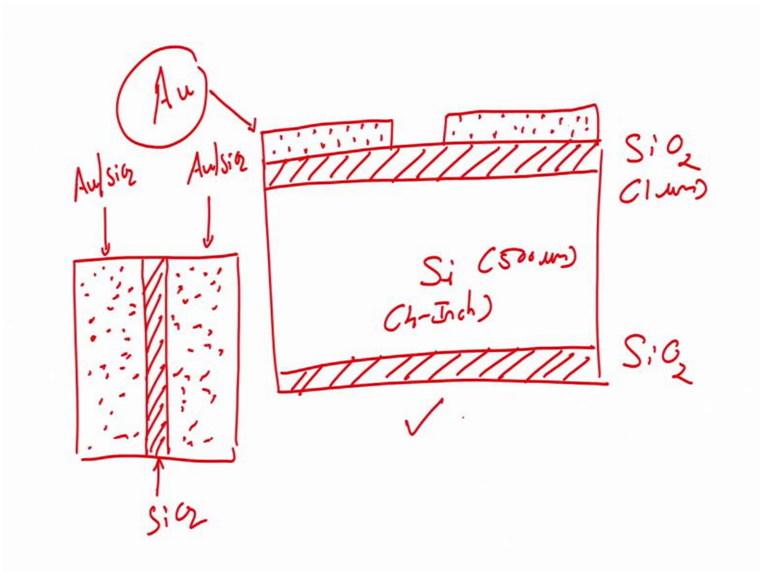

-ve PR
Au
Au
SiO2
Si
SiO2
HB / PEB
120°c/1min/HP
Etch Metal (Au)
Acetone
ve PR
Au
SiO2
Si
SiO2



SiO2
Glass
Au
←SiO2→
UV
MASK
-ve PR
PR
Develop
PR
SB
90°C/1m
HP



Au
Si
←SiO2→
UV
MASK
-ve PR
PR
Develop
PR
SB
90°C/1m
HP



So, if you do that, if you perform the developer developing step what you will have you will have a wafer which is our oxidised silicon wafer with gold coating on it. Now, I am still not going too much into depth about the fabrication methods otherwise, instead of when I say gold, gold is always comes with chrome layer at the bottom of thin layer of chrome that will improve the addition of gold on to the oxidised silicon substrate. But I am not going into depth of this. So, right now, we assume there is a metal and which is gold.

So, on gold you have your photoresist and photoresist will be shown by x. Now, you understand the photoresist after development you see here that because we are using negative PR and our mask is this such why the exposed region is stronger and the unexposed region is weaker you can see here the unexposed region is weaker because this is our negative photoresist.

After this our next step would be hard bake or post exposure bake 120, 1 minute hotplate. So, if I go for hard bake at post exposure bake next step would be to etch metal, what is metal in our case Au. So, if I dip the wafer in Au etchant, what will I see? I will see again understand the oxide layer below it will not get affected because the etchant for gold will not affect the oxide, the oxide will get affected mostly when you use HF based etching material.

So, what you have here now, you will have the gold etched from the area which was not protected by photoresist, is not it? You see here. Now, you have photoresist negative photoresist let us write negative and you have gold you have Sio2 you have silicon and here you see that the gold is etched.

Next step after this what is the next step everyone knows. Next step would be that you take this wafer of course when I dry this you take this wafer and dip it in acetone. If you take this wafer and dip it in acetone, what we will have we will have photoresist will get stripped off photoresist will be stripped off and you will be left with metal pattern on oxidised silicon substrate, is not it? You have metal on oxidised silicon substrate this is what we wanted.

Let us, see we go back you see easy. So, this is how we can pattern the metal on an oxidised silicon substrate also there is an alternative instead of using oxidised silicon substrate, you can perform everything if you have glass. So, if you have glass here, then you do not have to grow oxide here because glass itself is silicon dioxide. So, directly you after a glass, you can start with this step that you use deposit gold on glass and the remaining step remains the same.

The only difference is if you use silicone substrate you had to grow oxide because silicone is a semiconductor and oxide will help to help as an insulator between metal and semiconductor. When in case of glass since glass itself is an insulator, you do not have to separately grow silicon dioxide on the glass you got it. So, I hope that this helped you to understand how to pattern the metal on an oxidised silicon substrate.

(Refer Slide Time: 21:23)

Now, let me show you to you if you see my hand I am holding a wafer, can you see? See, I am holding a wafer that has been pattern you can see gold is pattern on an oxidised silicon substrate. If I show it to you in a different manner, see, gold is patterned this is a different pattern, this is one pattern, there are two wafers it is not magic, there are two wafers both are oxidised silicon wafer.

And you see here, there is one pattern that you can see on an oxidised silicon substrate process was same, you take a silicon wafer, you oxidise it, you see in the backside, the colour is different that means there is an oxide on silicon wafer. When you oxy when you grow oxide on silicon wafer, the next step would be that you deposit gold on the oxidised silicon wafer, then sprinkle for positive photoresist or negative photoresist depending on the mass that you have to use, soft bake, align the mask, expose it with UV light, develop the photoresist hard bake then etch the gold from another area except the area which is protected by photoresist it will not get etch.

Finally, you had to dip this wafer in acetone to remove the photoresist that will be on the top of this layer and that is called stripping step when you dip the wafer in acetone, you will have this particular wafer. Again please understand that for getting any kind of pattern after every etching step, you need to rinse the wafer in deionized water.

And after rinsing the wafer you have to dry the wafer with nitrogen, nitrogen is a gas that can or air can be used for drying the wafer and di water is to rinse the wafer is this is by default is a step that is used during the photolithography process, no wafer can be processed if it is not rinsed or dried before it can go to next step.

You should not go to next step before the wafer rinse and dry this very important step that you have to understand that every time when we draw we do not discuss about it, but it is by default it understood that when you get a new wafer you always had to dip in HF to remove the native oxide, then you have to rinse it then you had to dry it, then you had to pre-bake it at 120 degree or higher temperature so that to remove the humidity from it, it is known.

So, generally, when you see in the process flow they say take wafer grow oxide but in between you have to understand that when we take the wafer and grow the oxide this process is already there which called RCA1, RCA2 cleaning. Then you have oxide after you oxide you deposit the metal there is no chemical involved here you take the oxide and grow or deposit or metal.

Now you spin code photoresist again you do not have to do anything soft bake nothing expose align and expose nothing develop photoresist so chemical came after developing you rinse it, dried then go for hard bake then take it then etch gold let us say in this case, when you etch gold chemical is involved, after you etch it, you have to rinse it dry it, then you have to dip it in acetone again chemical is involved.

You take it out once photoresist is stripped off, rinse it with the di water or wash it with di water and then dried with nitrogen you understand wherever a chemical step is there you need to take care of it. If you want to understand this recipe in detail there are a lot of photolithography examples that you can find it from YouTube videos, lot of videos available.

But what I was thinking as a part of this particular course as a some of the modules that I have taken of course, the detail will be taken by Doctor Mahesh on the neuroscience and neuro-instrumentation but what we were able to show it to you is right from the oxidised silicon substrate, all the way to patterning the substrate, there are many -any steps that are involved in we try to cover this through these modules.

So, what you learn in this instrumentation side, you are seen how silicon is made, you have seen how oxide is grown, you have seen different PVD techniques, whether it is thermally di operation or sputtering, then you have shown in the thermal oxidation technique which is silicon dioxide is grown you have seen wet and dry then you have seen wet etching technique by which we were etching either BHF or either oxide or you are etching gold and also we have seen the how silicone can be etched with example of KOH.

Then we have seen how can we pattern the wafer on to the using the photolithography technique that we have seen, then we have seen how the Comsol simulation can be used for simulating a pressure applied on a skin, then we have seen how to develop an electronic module using a multi-sim pair technique and then we have also seen how if you have the EEG electrode, what is a complete electronics that is there to acquire the signal and to process the signal.

So, this is this was the part of the neuro instrumentation that we wanted to teach you again understand this an introductory neuroscience and instrumentation it is not an advanced level that is why we kept it at the more of a introduction and we cover the basics around it. Once you are familiar with the technique and you are familiar with the introduction of the neuroscience, we will try to see if we can take an advanced course on the same subject, till then you take care if you have any question feel free to ask us via the NPTEL forum, bye.