Mathematical Aspects of Biomedical Electronic System Design
Lecture 15
Basics of Photolithography with Process flow examples

Hi welcome to this particular class, in the last class what we have seen? We have seen silicon dioxide and in this class, let us see photolithography. So, for photolithography, the name comes from a Greek word, where if you divide it is like a carving of a single stone. And a photo sense for photon, or light. So, we use UV light for performing, or creating a pattern onto silicon substrate. So, let us understand how photolithography works, and we will take one example to understand the different steps involved in lithography.

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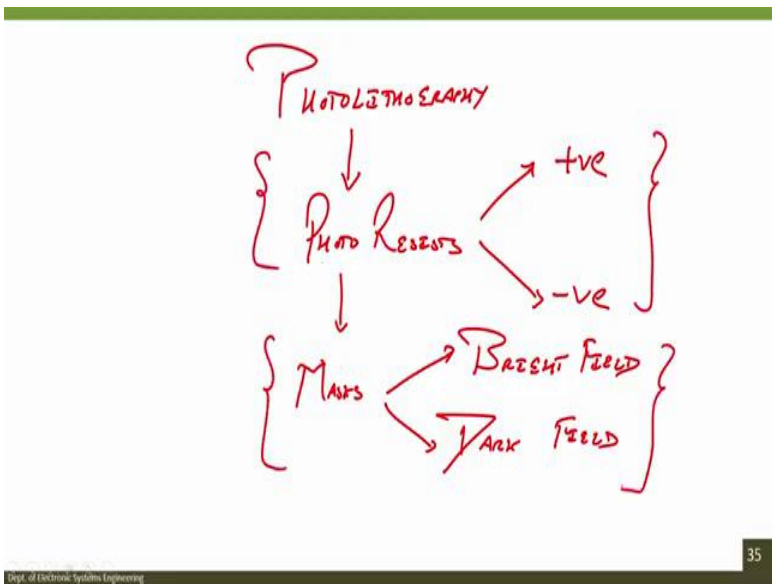

So, in photolithography, if I write down photolithography as you can see here, photolitho and graphy, you use photo resist, this photo resist are two types, positive photo resist and negative photo resist. Then you use masks, masks are two types, bright field mask, and dark field mask, bright field mask and dark field mask. Now, photoresist positive and negative, mask bright field and dark field, this is very easy.

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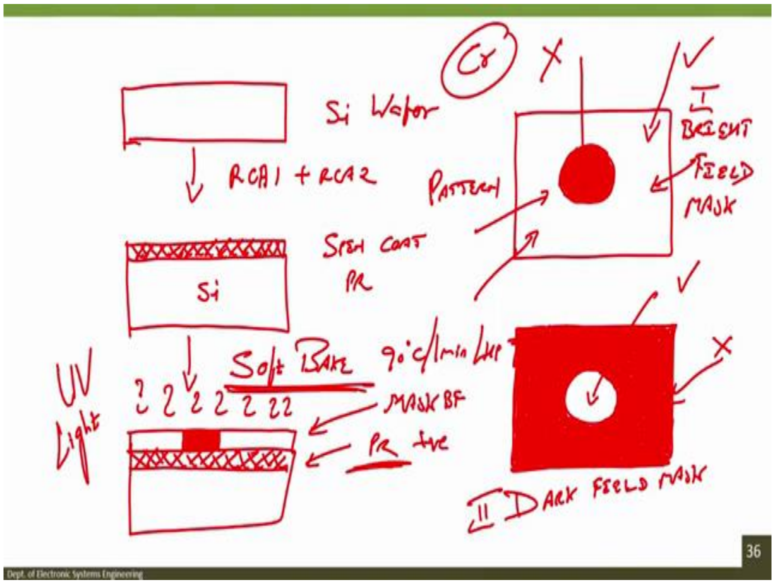

Now, this step for performing lithography is, you take a silicon wafer, they will take a example of a silicon wafer, take a silicon wafer, you clean the silicon wafer with RCA 1, and RCA 2, cleaning steps, then you spin coat, spin coat photo resist. So, let us say this is our photo resist, it can be positive photo resist, can be negative photo resist, spin photo coat resist.

Next step is you soft bake, you bake this photo resist at 90 ℃ for 1 minute on hot plate. Next step is you load the mask, load mask this can be bright field mask, or a dark field mask. Now, what is bright field mask? What is dark field mask? I will tell you, in the next class I will show it to you also.

Here you I will draw the bright field mask and I will draw a dark field mask, where my field is bright and the pattern is dark, field is bright and pattern is dark is called bright field mask. You can see here the field is bright and my pattern is dark, this is field and this is the pattern, in dark field mask, my field is dark, you assume that everything is dark, just completely, where light cannot pass through it, like this complete dark.

So, when my field is dark and pattern is bright, you can see the pattern is transparent, this is called my dark field mask, field is dark and pattern is bright, dark field mask, when field is bright and pattern is dark, then we have a field is bright and pattern is dark we have a bright field mask. So, in this case everywhere, you whatever I am drawing here with red shade is chrome, we are talking about chrome mask.

So, mask is made up of different material, one is called chrome mask, another one is called Fe_2O_3 mask, chrome mask in Fe_2O_3 mask. So, this all-red color thing is actually a chrome, you assume that it is a chrome. What will happen, why what is a reason of using dark field mask and bright field mask at certain point of time, I will tell you. But right now, you understand that, the light cannot penetrate to metal, is not it. It is very simple light cannot pass through metal.

So, wherever this red color is there, light cannot pass through it, where there is a transparent area light can pass through it, in this case you can see very clearly here, that the light cannot pass through this metal, but light will be able to pass through this area, is not it? Here the light will be able to pass through this area, light can pass through, where in through this area it is not able to pass through.

So, for this region it is not able to pass through, a transparent region is there, it is able to pass through. So, the first one is our bright field mask, one, bright field already written mask, the second one which is this one, is the dark field mask. So, there is a difference bright field mask, and a dark field mask.

Now, I told you that, these are a chrome mask, chrome, chrome mask. So, we have, we have taken a silicon wafer RCA 1, RCA 2, cleaning, then we have spin coat photo resist and we have a soft bake at 90℃ 1 minute on hot plate. Then we load the mask, after loading the mask, we expose the wafer with UV light, ultraviolet light, expose the wafer with UV light. Now, you will see the difference.

So, now assume that, we have used this bright field mask. So, this mask is bright filled and the photo resist that we have used is positive photo resist, bright field mask and positive photo resist. So, then after soft bake, you have to load the mask, expose the wafer.

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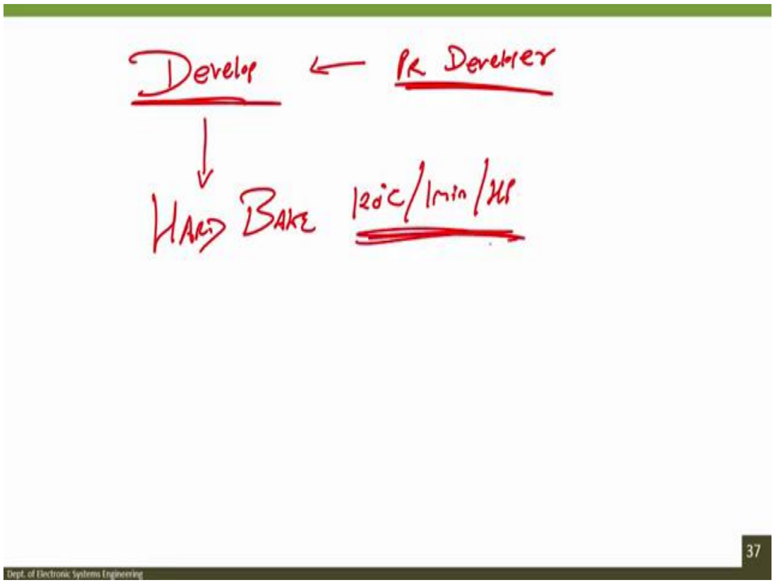

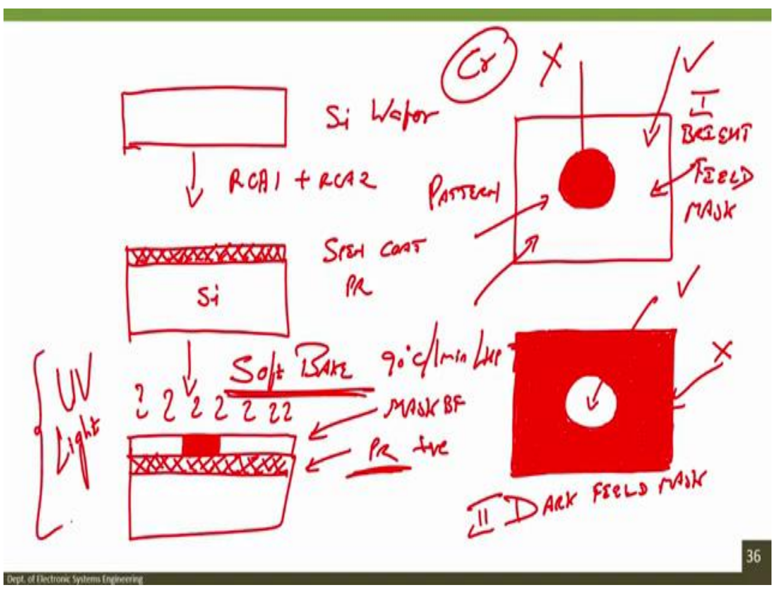

The next step is develop the wafer, develop the wafer in photo resist developer, developer, you go back, once you expose the wafer with UV light, you unload the mask and dip the wafer in a photo resist developer. After that, the next step is hard bake, 120, 1 minute hot plate, 120, 1 minute hot plate, hard bake and the process is over. So, these are the steps.

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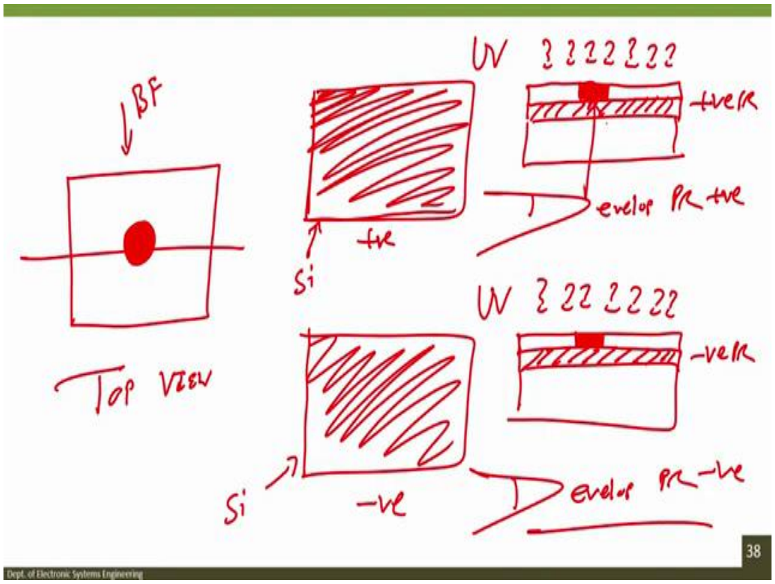

Now, let us understand, the same example what will happen, if I use this bright field mask with positive photo resist and negative photo resist. So, in one case, I have positive photo resist and second case I have negative photo resist, this is a top view, top view, this is a cross sectional view, cross sectional view.

So, in one case what I said there is a positive photo resist and second case I have a negative photo resist, this is my positive photo resist, this is negative photo resist. Now, so I have everywhere positive photo resist, here I have everywhere negative photo resist, positive, negative.

Now, what is the next step, if I have positive photo resist, now spin coat positive photo resist onto this silicon substrate, the next step is I have to go for the soft bake, soft bake, after soft bake I will load this mask on to this particular wafer. I load this mask onto this wafer, that means let me show on the cross section. I load the mask, I load the mask here and I load the mask here.

So, cross section of this would look like, the one that I am drawing here, what is this mask that we are using, we are using bright field mask, and we are using positive photo resist. In this case, we are using bright field mask, but negative photo resist, positive, negative.

Now, I will expose this wafer through the mask with UV light, same thing goes for here also, UV light. And then I will develop the wafer, develop in photo resist developer, this also I will do the same thing, develop the wafer in photo resist developer. In this case it is a positive photo resist developer, in this case it is a negative photo resist developer, when I do that and I unload the mask, when first of course we are unload the mask and develop the photo resist.

So, the step is spin coat the positive photo resist onto the substrate, then soft bake, then load the mask, then expose the wafer through the mask with UV light, then unload the mask. Next develop the photo resist, what will happen is that, for the positive photo resist the unexposed region would be stronger, which is unexposed region? This region where there is a pattern is a unexposed region.

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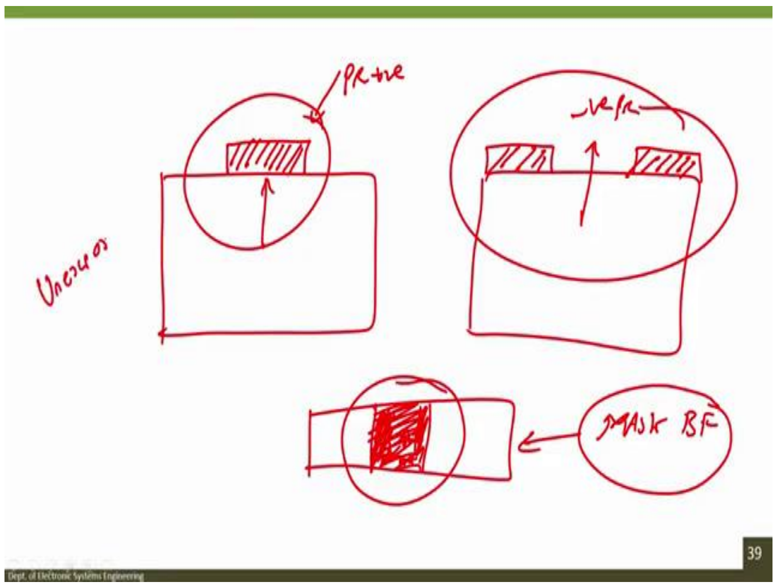

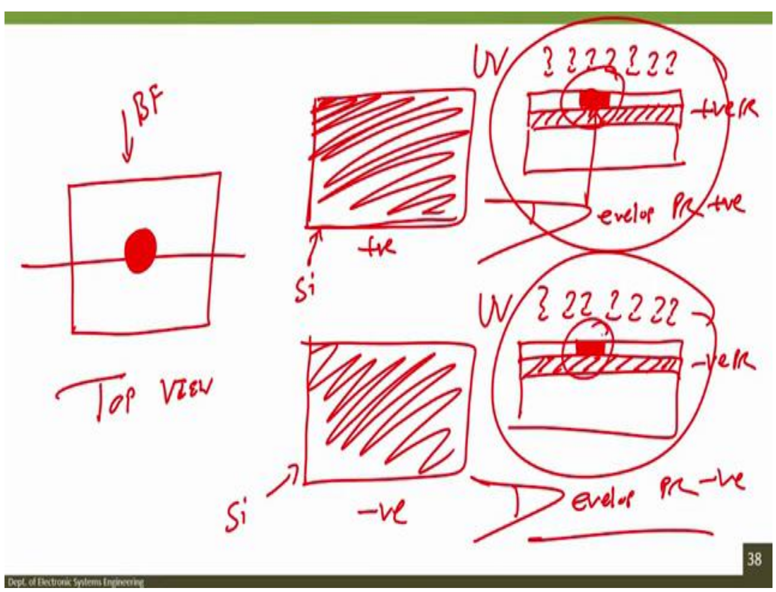

So, in positive photo resist after you develop here what you will get is, that this region you will see that photoresist is still there, you see here this one, in this case the unexposed region which is this region is stronger and you can see that is why you can retain the photo resist after developing into positive photo resist developer.

While in case of negative photo resist the unexposed region becomes weaker, the unexposed region which is this region becomes weaker. So, what you will have is opposite of positive photoresist like this. How the mask was looking? Mask was, this was a mask, cross section of bright field mask.

So, what you see here is, what you see here is the pattern that you had on the bright field mask same pattern has been retained in case of positive photoresist while the complementary pattern came on the negative photoresist, opposite, where the area was protected this is area is etched where the area was protected same area is protected in the case of positive photoresist.

That means that the positive photoresist you can pattern the same pattern that you have on the mask you can replicate the same pattern using positive photoresist onto the wafer, in negative photoresist the opposite of the pattern that is there on the wafer will come. That means that the area which was dark in this case of mask that area will get etched the area which was bright will be there.

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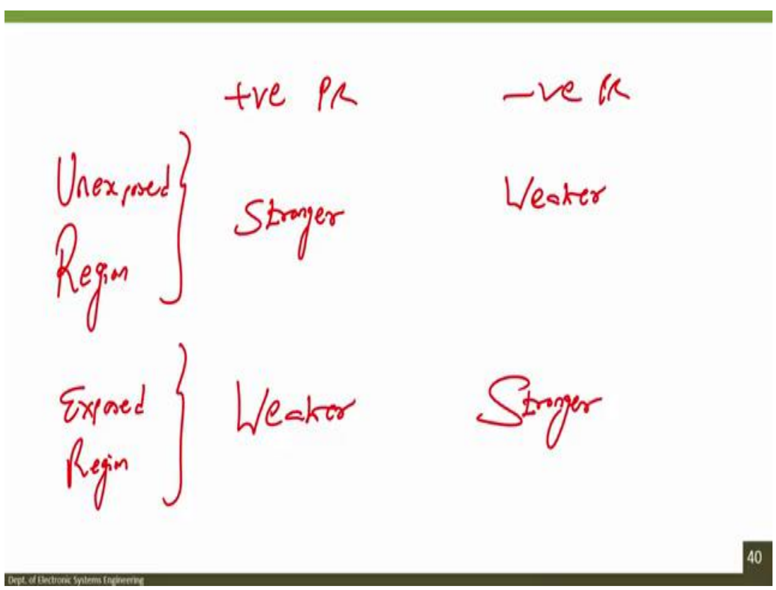

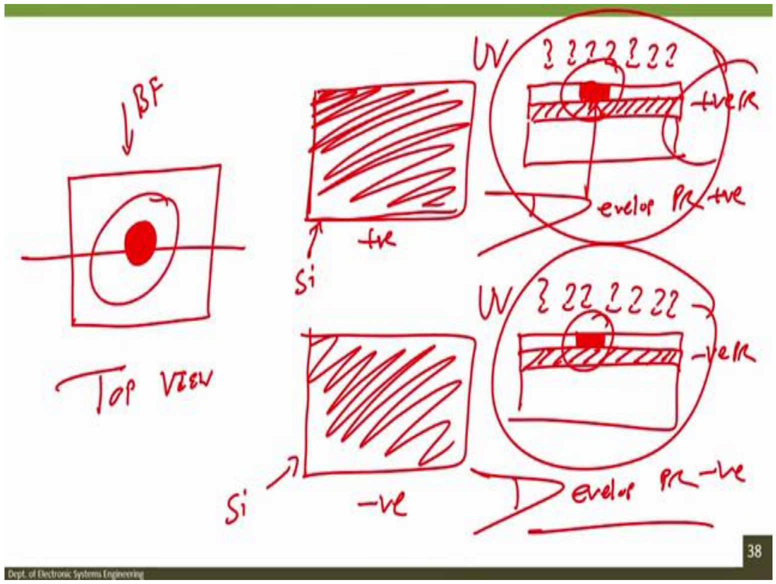

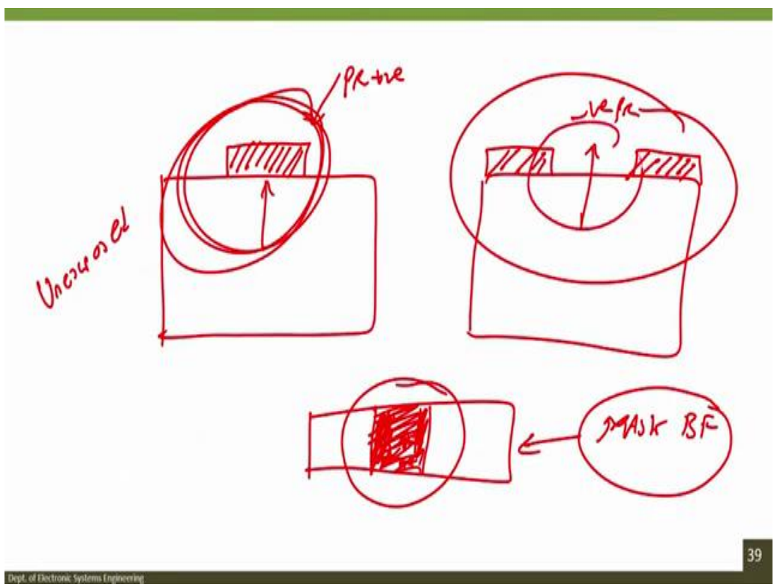

In another way you can say that the unexposed region let me exposed, let me write down in this one it is becoming easier, it is becoming easier for you, positive photoresist, negative photoresist. The unexposed region, unexposed region in case of positive photoresist will become stronger, in case of negative photoresist will become weaker.

Exposed region, in case of positive photoresist will become weaker, in case of negative photoresist it will become stronger. That you can see, see here the region which is unexposed, in case of positive photoresist is becoming stronger, the region which is unexposed in case of negative photoresist is becoming weaker. So, the unexposed region is stronger in positive photoresist, unexposed region in negative photoresist is weaker. If you say about exposed region the exposed region in positive photoresist is weaker, while the exposed region in the negative photoresist is stronger.

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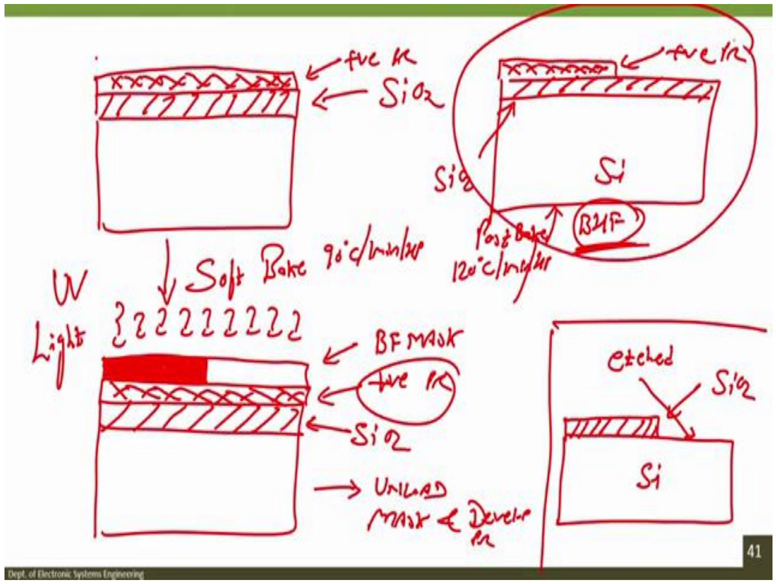

So, you now learnt how to grow a silicon dioxide on a silicon wafer. You know how to grow a silicon dioxide on silicon wafer, everyone. Yes, because we have seen thermal oxidation technique Sio_2. I am just going to silicon dioxide and one side of the wafer. Now, what I want is my silicon dioxide I want to create a step, you have seen the step earlier that we used to understand the thickness of silicon dioxide.

This step I want to create that means that in this region silicon dioxide is etched, it is etched this region, is it not? So, what I will do is to get this particular pattern I will start with a silicon wafer, grow silicon dioxide. The next step is I will spin code, spin code positive photoresist, I will spin code positive photoresist.

After coating positive photoresist, I will soft bake 90° 1 minute hot plate. After doing that, we will load the mask, so let me do it here, your oxide, you have photoresist, load the mask. I will load the mask there is pattern like this. Now, this is my bright field mask, after that you have to expose this wafer using UV light, after exposing you have to unload the mask, unload the mask after exposing unload mask and develop the photoresist, develop photoresist.

If I do that what will I have is silicon wafer, my oxide and photoresist will stay in the region which is not exposed to UV light. The unexposed region will get stronger in case of positive photoresist.

You can see the unexposed region is stronger in case of positive photoresist. Then next step is I will dip this wafer in BHF, BHF is, but before that I had to perform post bake, after this I had to perform post bake, post bake is done at 120℃, 1 minute on hot plate.

So, if you repeat it is positive photoresist spin coating, soft bake a 90° 1 minute hot plate load the mask, expose the wafer, unload the mask, develop the photoresist then post bake, post bake 120° 1 minute hot plate then you load dip this wafer in BHF, BHF will etch silicon dioxide from the area which is not protected by the photoresist, which is not protected by photoresist. If I draw it after this, this particular work, if I go to next slide, how it will look like.

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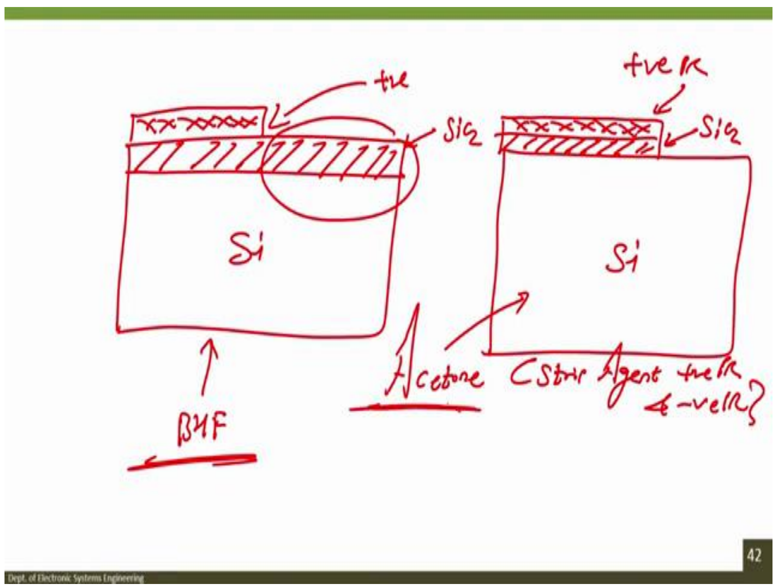

If I dip that wafer, which wafer let me draw it again here, the wafer where your positive photoresist was protected in this region and from remaining region positive photoresist was developed, this is your positive photoresist, this is your silicon dioxide, this is silicon. Now, I dip this wafer in BHF buffer hydrofluoric acid. Then what will I have? If I dip this wafer in BHF, what will I have?

I will have, this is positive photoresist silicon dioxide silica, you can see that silicon dioxide from this region got etched but the silicon dioxide that was protected by positive photoresist is intact. After this the next step is if I dip this wafer in acetone, acetone is stripping agent for positive and negative photoresist, for positive and negative photoresist acetone is a stripping agent. So, if I dip this wafer in acetone, what will I have?

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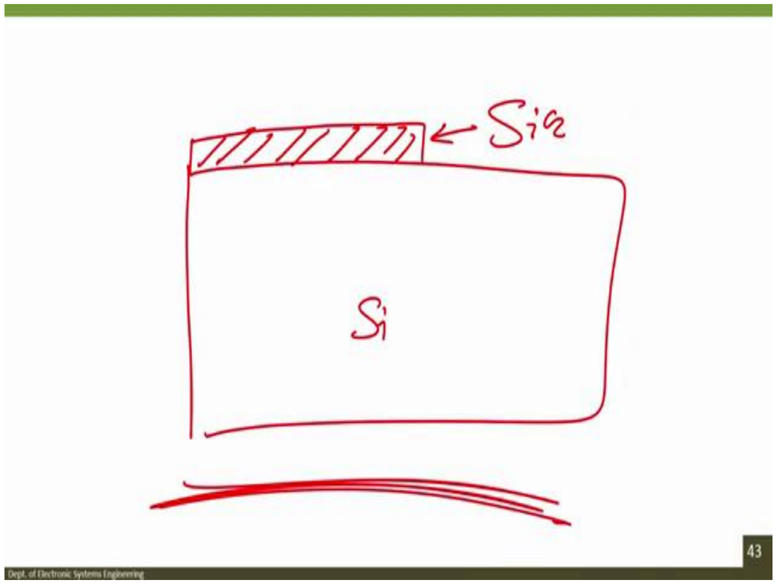
SiO2
Si
43
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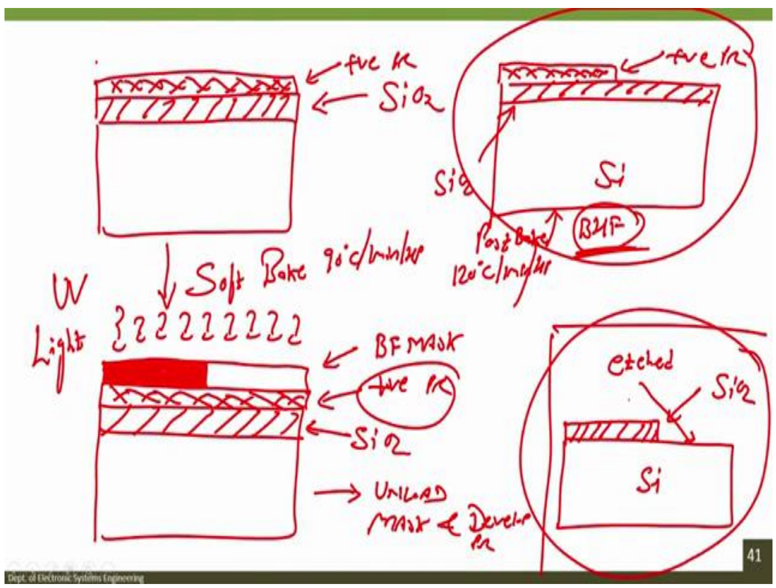
+ve PR
SiO2
Si
Post Bake
120°C
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UNLOAD MASK & Develop PR
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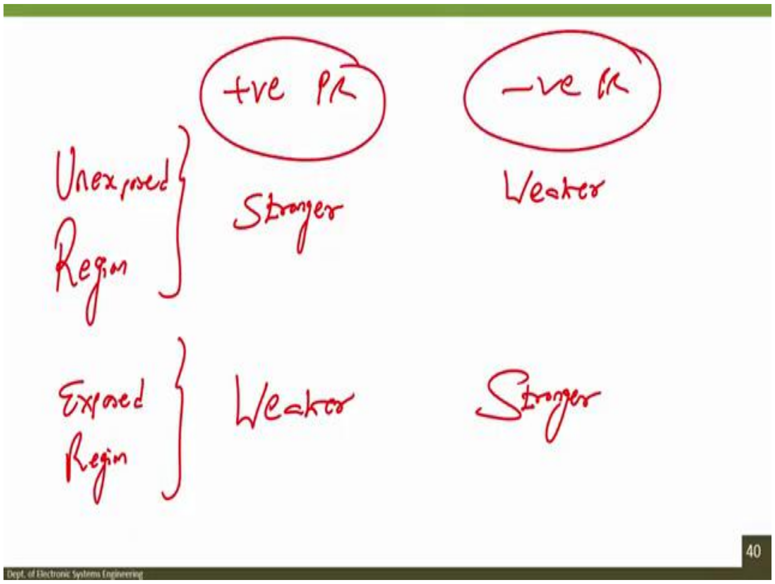

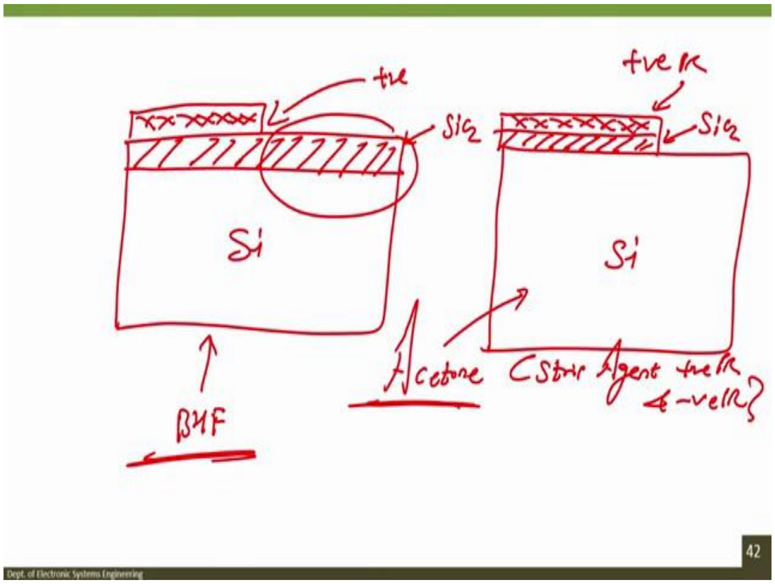

I will have silicon, silicon dioxide, this is what I want. Let us go back, you see here silicon and silicon dioxide same thing I got here silicon and silicon dioxide, is not it? This process is called photolithography. So, if I repeat this step you always understand positive and negative photoresist and bright field and dark field mask.

So, if you take a silicon wafer, if you grow silicon dioxide, spin coat positive photoresist, soft bake it is $90°C$ 1 minute hot plate, load the mask, this mask is the bright field mask, expose the wafer using UV light, then unload the mask, develop the photoresist in a photoresist developer, in this case it is a positive photoresist developer.

Then you post bake it at $120°C$ 1 minute on hot plate, after that, if you load, if you dip the wafer in BHF which is buffer hydrofluoric acid, you will etch the silicon dioxide and the area which is protected by the positive photoresist is saved after this if you load the, if you dip this wafer in acetone then your positive photoresist will be stripped off and you will get only silicon dioxide pattern on silicon wafer. This is how you created a step on silicon wafer, step is of silicon dioxide, this process is called photolithography, you got it.

So, this is an introduction to your photolithography technique. In the next class I will show you how the bright field mask looks like, how the dark field mass looks like and we will take an example of one single example of a sensor that has a multiple or you can say a chip that will have a multiple sensors indicated on to it.

With that you would have some explanation, some understanding about how the photolithography technique works and what was the reason of learning rather from silicon wafer through the oxidation to the lithography and how we can use this chip for a certain application. So, I will teach till there and as a part of the TA class and then later on we will see some other aspects of the micro fabrication as well. Till then you take care, I will see you in next class, bye.