Integrated Circuits, MOSFETs, OP-Amps and their Applications
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Lecture - 04
Introduction to IC fabrication Contd.

Welcome back. So, in the last class, we were discussing about how to fabricate and interdigitated electrodes right. So, what I have shown you is if I want to fabricate an interdigitated electrode on oxidized silicon substrate. What are the processes? Correct and before that we have seen the substrate which is silicon and how silicon is manufactured from the bowl.

So, the next step would be to create a SU 8 well. So, let us see what we want to do and then we will continue. So, if you see the screen the class was on understanding the fabrication of integrated circuit and we talked about silicon we talked about the clean room.

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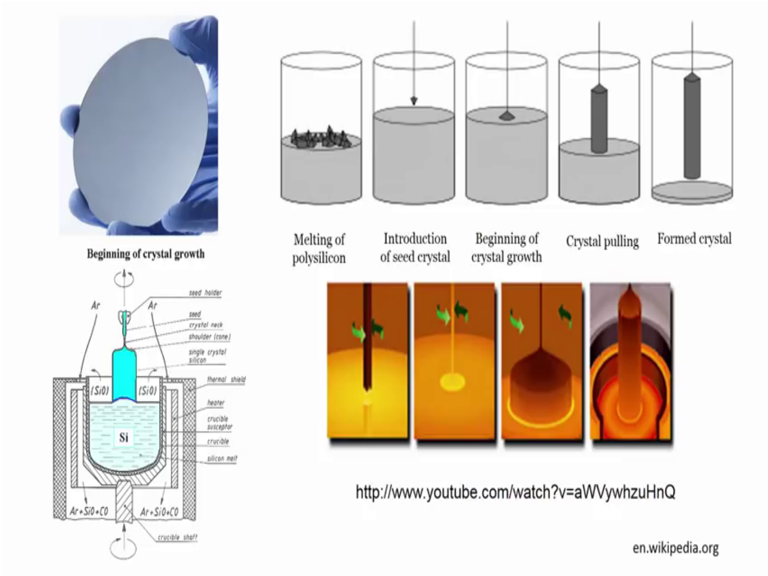

We talked about the process.

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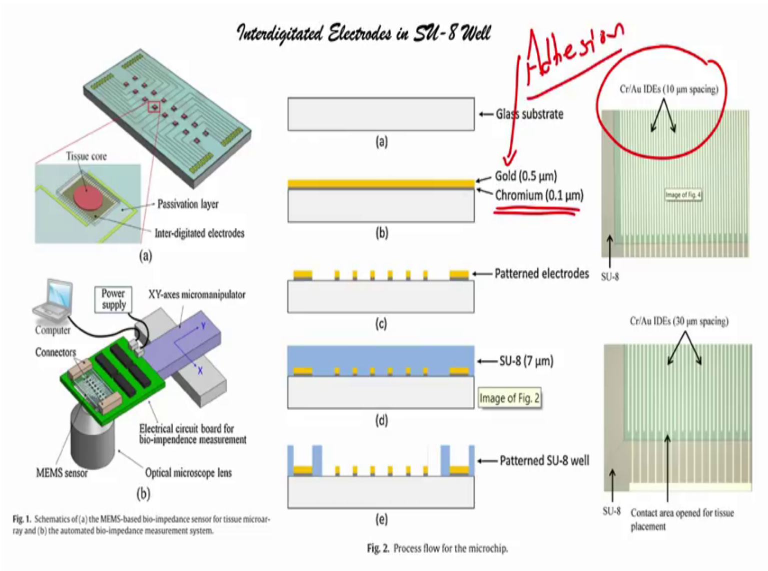

Then we came to this particular slide and then we have seen how you can create or fabricate int or interdigitated electrodes. An interdigitated electrodes right with metal that is chrome and gold; I said that chrome is used to improve the adhesion, a, d, h, e, s, i, o, n, adhesion of gold of gold right.

So, we have seen that now we have not seen that. Now, we will deposit this gold what is the technology to deposit the gold that we will discuss in the next lecture. This lecture particularly this particular module is to understand how we can finally, fabricate a sensor? A sensor with an SU 8 well you see this is a well right you see this entire section is a well and there are electrodes tri electrodes inside the well.

So, how we can create this particular this particular sensor?

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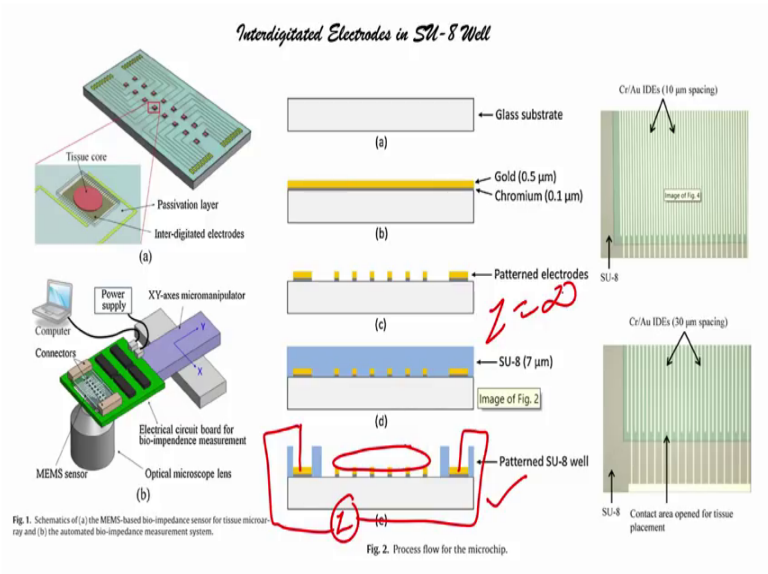

Which is shown, in e in this particular figure right e you see and what is the advantage of sensor? That once you have this sensor, if you place the tissue if you place the tissue on this interdigitated electrodes, then you can measure the impedance of the tissue right. Initially when tissue is not that your impedance would be like I said infinite; When you place the tissue, you will see a change in dependence which you can measure it is not anymore infinite it is not anymore infinite right.

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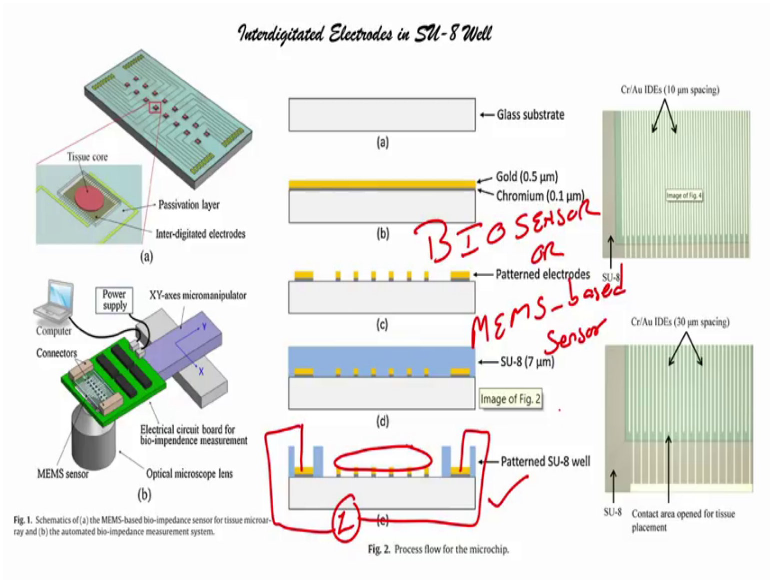

So, the idea is that let us have this kind of sensor this sensor can also; we can also call bio sensor or we can say MEMS- Micro Electro Mechanical Systems based sensor all right. So, we are looking at this particular process. So, that we can finally, understand the MOSFET right. So, this if you see this particular images this one.

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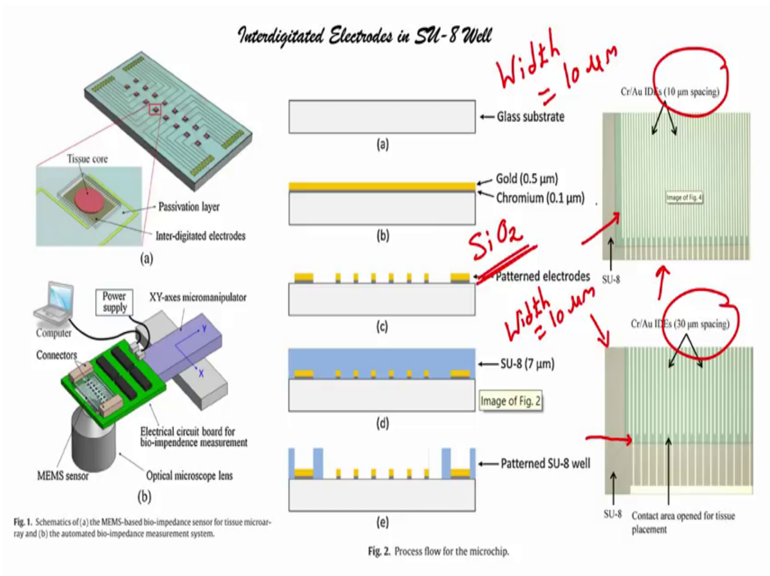

Alright, what we see is there are interdigitated electrodes with spacing. So, the width w i d t h width is 10 micrometers and spacing is 10 micrometers.

While if you consider this image, the width is 10 micrometers, but the spacing is 30 micrometers alright. And you can see a greenish color can you see greenish color here or greenish color here right. This green color is because of the oxide layer on silicon this green color is because of the silicon dioxide silicon dioxide. We will see how we can grow silicon dioxide as well in the in the following lectures right.

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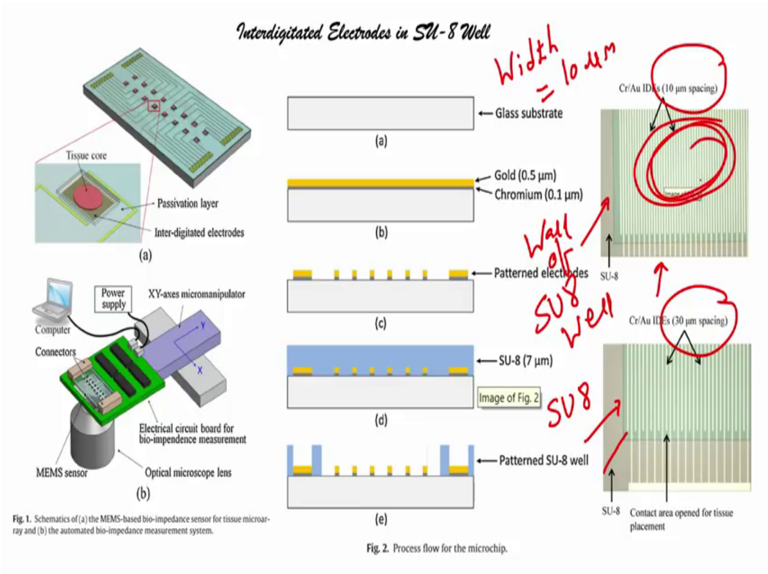

Now, you see this particular color which is brownish right brownish and that brown color comes of SU 8 actually SU 8 is transparent, but when you deposit SU 8 on the oxidized silicon substrate you will see the change in color. This is an optical image taken from the metallurgical microscope. And within this SU 8 that is why you can see here it is like a like a well like a well right and this interdigitated electrons are within this well. These are the walls of the well this is a wall of SU 8 well and in this well, we will place the tissue alright that is idea.

So now, let us quickly see let us quickly see what we have understood how we can design the interdigitated electrodes.

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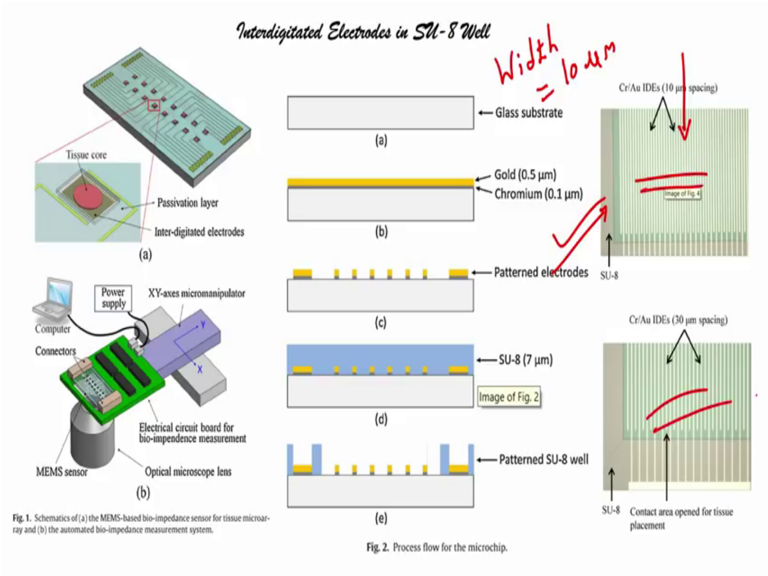

And then finally, how we can design the SU 8 well that is the idea.

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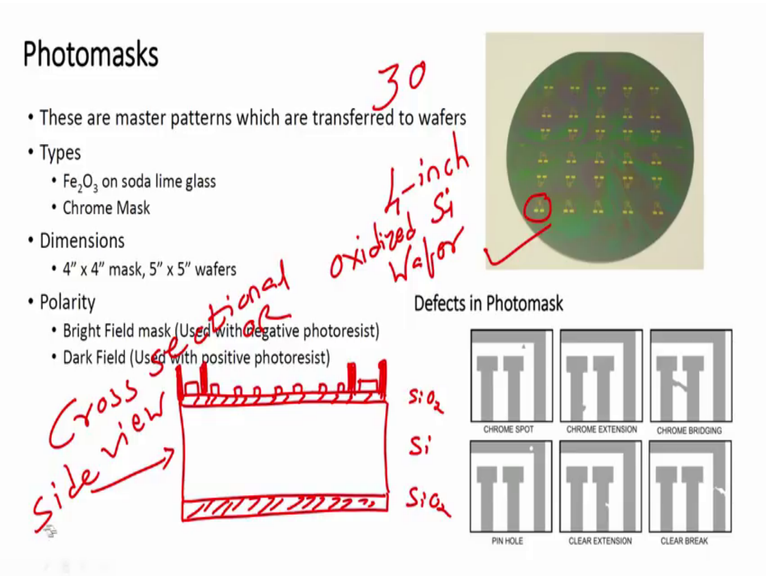

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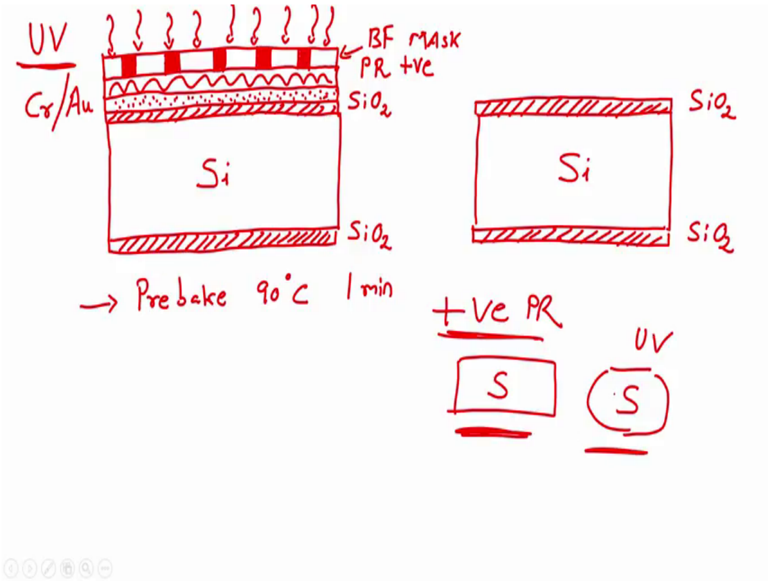

So, let me draw here what we saw what we have what we have seen until now is, you take an in to take an oxidize silicon wafer, I will draw 2 wafers right. Then you grow silicon dioxide, you grow silicon dioxide. This is silicon dioxide. What you are doing? You are growing silicon dioxide and understand this thing because the same kind of process steps you will use to fabricate your MOSFET as well alright silicon dioxide.

Now, on this silicon dioxide we have to deposit we have to deposit what? Chrome gold. We are you deposit thin layer of chrome followed by the gold of our required thickness thin layer of chrome followed by gold of required thickness. That is, chrome gold right. On this chrome gold, we have spin coated photoresist we have spin coated photo resist this photo resist was positive photoresist. Correct on this we placed a mask we placed mask was the cross section of the mask, is here cross section of the mask right. This is your mask correct and then this is which kind of mask? This is my bright field mask. Right let me write be clearly, bright field mask correct this much was easy.

Then so, what we missed after we spin code photoresist after we spin code photoresist. We have to pre-bake it at 20 degree centigrade for 1 minute right; that means, let us start from scratch silicon oxidized silicon that is silicon dioxide we have grown. On that we had deposited chrome gold, on we have spin coated photoresist after photoresist we will pre-bake for 90 degree. Then we will we will load the mask and we will do the hard contact. Hard contact means 2 contacts are in touching each other. Alright mask is touching the mask is touching the wafer, spin coated with photoresist this much easy very easy.

Now, we expose this we expose this wafer with the mask loaded on it with UV light ultraviolet light alright; what we do we expose this wafer with masks loaded on it with a ultraviolet light. Once we expose it what will happen I told that if I use positive photoresist. Then whatever the pattern is there on the mask right if my mask says s then my wafer with photoresist right, when exposed with UV and developed I will get the same, s I can retain the pattern. So, if I use positive photoresist and if I mask is this I will get a wafer which is similar to it right this is what we have understand this is your way understood.

Now, let us see let us see once you expose it, what you have to do? You have to unload the mask.

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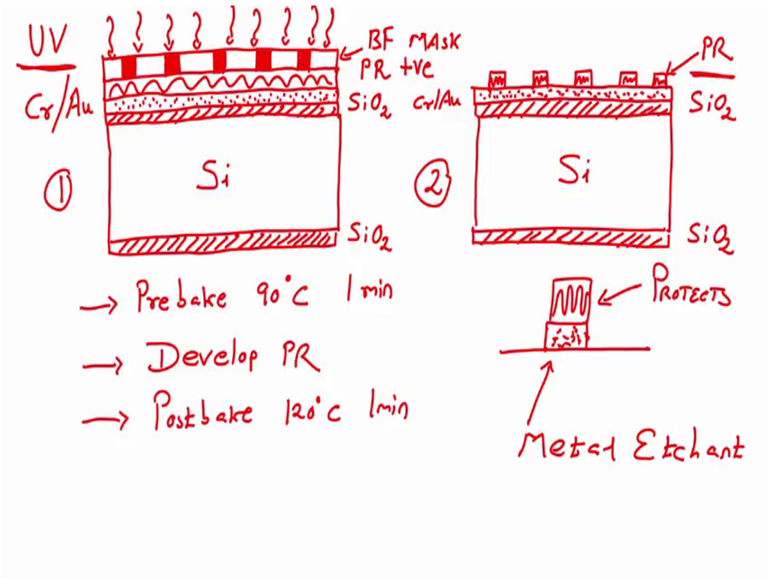

Unload the mask right and develop developed photoresist once you develop the photoresist; however, wafer will look like? A reefer will look like your wafer we will look like the one that I am drawing here like this so; that means, I have chrome gold I have my photo resist this is after developing. After developing, I will get this after developing pr I will get this particular wafer from this one. So, one I will write 2 I will write 2 easy.

Now, after we develop the photoresist it looks like this. Now, what is the next step? Next step is, we have to post bake it post bake 120 degree, 1 minute right. Post bake 120-degree 1 minute. So, that this gets this gets hardened, this photoresist is a polymer. After exposing and developing this will get soft so, we had to harden it harden the polymers right. So, I am again telling you in terms of very basic experiments alright this, itself is a whole course. So, do not do not get too much confused you just follow the step pre-bake develop post bake. After post bake, what we have to do? So, this what; it will help the metal below it not to get etched.

The photoresist if I see you here, right and if you see the metal here metal layer is here like this correct and the photoresist is here. If I put this in metal etchant, then what you will observe is what you will observe is the metal from all the sides will get etched. Except where photoresist was there except photoresist was there; that means, this photoresist will save my metal. Right so, it protects it protects the metal below it protects the material below it that is the role of photoresist.

Now, once I have this photoresist, my next step my next step is, that I have to I have to etch the metal. So, next step would be I will load this or I will put this wafer in the gold etchant.

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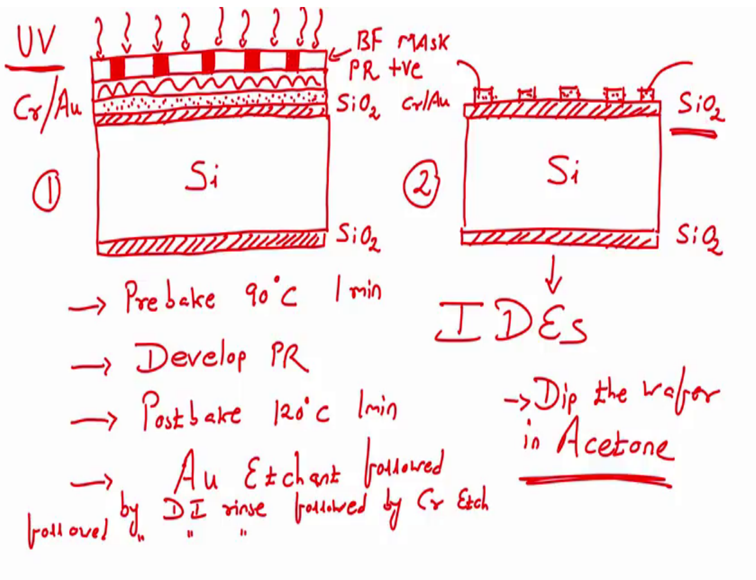

Right followed by DI rinse followed by chrome etchant followed by DI rinse right. This is a next step after I have after I have photoresist on this chrome gold. I will follow this step, which is I will first etch gold then I will rinse it, then I will etch chrome then I will again rinse it. Once I do that what I will get? You already know what I will? Get we will get we will get the metal below the photoresist would be saved.

It will not get etched metal that is our chrome gold will not get etched, do not get removed. Alright and the metal from other areas will get removed from other areas will get etched easy very easy.

So, if that is the case, that is the case what is my next step? My next step would be I will dip this wafer which wafer? Now, the wafer that I see right now in front of me which is my wafer number 2. This one this one I will dip this wafer in acetone in acetone. Why? Because acetone will work as a stripping it works as a stripper. Stripper for what it will strip the photoresist it will strip the photoresist; that means, I will have I will have only only chrome gold. I left with chrome gold and this is what these are my interdigitated electrodes interdigitated electrodes. So, easy right

So, from silicon from silicon to chrome gold we can do the following or we can follow this process to get what is it interdigitated electrodes. It is like digits which are interrelated right, but not connected to each other. You can see there is not connection no connection; that means, if I measure the volt that; that means, if I measure the impedance between two electrodes right, if I measure the impedance across this then I will see infinite impedance or resistance across this in finite resistance. Because, metal is not connected and in between metal there is an insulator which is my silicon dioxide this much is easy extremely easy.

So, from here what we got? We have got this particular wafer. This much which one the electrodes this electrodes all right. This electrodes this we have patterned it excellent. Now, we had to pattern the SU 8 right because the electrodes where within the SU 8. So, what is the next step? So, I will start with I will remove this. Let me remove it and we will start with the wafer which is already having this interdigitated electrodes this one right this wafer we want this one.

So, let us use this wafer and let us form the SU 8 well. So, interesting so, let us remove this let us remove this let us clear the screen. And let us see how we can how we can form the SU 8 well alright SU 8 well excellent.

Now, what we had to do? We had to form the SU 8 well. So, I will take the wafer.

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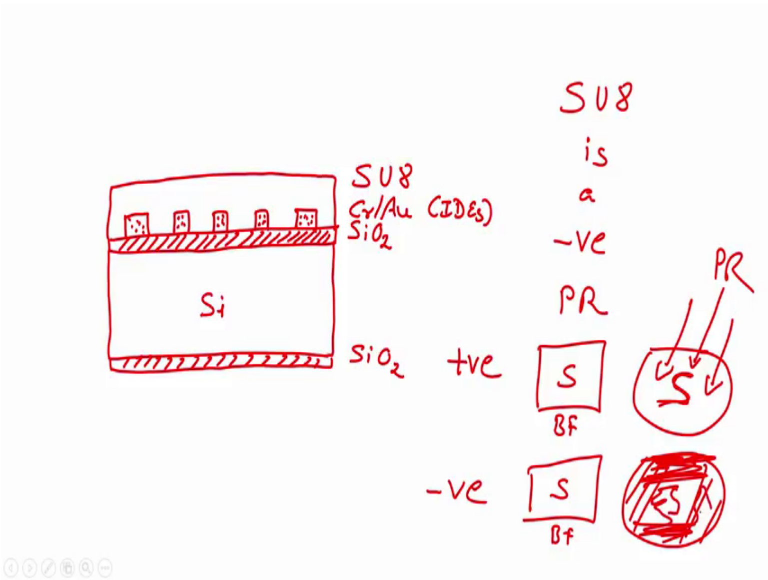

I will which wafer which already has the interdigitated electrodes. So, I can directly draw oxidized silicon wafer on which I have chrome gold. Right chrome gold has interdigitated electrodes. On this on this I will spin coat SU 8. Alright SU 8 is a negative photo resist. Until now what we have seen? Positive photo resist right positive photoresist, what happens? If I have a mask then my wafer would have same pattern. In negative this is my bright field mask.

In negative photoresist reverse happens if I have my mask right bright field my wafer everywhere I can have the, what you call the material except in this area except in this S. So, S would be not there in other than S everything would be there you understand opposite of this will happen opposite of this only this S would not be there. So, let me just quickly draw like this is assume that this is the metal everything metal is there and if I use a negative photoresist, what will happen that is see. If I use a negative photoresist and I use a bright field mask then, exactly opposite of my bright field mask of positive photoresist the pattern will be exactly opposite let us see.

Now, my pattern would be very difficult. So, anyway point that I am making is, everything would be let me draw like this is better, except this area. So, you see here everywhere the metal is etched right metal is etched metal is etched here the metal is there or the PR is there right. In this case only in this s region PR would not be there PR would not be there other all the region PR would be there everywhere PR would be there. Except this S region everywhere PR would be there alright.

So, to give you a better example to give you a better example here you remember that here you remember that positive photoresist.

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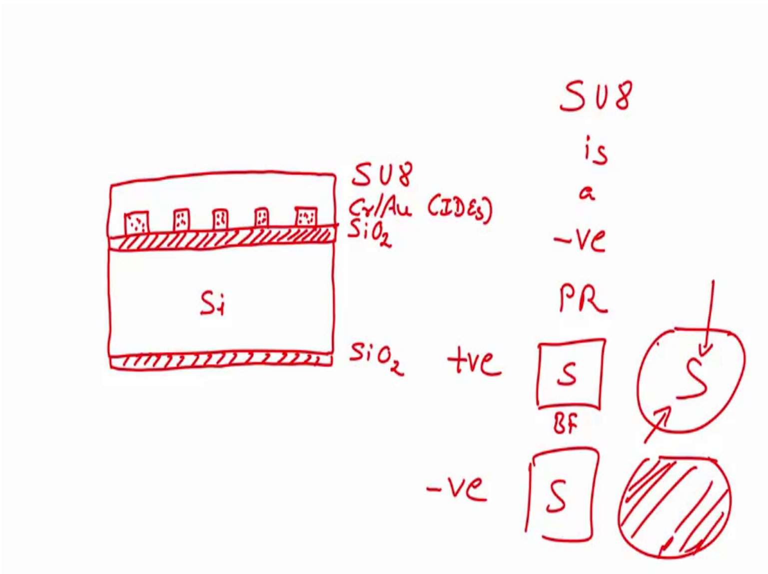

Same pattern; So, let me draw wafer let me draw wafer same pattern you get. Negative photoresist opposite of this will happen opposite of this. Where there is S there will be nothing, where there is nothing everywhere there will be photoresist. You got it everywhere there will be photoresist there is a role of negative photoresists.

Now, what we had to understand where I will teach you negative photoresist in detail in some lectures. Right now, let us see that SU 8 is a negative photoresist.

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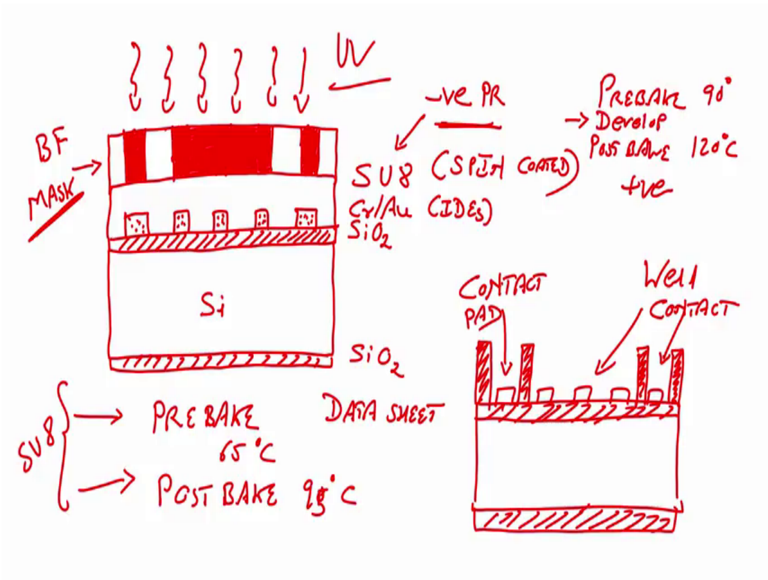

So, when you have SU 8 as a negative photoresist, you how can you make the well? Right your idea is your final idea is that you should have a substrate you should have a substrate right. Let me remove this you have a substrate with interdigitated electrodes and then you have SU 8 well. This is what you want this is what you want right this is the well. This is for the contact right this is also for the contact pair contact right.

So, we this is our final device this is our final device it should look like this, where were we? We took the oxidized silicon wafer with interdigitated electrodes and on interdigitated electrodes, we have spin coated SU 8. What is the next step? Next step is we have to pre-bake it pre-bake. Now, how you know that what is the temperature for a pre-bake?

How you know; what is a temperature of for post bake? How you know that what is the next step? When we use SU 8 it is already given in the data sheet. When you get the SU 8 the manufacturer already gives you data sheet which says that when you use SU 8; you first pre-bake SU 8 after spin coating at 65 degree centigrade.

After pre-baking, you use the mask will look like you will you will use the mask and your mask will look like something like this. This is correct right or to be more precise let me draw exact.

So, we had to cover this area alright we had to cover this area. So, it will look like this like this, like this, like this and like this ok. This is good this is good all right. So, our mask is bright field mask bright field mask with a pattern as you see on the as you see on the screen. This is the pattern of my bright field mask bright field mask. My photo SU 8 is SU 8 is negative photoresist. We will see positive photoresist, negative photoresist mask everything. This is just a quick example of a sensor.

So, that you when you when I talk about when I talk about other devices you do not get confused all right. So, I have my negative photoresist which is my SU 8 right I have this bright field bright field mask. Now, what I said? Whatever this terrace mask whatever the pattern is there on the mask, opposite of that will happen when we use negative photoresist. Opposite of this pattern will come on the wafer when we use negative photoresist; that means that after this after I do pre-baking I will load the mask with this particular pattern. If you see, the pattern is covering the electrodes you see here it is covering the electrodes, but other than electors other than electrodes is not covering any other area is not covering any other area.

So, in fact, how was this? This is even better right this is even better. How come I will tell you ok. How come I tell you? If you have mask like this; now, what will happen? What is the role of SU 8? SU 8 is the negative photoresist. The role of negative photoresist is that whatever the pattern on the wafer opposite of that would come or whatever the pattern on the mask whatever the pattern on the mask, the opposite of that would come on the wafer the opposite of that would come on the wafer. What does that mean? Let us see.

Now, let me repeat the property of the negative photoresist is, that if you use a bright field mask whatever is there on the mask write a pattern on the mask the reverse will come on the wafer so; that means, that let me expose this wafer let me expose this wafer with UV light with UV light right. Then what will happen? After exposure after exposure in case of SU 8 the manufacturer tells us you do post bake before you develop it. Post bake is done as 90 degree or 95 degree right. If you understand in the in the positive photoresist positive photoresist we were pre-baking at 90 degree and post baking at 120 degree correct in case of positive photoresist.

In case of SU 8 we had to pre-bake at 65 degree, before post bake here after pre-baking exposure we were developing right pre-bake. So, in the photo positive photoresist that as right once again it becomes easier when we write again and again for you as well as for me.

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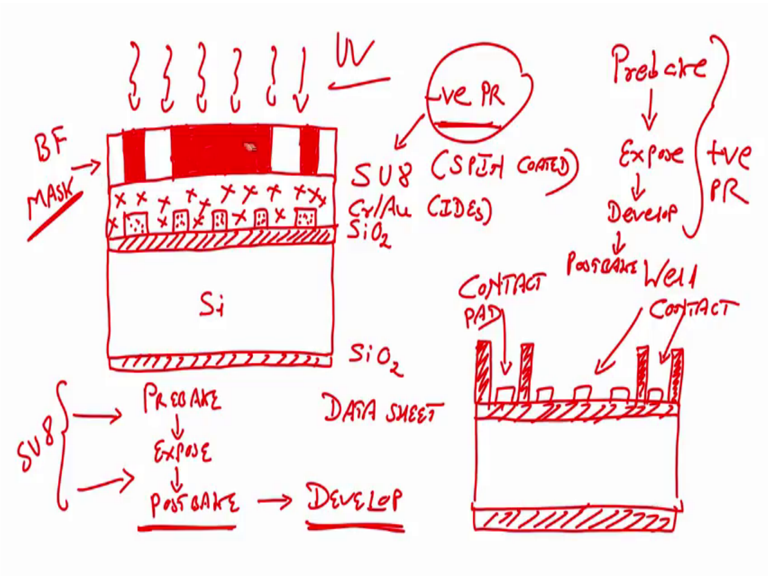

See pre-bake positive we are talking about positive then you have to expose then you have to develop then you have to post bake right pre-bake expose develop post bake this is the case of positive photoresist right.

In case of negative photoresist or in case of SU 8 what is what are the steps? what are the steps first step is you spin quote then you pre-bake then expose. Then you post bake, then you post bake followed by developer all right. So, you see here pre-bake expose develop post bake here, pre-bake, expose, post bake and develop right. So, what we have done now we have exposed it we have pre-baked it we have pre-baked this SU 8 which is this one right.

So, let me let me draw xx. So, that xx pattern is your SU 8 this is SU 8 hum. So now, what will happen? Now we have pre-baked SU 8, we have exposed the SU 8. After exposure what we are do we have to do? Post bake post bake and after post bake we have to develop it. Now, what is SU 8 SU 8 is negative photoresist negative photoresist opposite of this will come. Opposite of this will come means opposite of this pattern will come on the wafer; that means, if I what will happen? If I develop the I am removing this ok. You know what this one is or let me write it down let me let me draw it here. So, yet you understand what is the opposite meaning? What is the opposite of that meaning? The opposite of mask the pattern in the mask means.

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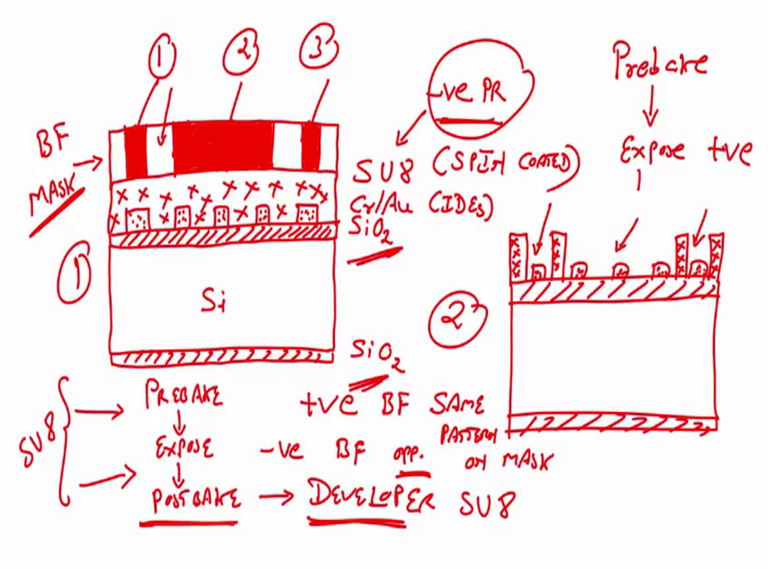

Now, I have a wafer here. Correct I have electrodes right and. Now, I have opposite of this; that means, that my SU 8 would be here my SU 8 would be here, my SU 8 would not be here, my SU 8 would be here, my SU 8 would be here. You see you see if I if I draw xx. So, that we you have understand where is SU 8 where is SU 8? What happens? Where the pattern was dark right there is nothing here. Where the pattern is dark here right this particular area right.

So, let me just remove this. So, either we understand clearly again. You say this area this area and this area 1 2 and 3 this 3 area on the mask. Very dark right and we got opposite of that wherever the dark area was there SU 8 is not there. Wherever it was exposed SU 8 is there right, but in case of positive we will get opposite of this right.

So, positive photoresist right field mask same pattern same pattern on mask negative photoresist to right field mask opposite pattern on the mask opposite pattern on the mask right; that means, you see wherever the dark area region was there SU 8 is gone right. After this after this step right after this step means what we are done? We have pre-baked, then we have loaded the mask, we have exposed, we have post bake then, we have developed, when we developed from one we get 2 right.

So, once we have this one what is this is your well within the electrodes interdigitated electrodes within the SU 8 well right. These are interdigitated electrodes within the SU 8 well. So, easy extremely easy you guys understood I think you understood. So, we will just see this all things once again in detail in some other class.

Right now, let us understand that what we have done? We have d1 2 things one is we have patterned the interdigitated electrodes. On this interdigitated electrodes we have spin coat the SU 8 which you can see on the screened on this SU 8 we have done pre-baking, after pre-baking we have exposed it by contacting by using a mask right. Where we are loading the mask and then we are exposing using UV light after exposure, we are unloading the mask we are doing a post bake because it is a SU 8 this is what manufacturers tells us. So, we have following the process given in the data sheet after post bake we will go for developer and in developer it is a SU 8 developer SU 8 developer all right.

So, this developer will develop SU 8 whatever area what was exposed whatever area on the mask that was exposed SU 8 will stay. And whatever area was not exposed SU 8 will go away or reverse of whatever the pattern is there will be there on the wafer. And thus, you can see here that we have this SU 8 well which is right over here. We have the area for taking the contact right. So now, we have contact pads on both the sides we have interdigitated electrodes in the center of the in the center of the well.

So, this is what is this is our complete device you see here see here. So, easy right now what we have done here? We have used oxidized silicon. What is that SiO 2? SiO 2 is nothing but SiO 2, is SiO 2. What is SiO 2?

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SiO 2 is glass right. So, I can use instead of oxidized silicon wafer I can use glass right. So, let us see let us see what I have done here I have use the glass.

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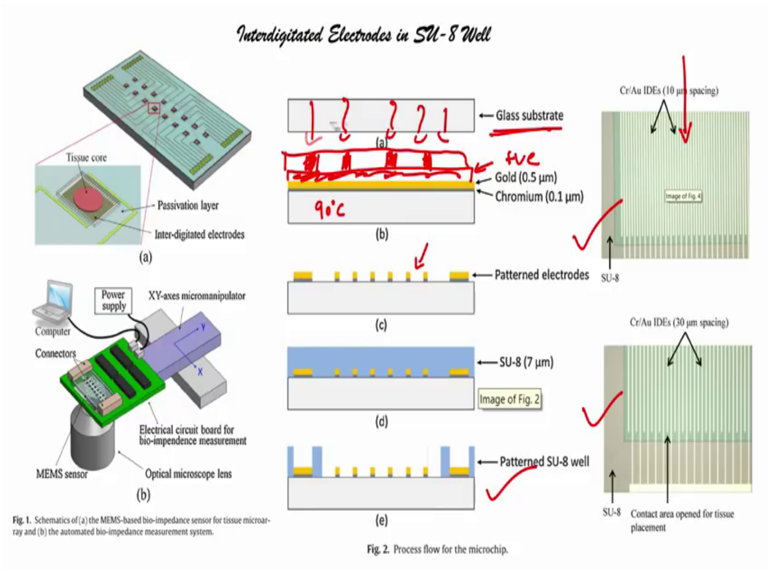

So, I have taken the glass substrate correct. Then I have deposited chrome gold easy then after chrome gold, I have spin coated photoresist. Right then I have pre-bake it this is positive photoresist positive. Then I have pre-bake it at 90 degree, then I have correct then I attach the mask, mask has some pattern which is similar to what you get here. Right, after attaching the mask or loading the mask I have exposed this wafer with UV light, then I have develop it and then I have post bake it post baked it. After post baking after developing and post baking what I will get I will get?

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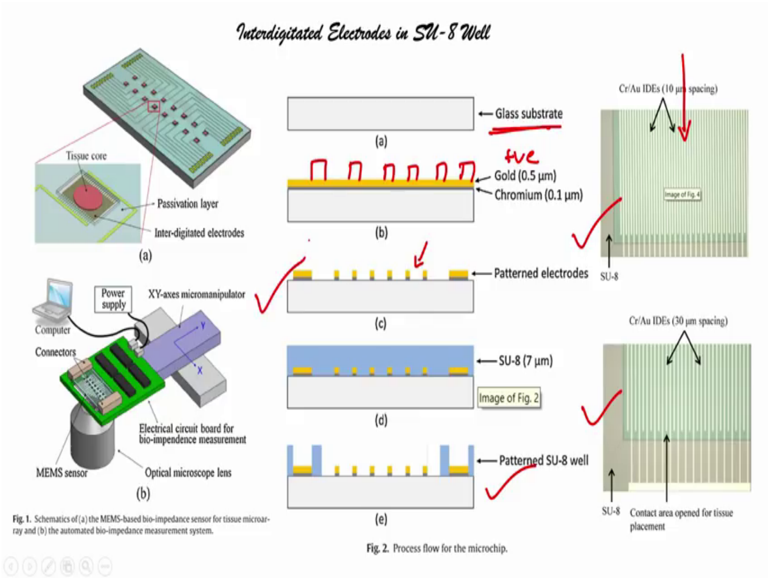

A photoresist just on this area right then I will h this wafer that is h chrome gold when I do hatching of chrome gold, what I will have I will have this particular substrate.

So, when I when I am showing you this particular substrate glass chrome gold then directly this; that means, this all the steps are done here in section b right. After chrome gold we are spring coating sorry after chrome gold, we are spin coating photoresist positive photoresist. On after spin coating photoresist, we are pre-baking at 90 degree, after pre-baking at 90 degree, we are loading the mask, after loading the mask.

We are exposing the wafer with UV light after exposure of wafer we are developing the wafer, after developing the wafer, we are post baking the wafer, after post baking, we are removing the gold and we removing the chrome. When you remove chrome and gold after that we are stripping of the photoresist with acetone and you get section c right. This whole process we do to get section c.

Now, on this section c there is a glass with interdigitated electrodes right.

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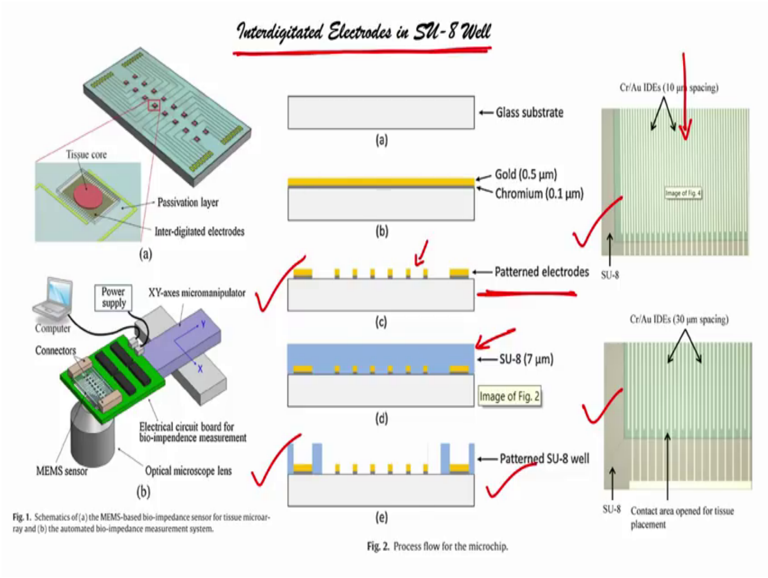

Fig. 1. Schematics of (a) the MEMS-based bio-impedance sensor for tissue microarray and (b) the automated bio-impedance measurement system.

Fig. 2. Process flow for the microchip.

Patterned electrodes we quote, we spin coat SU 8. You can see here we have spin coated SU 8. On the spin coated SU 8, what we will do? We will pre-bake it. Then we will load the mask, we will expose the SU 8 right and then we will do post baking. Then we will develop and then when we developed, we get this particular wafer, this particular glass. Glass with interdigitated electrode in the SU 8 well you got it.

So, whatever I am talking whatever I had told you today right or in this lecture and the previous 1. If the process is very easy we will once again see the process of photolithography and then you will understand in a better way how you can fabricate or what is the process to fabricate a biosensor or a interdigitated electrodes inside the SU 8 well interdigitated electrodes inside the SU 8 well right.

Now, once you have this sensor ready you can use for several applications if you read the papers, what you will find? The people have used to measure the impedance.

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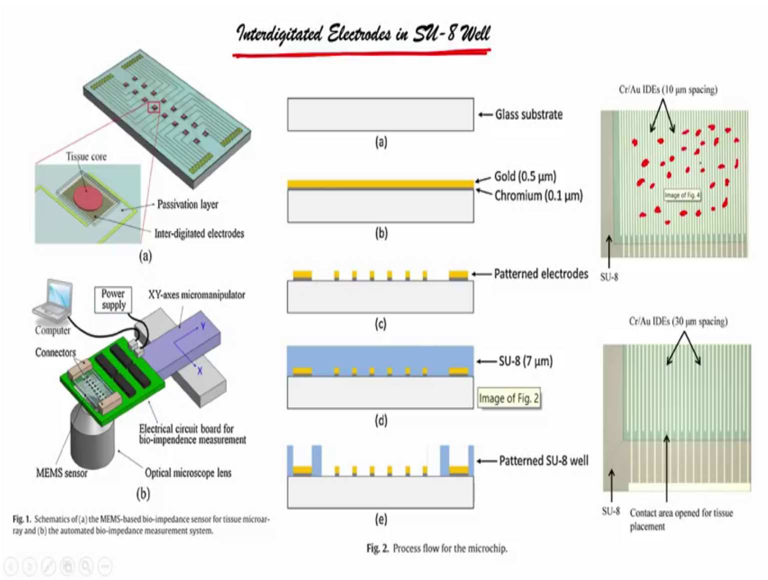

Of the cells human cells or micelles right and to see what is the change in impedance if I load different drug? What is the change in impedance? These are cells red things are cells. People I have also used right tissue directly place the tissue instead of cell.

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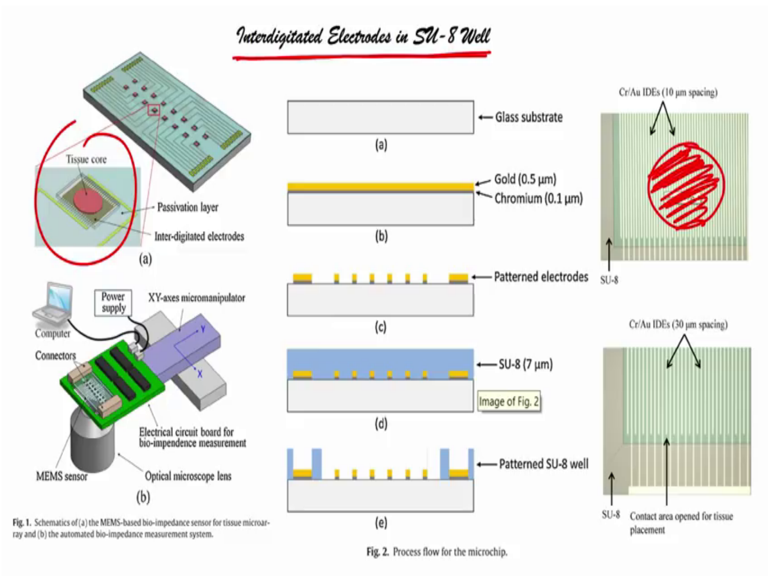

On this particular interdigitated electrodes like you see here, like you see here right. And measure the impedance measure the impedance, but this is a sensor that you have this is the sensor, that you now know how to fabricate or at least how to understand the process flow to fabricate interdigitated electrodes inside the SU 8 well.

Now, what we have seen we have used we have used masks right we have used mask. What kind of mask we have used? We have used bright field mask and we have used dark fill mask right we have seen in morning.

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A bright field mask right. So, right now what you see on the screen? It can be bright field mask if you assume that, the white is transparent. And this is your pattern what I have written is this is a bright field mask; right dark field would be opposite to this.

Now, and I have shown it to you in morning how the bright field mask looks like? Or a in the previous lecture how the bright field mask looks like? And we have also seen how the dark field mask look like? Correct. So, once you have the mask what are the defects in the mask. So, once you make these interdigitated electrodes and you have SU 8 then you can have interdigitated electrodes within this SU 8 well. These are this is our silicon wafer we look like oxidized silicon wafer with interdigitated electrodes and this interdigitated electrodes are within the SU 8 well alright.

So, this is how you can you your wafer will look like. This is a 4-inch wafer 4 inch oxidized silicon wafer. Right, if I want to draw cross section, the cross section is oxidized is a oxide no let me draw properly. I wanted to draw cross section of this particular wafer. This is a cross section, SiO 2 silicon SiO 2 I have interdigitated electrodes and I have SU 8 well. This is one chip one chip out of how many sensors are there at a time with a spacing that I have used? We can have how many sensors you can have 1, 2, 3, 4, 5, 1, 2, 3, 4, 5, right 1, 2, 3, 4, 5, 6, 6, into 5. 30 sensors we can have 30 sensors we have and what we are looking here? Is a cross sectional cross sectional or side view side view image of one single chip of one single chip ok.

So, this is what we have seen. This is how it looks like right and this is a, what we understood a process flow. Now once you understood this process flow excellent, but the thing that we have discuss a in the previous lecture was the mask. Bright field and dark field mask right. So, what are the bright field and dark field mask? This mask are nothing but they are made on Fe_2O_3 or soda lime glass the masks are made on Fe_2O_3 or soda lime glass and it is also chrome mask the material that we use is chrome is a chrome mask. Dimension of mask can be 4 by 4 if the wafer is actually this is wrong 4 by 4 is the wafer, then the dimension of the mask would be 5 inch alright.

So, if the wafer is 4 by 4 or 4-inch wafer I can use mask which is 5 inch. Actually, this is what is also correct in the way that what it is saying is I have this one is 4 by 5 this is what is saying 4 by 4 into 5 by 5. But, in general if what we say is just 5-inch mask we use 5-inch mask or 4-inch wafer.

So, that if you see the mask would be somewhere around, it will it will have somewhere around this particular area like this. Right a little bit closer so, it will somewhere around we can have mask which is like this. For 4-inch wafer, we have 5-inch mask right and another one is the polarity is nothing but the positive or negative or we can say; bright field mask or dark field mask.

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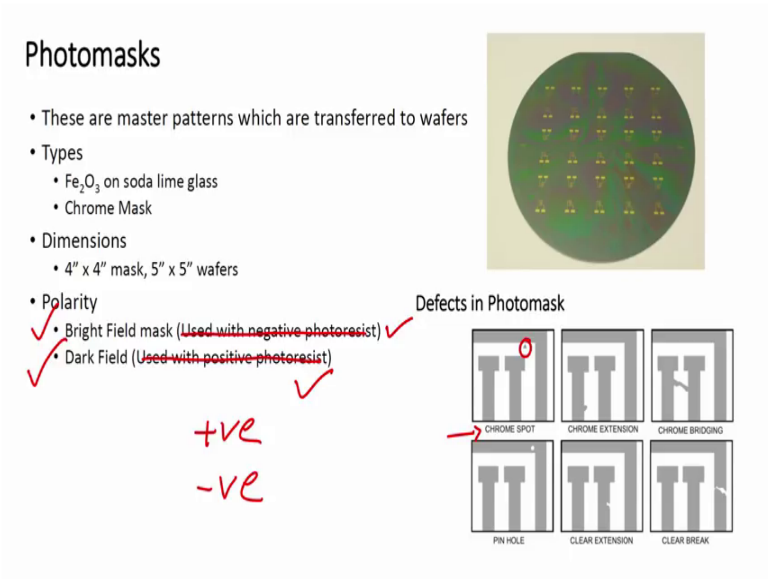

Now, this is not always true that bright field mask is used with negative for this or dark field mask is used with for positive photoresist. We have just seen an example where bright field mask can also be used with positive photoresist. Bright field mask can also be used with negative photoresist. So, so I believe that this sentence does not hold true in all the cases, but the masks are of two types that is completely correct. Bright field mask and dark field mask alright.

Now, to the last point of this particular module, we have to see a very important thing and that is the defects in the photo mask. That is what kind of defects are there when you take a mask right. So, there are several types of defects that you have to that you will encounter when you look at the mask. So, when you look at the mask, which I have shown you in the in the in the in the last lecture then what you were able to see was the pattern, but what you were not able to see was the, with as close as possible or within the microscope. How the mask looks like? And is there any defect in the mask or not? So, when you talk about defect in the mask what are the defects in the mask. The first defect is a chrome spot you will see a spot of chrome well in the mask.

Now, you will say what will happen if I have a first part of chrome? This part of chrome will destroy your a whole chip right. So, the spot of chrome is not correct when you are going to fabricate MOSFET, you this small spot will cause a big problem in your MOSFET fabrication. You should; cannot have this kind of defect when you are fabricating a, devices which are ultra-small. That is in terms of microns, in terms of nanometer, you cannot make this kind of error right. Again, when you talk about nanometers there is another process called a beam lithography that is used which we are not covering in this particular course. We are covering right now photolithography and the limitation of photolithography is that we cannot go below 2 microns below 2 microns alright.

But the process remains same more or less when we fabricate sensor, when we fabricate MOSFET and we will see that a case of a MOSFET in the following lectures. What are the second what is the second defect? The second defect in the photo mask as you can see on the screen is the chrome extension. You see this one this chrome is extended right you see this extended chrome then 3rd one would be chrome bridging. There is a bridge it is a short right, it is a short if I want to make a interdigitated electrodes and if I have this bridging then they then there will be short circuit between 2 electrodes. Between 2 digits right then, I cannot use this mask. So, there is defect in the mask what your 4 defect 4 defect a pin hole. You can see this pin hole right what is the 5th defect 5th defect clear extension you see is broken clearly extension. What the next one? Next one is clear break you see break edge in the pattern break edge in the pattern.

So, this kind of defects in the photo mask which are chrome spot chrome extension which are chrome bridging pin hole clear extension and clear break. This will cause a problem in the final device. That is why whenever you are given a photo mask, first you should check the photo mask in the microscope whether it is defect free or not. Then you should start experiments alright then you should start experiment.

So, the point is now in this particular lecture what we have seen is how to form SU 8 well? We have seen how to integrate interdigitated electrodes within the SU 8 well. And then we have seen that what is the application of this particular sensor? And finally, we have seen what are the defects in the photo mask right. So, it is a combination of lot of processes that we have seen in this particular lecture. Where I wanted to tell you how the process flows are used to fabricate a MOSFET, but before we go to the MOSFET you should first look at how we can fabricate a single sensor.

So, if you want to fabricate a single sensor, then you have to understand that what are the process? And whether you can fabricate a single sensor on glass? Or you can deposit or you can fabricate single sensor on the oxidize silicon? Or you can fabricate single sensor on the plastic? Is there a are there anyways? So, what we have considered in this particular case? Is glass which is SiO 2 right glass is nothing but silicon dioxide and we have taken a silicon substrate.

And I have shown that if you use silicon then we can grow an oxide, on the oxide we can deposit the metal, on the metal, we can do the lithography to form interdigitated electrodes. On interdigitated electrodes, we can deposit SU 8 which is negative photoresist, we can again patterned SU 8 to form the well. And finally, we get a sensor which can be used to measure the change in the cell properties, we can measure the change in impedance of the tissue. And this is a biosensor this is also called MEMS based sensor right.

So, in the next class let us understand 1 by one what are the steps to from setting of the silicon wafer to growing oxide because you have to understand when you have; we have when you are studying MOSFET? Right there is a field oxide and then there is a gate oxide right. Everybody or every one of us have studied field oxide gate oxide, there is a source, as a drain there is a gate. And there is a n type enhancement type MOSFET as a repletion type MOSFET, but how can you fabricate this MOSFET and to understand this fabrication the processes that we have learnt today would be useful and now I will tell you 1 by one if you have a wafer.

So, what is a technique to grow oxide on silicon wafer? Then what is the technique? Or what are the techniques to use this to deposit the metal or deposit another material? It is metal insulator or it can be a semiconductor on the substrate. Then we will see what are the methods to to grow a insulating layer at lower temperature right.

And we will see lithography steps a little bit in detail. Right positive photoresist what will happen I will take an example negative for this, what will happen? I will take an example. Today I have shown you an example, but I will show you in a different way. So, that you can understand further and you have more clarity on this particular process. Right then we will take an example of the MOSFET and in that you will understand why we are learning all these processes that I am talking today. And in another few lectures that I will be talking on why we have learned these things when you see the process flow of MOSFET, it will be extremely clear to you why what was the use of the previous lectures alright.

So, try to focus once again, on this particular module, it is extremely important. There are there are 2 modules, my last lecture and this lecture and combination of both will give you a sensor. A sensor there can be used as a bio sensor to measure the impedance correct. Now, I hope that you understood a bit of how the sensor can be fabricated this process that we are using, that is also called a recipe.

What is called recipe? Recipe is like a food recipe right the food recipe. So, in food recipe what we do we cook the food right. What is the first step suppose you want to cook rice? What is the first step? Right you to clean the rice and you put the rice in a bowl and you put the rice in the cooker, you add the water, add your salt right and close the cooker start your gas these are the recipes right.

Same way if you want to fabricate a sensor you know should know the process this processes are called recipe what is the thickness of material? What is the temperature it will be a 2 edge? What is the temperature at which we have to grow the silicon dioxide? Right then what is the temperature? At which the pn is to be pre-baked? What is the temperature it will needs to be post make? How much time we need to pre-bake? How much time you need to post bake? What is the etching time? If we change the recipe if we if we if we do not follow the recipe what will happen my rice? Will burn right or rice will be half cooked right or the water with one same way. If I do not follow a proper recipe I will not be able to get the sensor at the output my expected output will be different right when I when I do not follow the recipe.

So, recipe is very important process flow is also called recipe in the process what is a recipe of a process that is how we talk when we talk about micro fabrication all right. So, we will see the recipes will see the recipe for the positive photoresist. What is the state will see the negative photoresist? And we will see your MOSFET all right. So, till then learn about this lecture learn about this video understand this video if you have any doubt; you are free to ask me ask me after you finish certain modules then only you will be able to understand. What is the role of this right first time when you learn something you will have lot of patients, but maybe in following classes your answers are already there.

So, first try to attain few classes learn few classes understand what is there then you ask me questions if you do not have answer you are free to ask me questions alright. So, you take care and I will see you in the next class till then be nice look at the videos right read once again and be happy right. That is very important I was listening to one of the saint I think Sadhguru, his name Sadhguru. So, he was telling that keep laughing right because only dead body cannot laugh isn't it?

So, if you are alive be happy right keep laughing right leave a happy life try to live a happy life do not take stress academics is one part I am always telling you again and again academic is a part where we can improve right, but the reality is we are alive. So, we should live our life along with acquiring more and more knowledge right.

So, I will see you in the next class. Till then you take care bye.