Advanced Neural Science for Engineers
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Lecture 20
Soft Lithography - I

Hi, greetings, everyone. So, we were discussing photolithography in the last session, and then we have also seen the e-beam lithography just a function of that a schematic how the electrons are used to pattern or used for patterning different materials on the substrate. And a little bit about SU 8 and the difference between negative photoresist and SU 8 to an extent. I promised you that we will look into the soft lithography and we will also look into the mask alignment.

So, let us first understand the soft lithography part and then we will go to the mask aligner part. What does that mean is that if there are multiple masks how we will align the wafer with respect to the mask. And if you have first mask and you have pattern, certain material on a substrate, if you want to deposit another material.

And exactly on the top of the device, the material should be focused the pattern for the second material should be in alignment with the pattern of the first material. How can we align the entire wafer with respect to mass so we will look into that? Let us not worry about it right now. Right now we need to understand what is soft lithographic.

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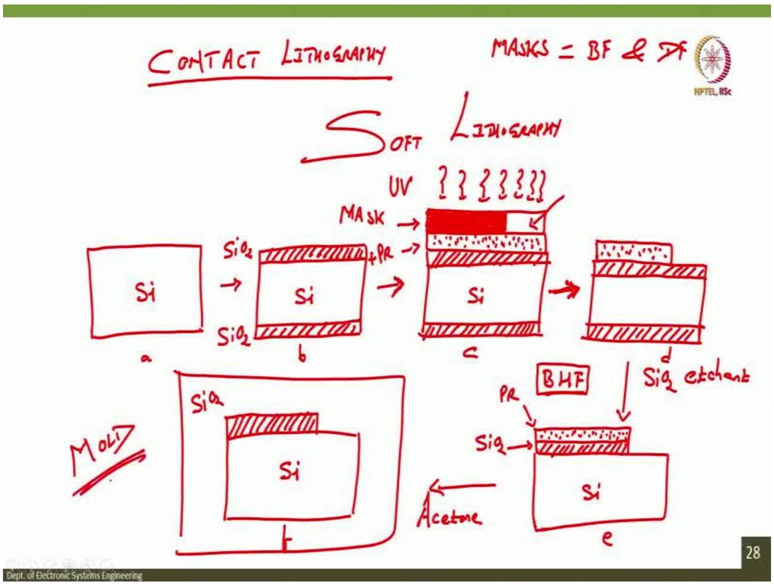

So if you see the screen until now we have seen the contact based lithography if you see the screen please contact the lithography in which I told you about the masks and mask are right fill mask and dark fill mask this must be known. Now what is the soft lithography let us look into soft lithography. So, you have as usual we take silicon as our substrate and then we grow silicon dioxide then the next part is we will perform a photolithography normal lithography let us see. So, we have to code the has been code the photoresist.

Let us been code photoresist. So, we will spin code the photoresist as you can see on this image and let us say photos this looks like this. Now, we create a step so, for creating step what is what we need to do we take a mask and we say that the masks look like this, this is your mask and then you expose the photoresist with ultraviolet light and assuming it is a positive photoresist.

Then you develop it you unload the mask and develop the photoresist in a photoresist developer. What you will get you will get. Is that correct? The unexposed region became stronger and the exposed region which is a region that you will light will pass through will get weaker and we will get developed.

So, this is now what we have so, when we start by spring coding photoresist you need to always understand that, that follows a soft bake at 95 degrees centigrade 1 minute on hotplate. And then you load the mask followed by UV exposure then unload the mask develop the photoresist by dipping the wafer in photoresist developer.

This is a positive photoresist, so we have positive photoresist developer followed by hard bake, hard bake is at 120 degrees centigrade 1 minute on hotplate. Now, our idea is to create a step and to do that, let us say the next step in this form the next step is we will dip this wafer in silicon dioxide etchant. What is silicon dioxide etchant? Do you remember? BHF - Buffer Hydrofluoric Acid.

So, when you do that, what you will get you will have your photoresist intact why because photoresist should have a high etchant resistance photoresist should have a high etchant resistance. So, it is resistant against the chemical which is buffer hydrofluoric acid it should not etch and the SiO_2 below buffer hydrofluoric acid is protected by the SiO_2 that was not covered by photoresist is gone.

Same thing happens here also you see in the backside SiO_2 from the backside is also etch when we dip the wafer in BHF. Now, the next step is that you strip the photoresist by dipping the wafer in acetone you strip the photoresist by dipping the wafer in acetone. So if you dip the wafer this wafer as I we give the name a, b, c, d, e, f.

So the e when we dip in acetone the photoresist will get stripped off and what we will have is the silicon dioxide for registered gets tipped off and what we have is the silicon dioxide as a step on the silicon. Now, this is our mold what do we call this as a mold.

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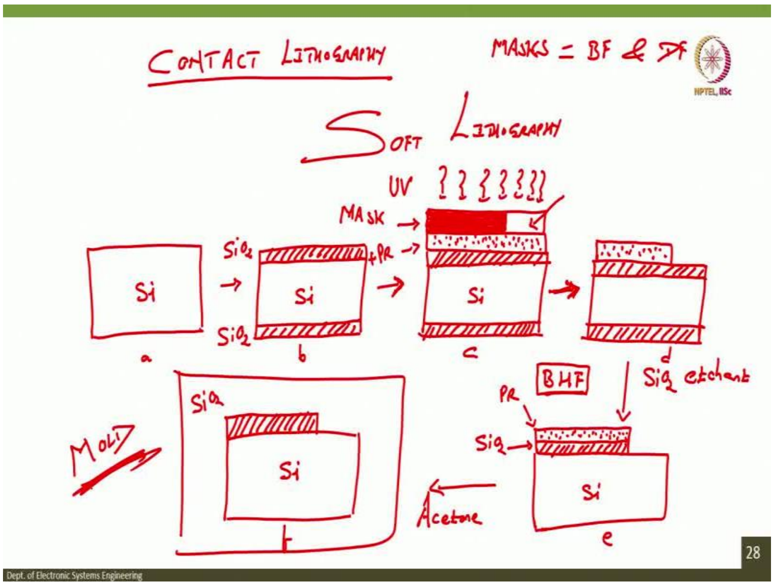

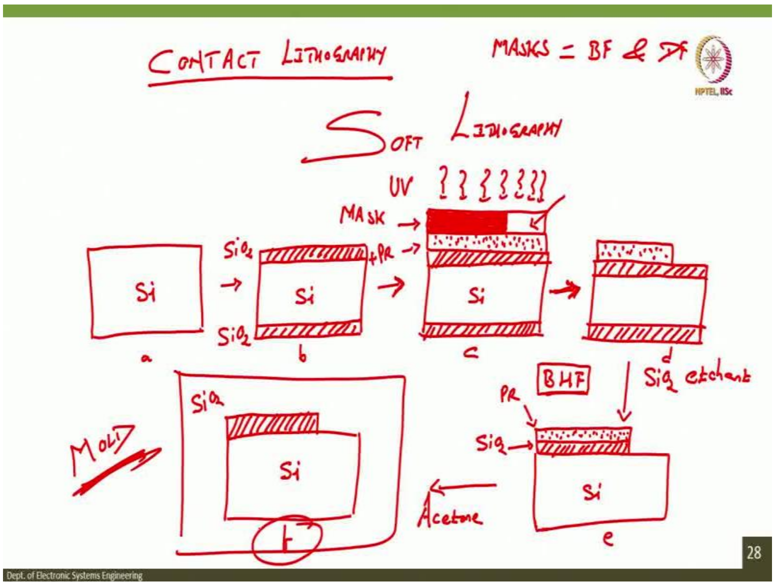

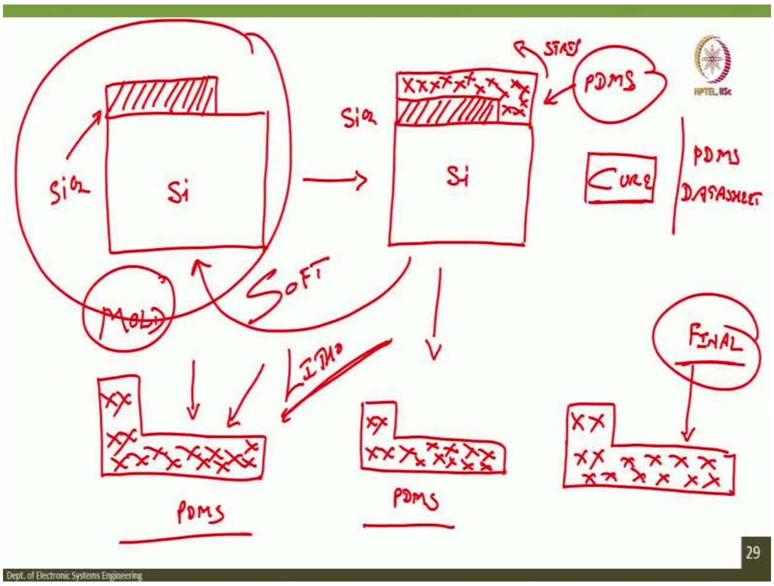

Now, if I want to if I want to have a device let us say a soft material, soft material that will look like this. Soft material that has pattern like this, this is what I want. So, what should I do? If I have a mold that we have seen previously, in which the silicon dioxide step was created you see this one the mold silicon dioxide step was created which is f this one.

Then if I take this wafer and pour PDMS, PDMS is also called a silicone. This is SiO_2 silicon and then we pour PDMS over the substrate. And then spin coated we poured PDMS over the substrate and spin coated. After spin coating, we cure it in PDMS data sheet you will find the parameters for curing the PDMS. So, once you cure it by hitting it at certain temperature in an oven, then you can strip this off, you can strip PDMS from the mold.

If you do that you see you have to strip it off and what you will have you will have PDMS like what we want in this final pattern, of course, do not worry about the thickness and all these things. So, now the point is that, to this is one time you have created this pattern. So, when I strip this off strip it off from the substrate, what I will have I will have my mold back.

See that when I strip this PDMS off, I will have my mold back. So, if I have my mold back can I pour PDMS again? I can again pour PDMS. Is not it? So, I am again pouring PDMS and I am curing it after pouring after curing I am stripping it off so, if I strip it off I will have my pattern once again the one that I want I am repeating it again and again and again.

How by stripping this PDMF off by step PDMS from this mold of recording it what I will have I will have my mold back that means every time we are patterning we are patterning PDMS but we are not using the UV light we are not using soft the photoresist we are not doing soft bake, we are not doing hard bake, we are not using mask alignment nothing just from the mold you keep on creating the PDMS structures.

This is called the soft lithography, got it is called the soft lithographic. So, easy you understood if once you have once you create a mold you can this use this mold for n number of times till the mold does not break. If mold breaks than we had to start again. So, this is about soft lithography.

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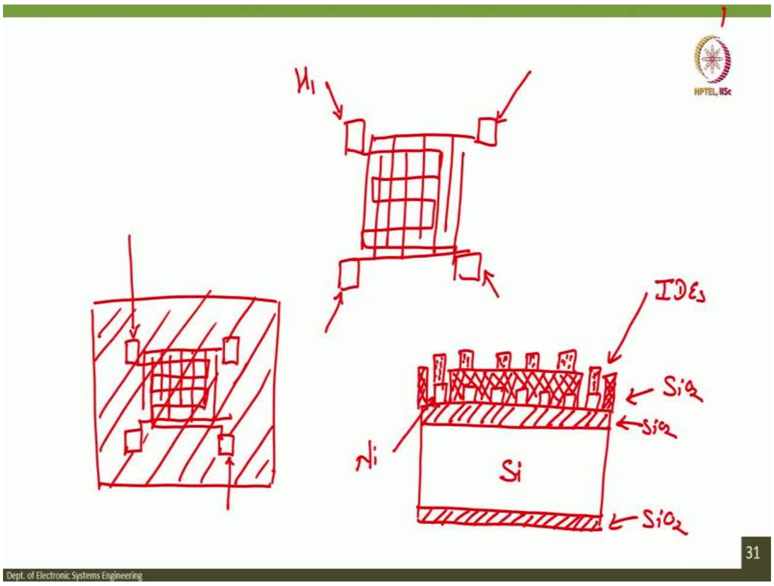

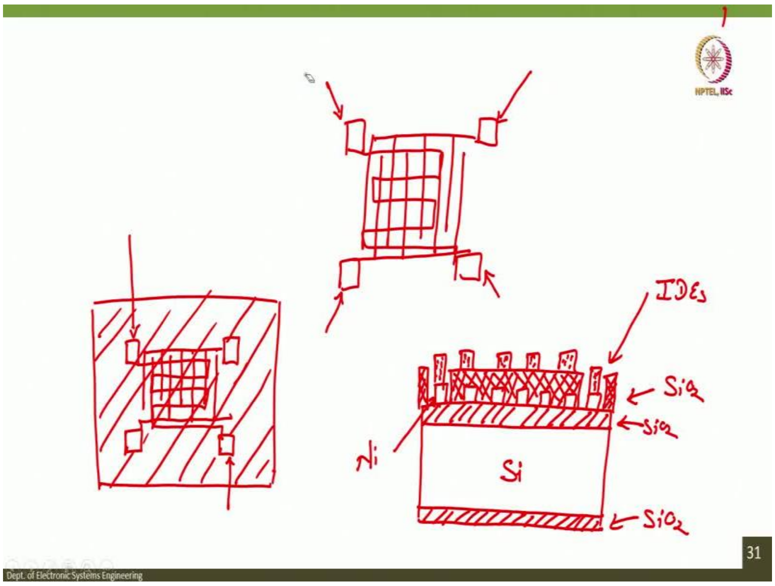

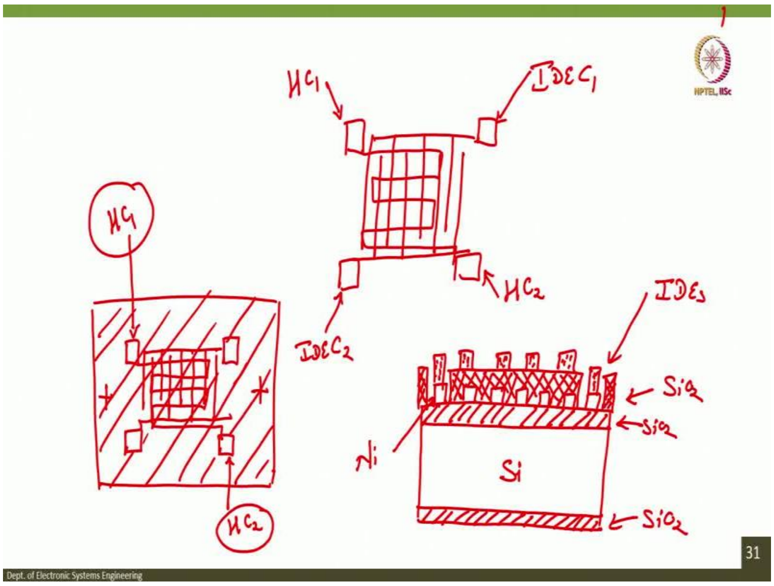

Now, let us see a very important point which is your patterning. How we will pattern different materials? And how we will align it? That is something that we need to see so let us understand. So, we will fabricate will go to do one more slide back.

So, we will fabricate we can take an example of a chip with microheater then an insulating material insulating material the micro-heater is of less than a nickel then on top of that we want to have interdigital electrodes this is the context of the interdigitated electrodes. Is there cross section schematics so, let us not worry too much this can be the context where the IDEs is interdigitated electrodes.

So, if I have a top view it will look something like this and then on top of this on top of this that is insulating material everywhere then you open the contact area this one and this one and on that top of this you deposit a metal and you create interdigitated electrodes like this. So, if I draw it here without insulating material it looks like this, but understand that the below the interdigitated electrodes, these are contact pads for interdigitated electrodes these are contact pad for the heater. So, it says heater, heater contact pad one. So, let us say HC1 heater contact pad two HC2, IDE contact pad 1, IDE contact pad 2. So, between interdigitated electrodes and a heater since both are metals, if I deposit directly metal over metal, I will have a short circuit.

So, there should be an insulating material below it and this is what we want to create we want to also make sure that when we deposit the insulating material after microheater the contact pads, the contact pad should be opened because otherwise you cannot take the contact from your heater contact 1 and heater contact 2 if it is covered by the insulator.

So, once you have silicon dioxide as an insulating material you have to perform photo lithography and open the heater contact 1 and open the heater contact 2. Now, important stuff here is that this should be properly aligned that means that the interdigital electrode should be on the top of the micro-heater if there is a misalignment it is not ok. Is there a misalignment, it is not ok. So, how to align this thing? That is a question, is not it?

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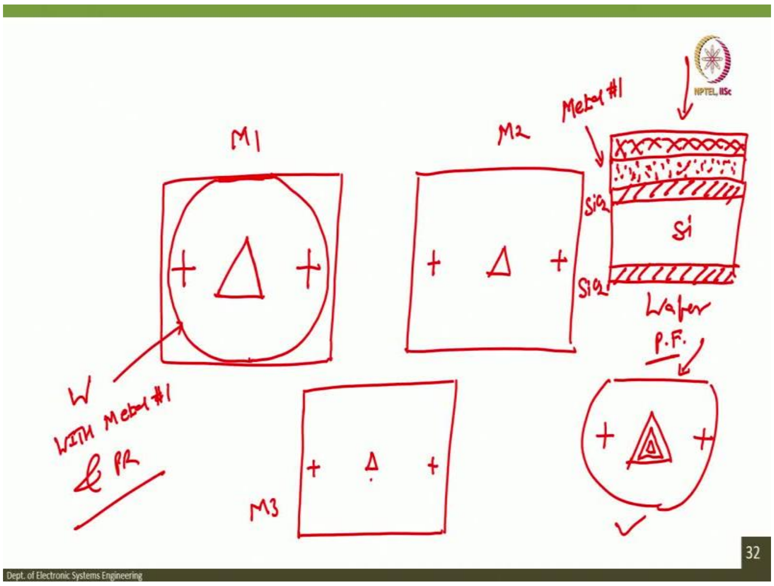

So, for that if you see until now whatever mask we were drawing, we always had alignment mark onto the mask. So, let us say this is the first alignment mark, this is the second alignment mark, this is the third alignment. Now, we think that there is a triangle then there is a smaller triangle and even a smaller triangle then the second triangle.

So, finally our wafer on which we are patterning this triangle it should look like this, three triangles first one, second one, third all in the center of the first triangle just to make our life easier, and I am just drawing a little bit bigger triangle. So, we understand first one, second one third one. So, we have big triangle smaller triangle and smaller triangle like this.

You see that this mask so, mask 3, mask 2 and mask 1 all three mask is having what alignment mark this plus is an alignment mark. Instead of plus you can have circle also you can have square also whatever you feel is good for aligning your wafer you can use that one. So, now you have plus you can have many element mark at different places.

So, the first time the for the first time when you take the wafer spin code with photoresist and then align with the mask one alignment mask one what you will do we have a wafer oxidized silicon wafer let us say and I do not like too bad drawings as well. So, this is your silicon dioxide and you have let us say one metal here this is your metal one silicone, silicone dioxide, silicon dioxide.

This is a wafer that we have and what do we want all three triangles should ally such that the smaller triangle where my mask three should fit in the triangle for mask two it should fit in a triangle for mask one. These are all metal triangles. So, metal one is that so, when you have first time metal you do align.

Now you see there is a primary flat. In the TA class where I taught you about the silicon wafer after that we you will be taught about the orientation of the wafer. So, please focus on that and see that how we understand wafers are determined with respect to primary flat and secondary flat. So, now with respect to this primary flat will align here this one and such that they wafer or not so easy to draw when a circle is not it looks like this.

If it looks like this what does it mean that I have a wafer with metal one and my photoresist on metal one all photoresist on metal one. So, this wafer would have photoresist below which there is a metal you assume like that it is. This how it is this one, I am not drawing it here, just to make you understand I am not drawing it.

So, now what do you see that you have a metal, represent them by dots, for which you have a photoresist. So, there is a wafer with metal one and photoresist. You will do UV exposure what you will have when you develop the photoresist the area which is not exposed will get stronger. So, this area which is drawn by the triangle and drawn by the alignment mark will get stronger after that if you dip the wafer in metal one etchant what will happen the area which is protected by photoresist will not get etched, is not it?

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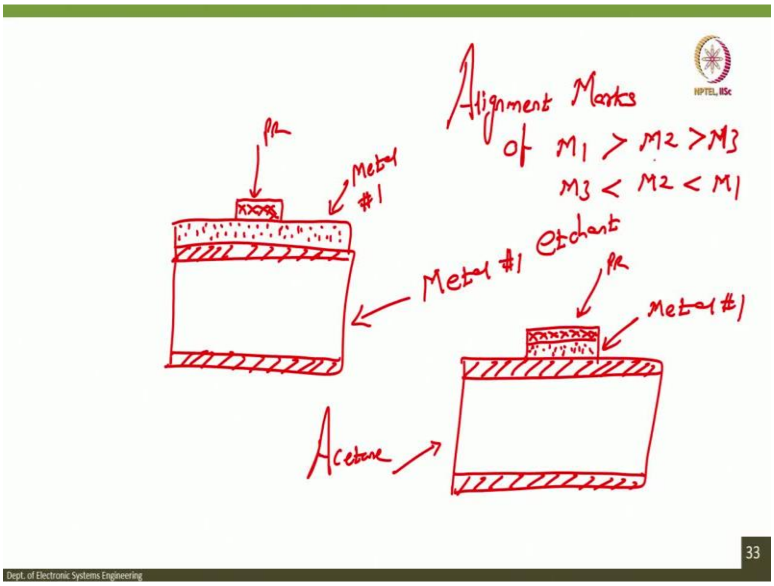

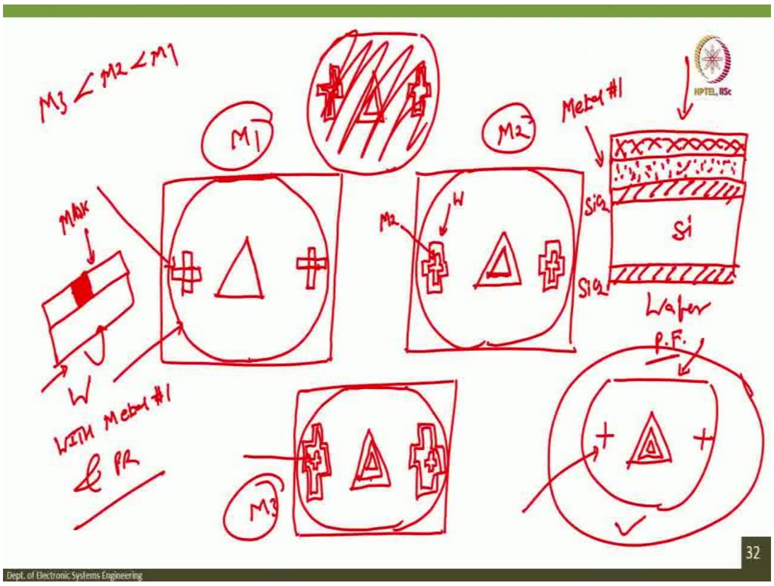

The area which is protected by photoresist will not get etched what does it mean? So, if I have let me draw this silicon wafer oxide, on oxide there is a metal and then when we use that particular mask which is this mask triangle then and we expose it and we expose it. So, in this we can show that the photoresist is only in this only left in the area which is not exposed by the UV light.

The photoresist will remain the area which is not exposed by UV light this area and of course alignment mark like this that the photoresist will be there. And below the photoresist the metal will be saved. So, if I etch this by we do hard bake and followed by metal etching. So, metal one which is this one if I did this wafer in metal one etchant what I will have all the area all the metal we get etched except the metal which is protected by this particular photoresist. Is not it?

Metal will get etched except the region which is protected by the photoresist and then I will remove or strip of the photoresist by dipping this wafer in acetone. So, when I do that, what do I what do I have, I will have I will have my wafer with alignment mark and metal in the center. This is my first mask. Now the second metal here we need to, again deposit our material.

So, once I have this wafer with this pattern, I will deposit another metal on it. We do not worry about the short circuit here we just want the design here. One triangle, second triangle, third triangle so, I will deposit a metal then photoresist spin coating, soft bake and followed by alignment mark so alignment mark. So, I will take a wafer and align it again.

Now you do understand that I had wafer with this alignment mark pattern on the wafer as you can see here. You can see here, alignment mark has already there on the wafer. So, what happens is if I really zoom this alignment mark, then I will see that the element mark is just not plus, but it looks like this, but here the alignment mark of mask two are there already and wafer had the alignment mark from the mask one because that area was protected.

Remember see this one this alignment mark that will come on the wafer one because once we etched and get the wafer, we will have a triangle and then we have the alignment mark from our wafer one. And the alignment mark of masks two is smaller than an alignment mark of mask one if you have noticed and the alignment mark of mask three will be smaller than alignment mask of masks two.

So, again the alignment mark or marks of mask one is greater than mask two is greater than mask three or an alignment mark of mask three is smaller than mask two is smaller than mask one either or is correct. Why we need to have an alignment of second mask smaller than mask one because we have to make sure that the wafer that has been processed through mask one the alignment with mask two happens correctly.

And that will happen when the alignment mark of mask two fits well within the alignment mark of the wafer. This alignment mark of the wafer and the alignment mark of mask two should align well and then only the second triangle the image this is from the mask but the wafer also has a triangle here and if it does not only have a triangle, but there is a metal on the triangle.

So, make sure that the alignment mark of masks two is smaller than alignment mark of mask one so that this second triangle, the design would fit exactly in the center of the triangle one. Then you have to expose it with UV after alignment and then to develop the photoresist and when you etch it the etchant wall metal two should not affect the etchant for metal one otherwise, the etchant for metal two should not affect the metal one otherwise the triangle the bigger triangle will get etched.

So, now once you have that, you have a wafer with two triangles and two alignment marks like this align in the middle of the first alignment mark, two triangles alignment mark. Now, we again deposit another metal spin coat photoresist, soft bake it align it with the third mask. And you already know that the alignment mark for the third mask. I do not have alignment mark of mask three can be smaller than mask two smaller than mask one.

So, my wafer would already have two triangles and alignment mark something on this domain. And second element mark like this. So, the third alignment mark which is here that should fit in the center of the second alignment mark which is already there on the wafer. Then, you are aligning the mask three with respect to the wafer that has been processed to mass two.

Once you do that, you expose it hard bake it, develop it develop the photoresist hard bake, etch the metal three, the metal three etchant should not affect the metal two or metal one material metal two or metal one material. So, the end of the day, when you do this what you will have you will have the wafer which will look like this of course, there are many alignment marks I just did it for ease of representation.

I was just drawn two plus but this is how the process is done. Now, it is everything is on a very large scale actually the dimensions are way smaller than what you can see on this particular screen, particularly the alignment mark is concerned. So, this is how the alignment is done. And that is why the mask the wafer has to be aligned with respect to the mask, mask is stationary and we can we can move the wafer.

Once you align the wafer then you make us hard contact until that you have some spacing between your mask and your wafer so that you can rotate the wafer you can move in x axis you can move in y axis. And once it is done, then there is a hard contact between when the alignment is done there is a hard contact between wafer and your mask. There is a hard contact between the wafer and your mask once the alignment is done.

So, now you I hope that you got some idea about how the alignment mark works, what is the role of the alignment mark when we talk about the photolithography. So, now, we will the stop here and in the next class I will tell you how the SU 8 can be used as a mold. We have seen silicone as a mold, what about SU 8 as a mold once we understand SU 8 as the mold will quickly cover the micro machining session and in that we will be looking at the bulk micromachining surface, micro machining and then moving forward we will understand the chemical weapons operations.

Now, once you grab all this thing, understand the digested then we will go into the neural part better understand what are the signals how the signals can be captured or acquired with the device and how it can be processed further. So till then you take care as soon as you in the next class training any questions asked me through the NPTL portal and I hope that you understood the importance of the alignment marks you understood what is soft lithography and you are not getting too much board.

It is a little bit different than the traditional way of understanding the different topics in different courses. Because it has a mixture of the chemistry because a lot of chemicals are used, right recipes, right process flow. What kind of mask we design that means you have to understand the CAD. We will take a class on mask designing and then the vision that what exactly how the device should look like.

So, but believe me that once you understand all these things, the game will be very easy for you to play. So, I will see in the next class till then cheers.