Electronic Systems for Cancer Diagnosis
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Lecture – 13
Fabrication of Piezoresistive Sensor

Hi, welcome to this module, and in this module what we will look at? We look at how to deposit a piezoresistive material on the interdigitated electrode and those interdigitated electrode as you remember from our last module where fabricated on a silicon dioxide material and that silicon dioxide acts as an insulator between a micro heater and interdigitated electrode.

So, just to help you out what we have studied we have studied how to fabricate a heater or oxidized silicon substrate how to deposit an insulating layer, open the contacts of the heater than deposit metal which is for the interdigitated interdigitated electrodes and then we have patterned id is now we will see how can you deposit piezoresistive material over ids using two techniques one is the standard lithography technique and second one which I will teach you today which is called lift off.

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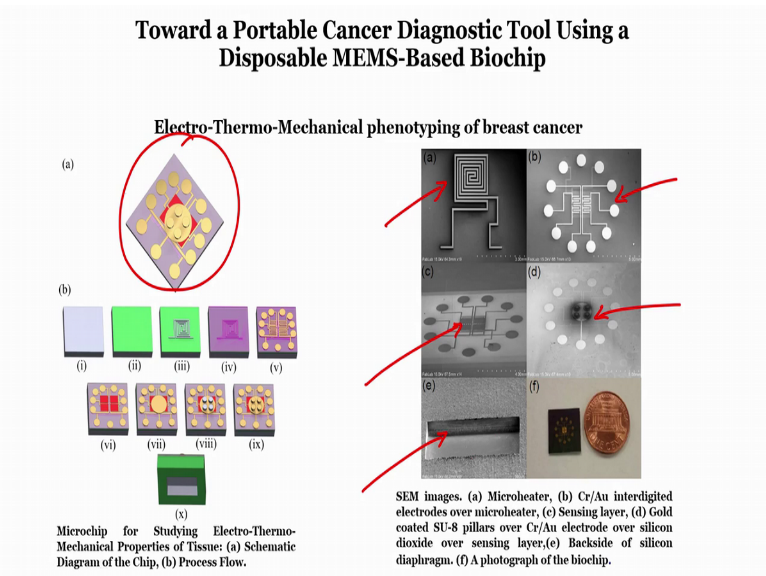

So, if you see the slide, as you know our goal is to understand how can we fabricate this particular chip. When you want to fabricate this chip like I said this chip is indicated with micro heater, this chip is indicated with interdigitated electrodes, on interdigitated electrodes there are piezoresistive materials and on that we have another insulator on that there is a gold pad which is over there are su-8 pillars which are we made it conductive on the backside of chip there is a diaphragm and I will tell you what is the role of the diaphragm when we understand the fabrication of the complete chip.

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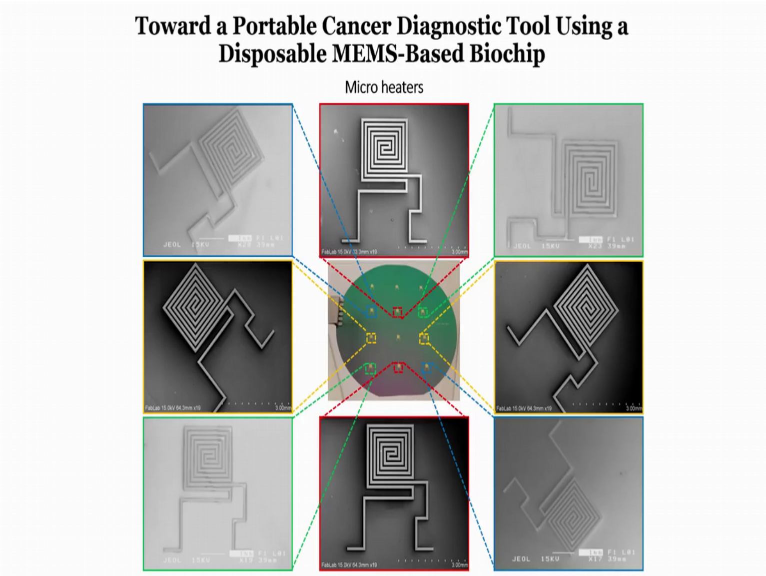

So, this we have seen.

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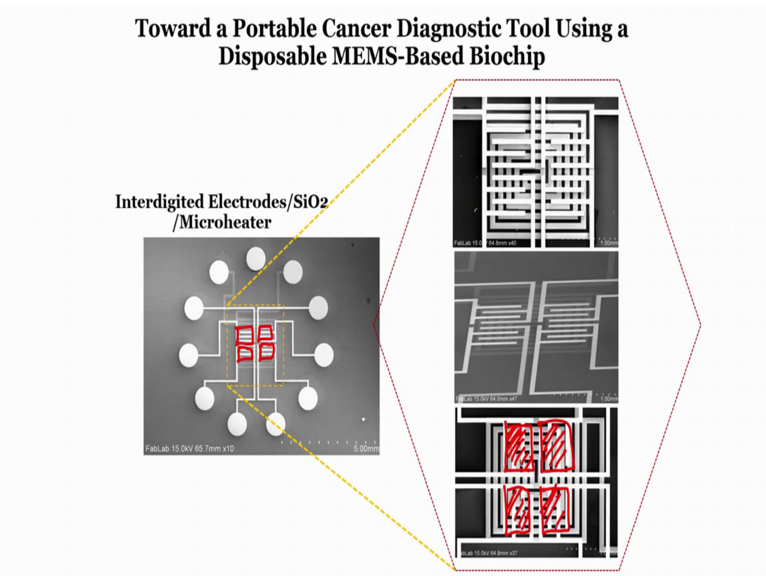

This we saw in the last module correct. Now, we will continue from this process onwards to deposit a piezoresistive material in this region, one two three and four ok. So, this is just a magnified view, this is what I want to do today and to teach you fabrication of piezoresistive sensors on the interdigitated electrodes alright.

Let us see the process flow. So, let us see how can we fabricate the piezoresistive sensors over the interdigitated electrode; for that what we will do?

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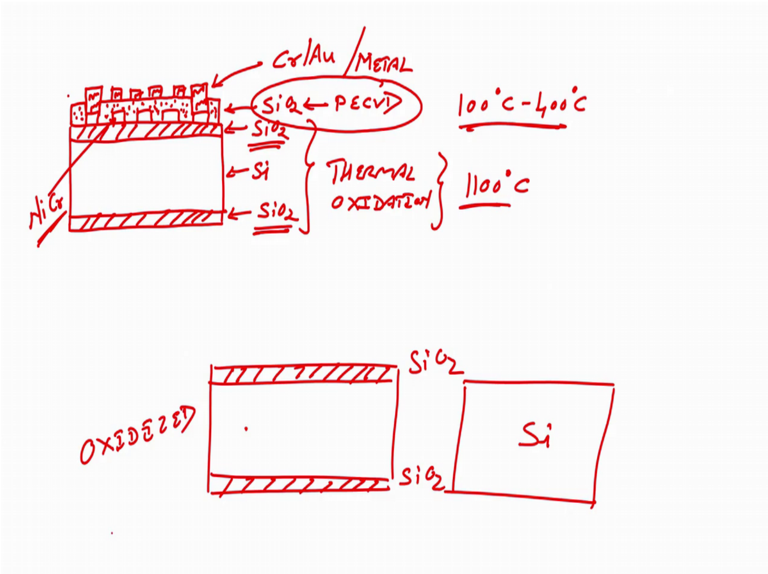

We will first take the oxidized silicon wafer and we have seen that our oxidized silicon wafer is integrated with micro heater right and then we have opened the contact correct this is our contact region which is open you can see right over here and this is my silicon dioxide which is grown using PECVD, we all know right. Silicon dioxide 1, silicon dioxide 2, silicon dioxide 3, silicon and then we have over nichrome this is a heater material right over that what we have seen yesterday or in the last lecture that we have a metal right.

So, let me represent the metal by this design and this is our interdigitated electrodes. Now over this, I want to deposit a piezoresistive material right. So, there are two ways, now this interdigitated electrodes we have used chrome gold right. But you can also use any other metal right any other metal alright. The silicon dioxide let this one and this is one is grown using thermal oxidation, while this silicon dioxide is deposited using PECVD. So, let me first explain you why we have not grown silicon dioxide using thermal oxidation like this two thermal, that like this oxidized or silicon dioxide layer that we used thermal oxidation why we have not used thermal oxidation for this silicon, dioxide why we have used PECVD.

Let me first explain you that and then we move to the piezoresistive material. You see PECVD we can vary the temperature from 100 degree centigrade to 400 degree centigrade for the chemical vapor deposition. Thermal oxidation the temperature is 1100 degree centigrade. Again you can vary from 1000 to 1200 generally it is 1100 degree centigrade. Now, you have nichrome. So, I will just draw quickly a heater on oxidized silicon wafer right see please understand the term. This is a silicon wafer, when you grow silicon dioxide on silicon wafer it becomes oxidized silicon wafer al   right.

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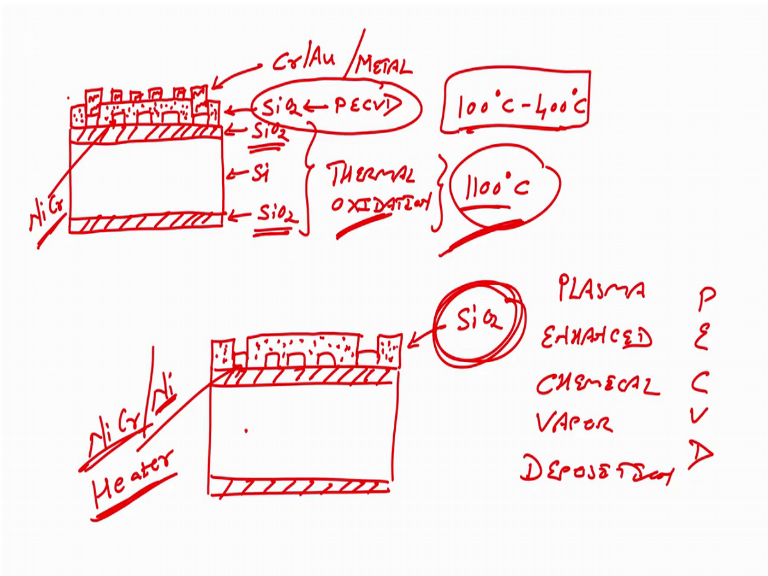

So, oxidized silicon wafer we are fabricating a micro heater right, this is our structure. On this what we said I want to deposit or I want to grow I want to grow my silicon dioxide or I am deposit my silicon dioxide on the heater right so, that I can further process my wafer to fabric interdigitated electrodes and other materials. Now, if I use thermal oxidation to grow this silicon dioxide the temperature that is used as 1100 degrees centigrade while the material can be nichrome or it can be nickel for my micro heater or for my heater right.

So, this material which is nichrome or nickel should withstand 1100 degree centigrade right, if it cannot withstand this high temperature then what will happen? It will melt and that is why we want to grow silicon dioxide or we want to deposit silicon dioxide at a lower temperature you got it. Because, if I use thermal oxidation for growing this silicon dioxide then my temperature is around 1100 degree centigrade and that temperature the material below it that is the material below silicon dioxide which is my nichrome or nickel for my micro heater should withstand.

Now, if it cannot withstand then I will not get the heater, it will melt and that that will create a problem. So, to avoid that I will deposit silicon dioxide using a technique called plasma enhanced chemical vapor deposition right. It stands for PECVD right and the advantage is that we can deposit at a lower temperature you got it. That is why I said that for insulating layer over heater we will go for PECVD right. So, that is the reason of using PECVD instead of the thermal oxidation. Okay guys easy, very easy right once you understand fabrication it becomes very easy to design the chip and once you design the chip then we will go for this system design system design alright. Now this is the material, over that what we have to do?

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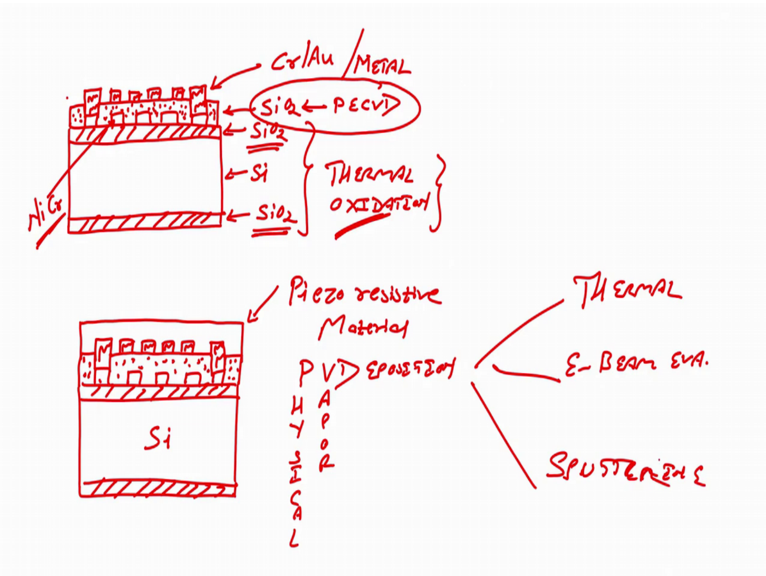

So, I will again draw the schematic where we can see what silicon dioxide, silicon heater, insulator, interdigitated electrodes in a silicon dioxide. On this I will deposit, sorry on this I will deposit a piezoresistive material. Now, there are piezoresistive materials which can be deposited using PVD, PVD stands for Physical Vapor Deposition. Physical vapor deposition three types thermal evaporation, electron beam evaporation and sputtering alright; physical, vapor, deposition, thermal evaporation, e beam evaporation and sputtering. So, using e beam evaporation or sputtering we will deposit piezoresistive material.

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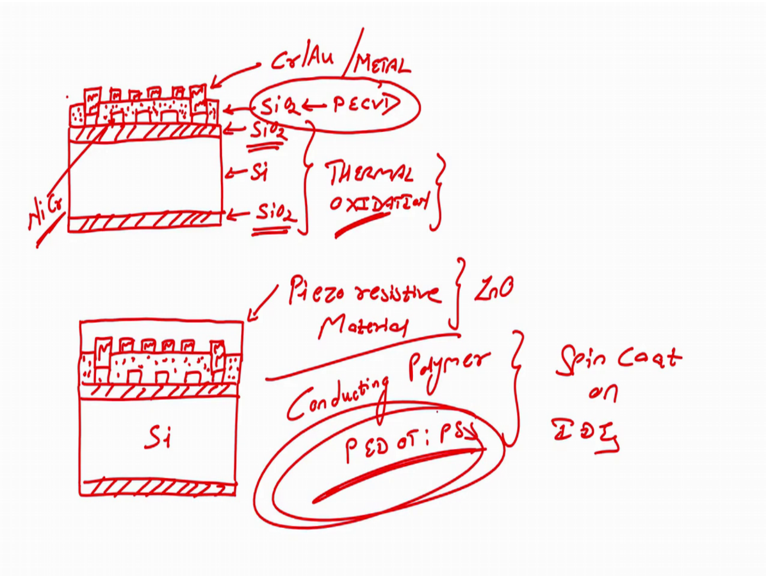

Now, there is an alternative material which is a conducting polymer. Now this can be zinc oxide right or any other piezoresistive material, but if I want to use conducting polymer conducting generally polymers are non conducting, but if I want to use conducting polymer I can use PDOT PSS and for using PDOT PSS, I have to spin coat it, spin coat on interdigitated electrodes, this is also piezoresistive material. So, point is that we will deposit or we will spin coat piezoresistive material right using either PVD or using spin coating right. Once you do that what you do? You have to perform lithography and all of you know how to perform lithography we will take we will spin coat positive photoresist right.

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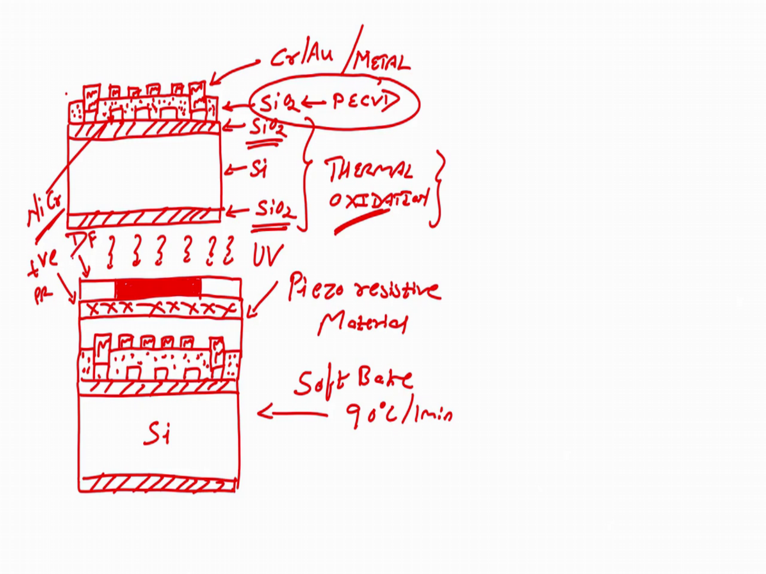

Let me put checks for positive photoresist, after that what is the step after positive photoresist I will soft bake the wafer at 90 centigrade for 1 minute alright. And after soft bake next step is to load the mask and we only want the material which is a piezoresistive material to be on the interdigitated electrodes and not on the contact region right this is correct mask no. I will also show it to you two different ways, if I use bright field mask bright field mask like this one right, this is my bright field mask.

And if I expose the wafer with UV what would happen the unexposed region will be stronger; the unexposed region will be stronger. But, if I do not have bright field mask and I have a dark field mask; if I do not have a bright field mark mask and I have a dark field mask right in that case my dark field mask will look like this right.

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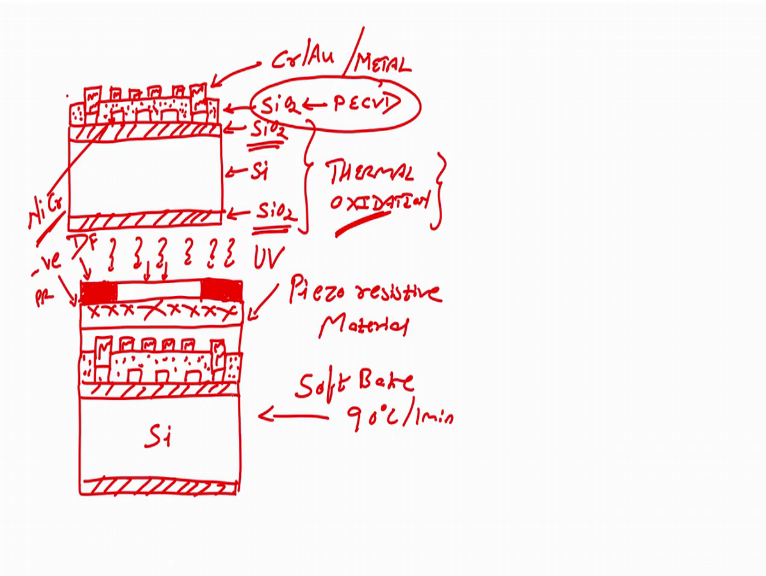

So, in this case, if I use positive photoresist then, the region which is unexposed will be stronger which we do not want, we want our piezoresistive material to be on this area right only on this area we do not want on the contact. So, if I use dark filed mask with positive photoresist my problem will not solve. So, what I will do? If I have sorry let me just select the red color, if I have dark filed mask then I will change my positive photoresist instead of positive photoresist I will spin coat negative photoresist you got it because, if in negative photoresist the unexposed region will be weaker and the exposed region which is this region will be stronger.

So, finally, what will have we will we can save the piezoresistive material over this particular region which is our region of interest and there will be nothing over the contact, you got it. So, very simple if I have dark filed mask I will go for negative photoresist in this case.

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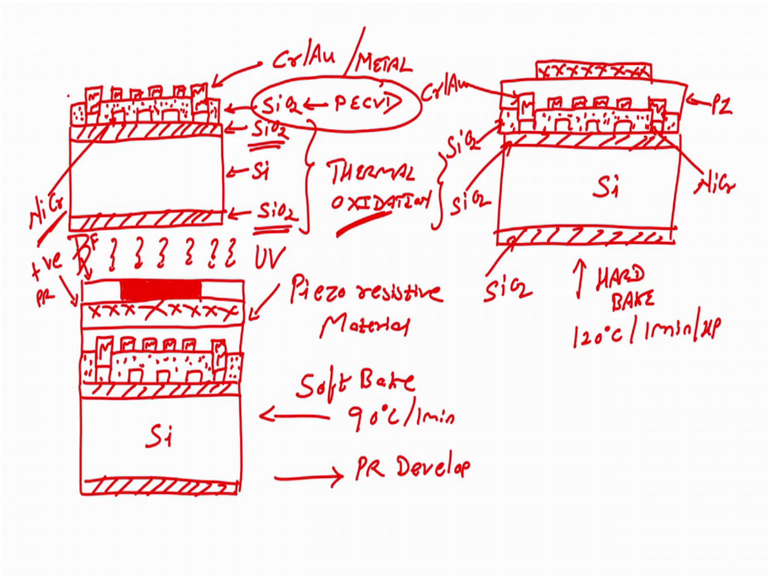

But if I have a bright filed mask; if I have a bright filed mask then I will go for a positive photoresist. So, you have to select the recipe according to the design of your mask and the ability of a photoresist right. So, here I will use positive photoresist, this is my bright filed mask easy after exposing what will happen we have to we have to develop the photoresist PR development right. If I did the wafer in photoresist which is photoresist developer then what will I have?

I will have my oxidized silicon wafer on that there is a micro heater, on that there is a insulating material which is my silicon dioxide on that I have interdigitated electrodes right, on there is a piezoresistive material this is silicon dioxide using PECVD, silicon dioxide using thermal oxidation, silicon dioxide using thermal oxidation, silicon wafer nichrome, chrome gold right and piezoresistive material over that I will have my photoresist only in this region, only in this region.

Why? Because, I have used a bright field mask with positive photoresist and the unexposed region will be stronger and that is why I can see that the unexposed region is stronger. The next step is we will go for a hard bake. Hard Bake is done at 120 degree centigrade 1 minute on hard plate. After this, the next step would be to etch piezoresistive material.

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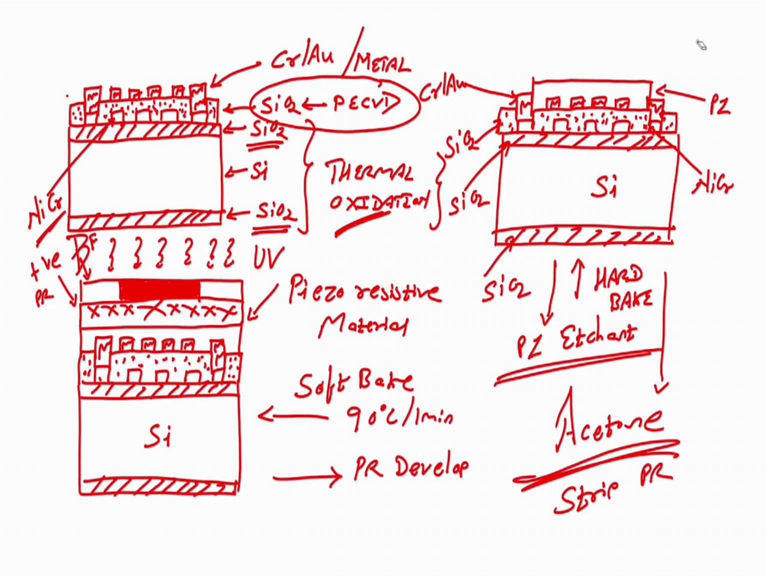

So, we have to dip this wafer in a piezoresistive material etchant right wet etching. If I do that what will happen the material which is protected by the preservation material which is protected by the photoresist will not get etched, but the photoresist material which is not protected by photoresist will get etched.

So, I will have piezoresistive material in this area all right you got it; because, there is no photoresist that can protect the piezoresistive material in this region and this region. So, once I deposit the wafer or once I dip the wafer in a piezoresistive etchant, I will etch my piezoresistive material which is not protected by photoresistor. Next step for this would be that I will dip this wafer in acetone. If I dip the wafer in acetone what will happen? We will strip off, we will strip the photoresist, if the dip if I dip the wafer in acetone we will strip the photoresist. If I strip the photoresist, then what will I have? I will have a piezoresistive material over interdigitated electrodes right.

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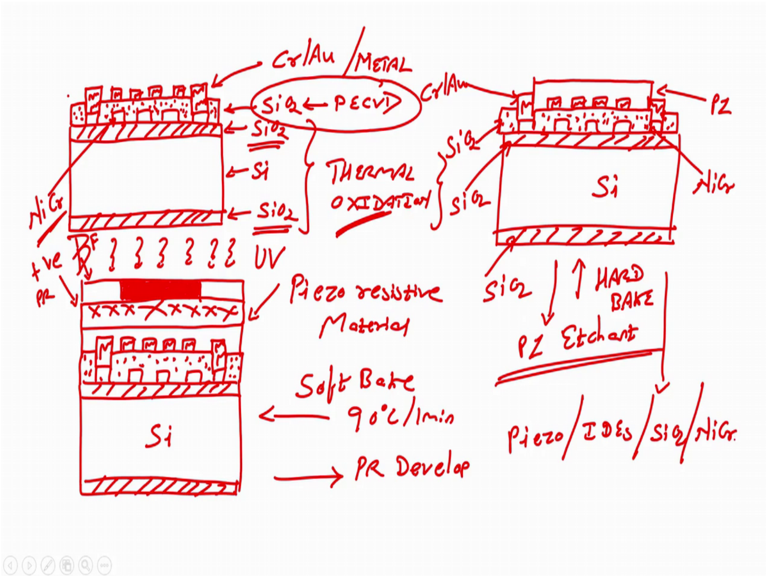

I will have a piezoresistive material over interdigitated electrodes over s i o 2 over nichrome heater and then this will look like.

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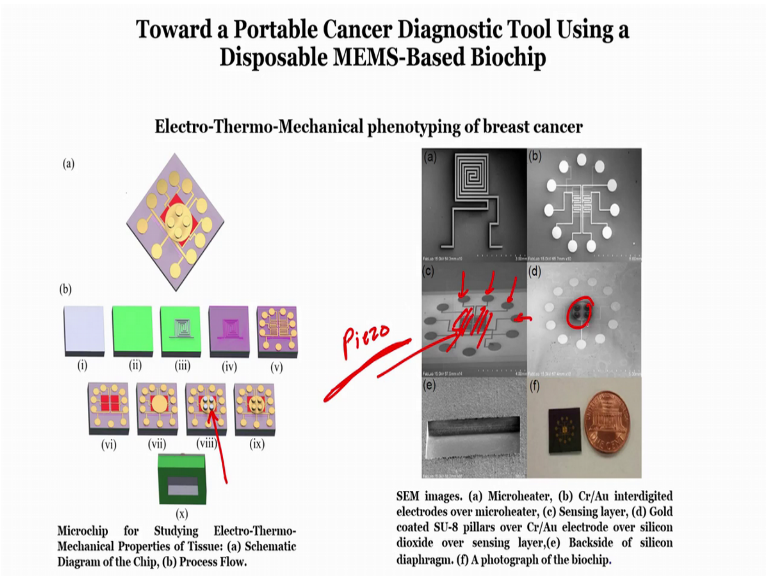

You got it easy. So, what is our next step? Our next step is to have a gold pad right which is in the center this one, gold pad and on that gold pad we require SU-8 pillars; on that gold pad we require SU-8 pillars.

So, can I deposit gold directly on pizeoresistive material. This is piezoresistive material right this four black squares in center or gray squares in the center are piezoresistive materials, but can I deposit gold which is a metal on piezoresistive material? It will get short right. So, what we have to do, after this we had to grow a silicon dioxide layer right open the contacts in all the area except in this area right and then we will deposit metal will pattern it to form the gold pad.

So, still till now let us see in this particular model what we have learnt? We have learnt how to deposit a piezoresistive material on interdigitated electrode. But like I said, I want to teach you in this module itself how, what will happen if I want to use liftoff. So, what exactly liftoff means and why we have to use liftoff right?

So, let us understand, if you go back to the slide what you see here is that we have done a standard lithography technique where we have piezoresistive material. So, if I just continue from this section it will be easier for you to understand why we will go for liftoff.

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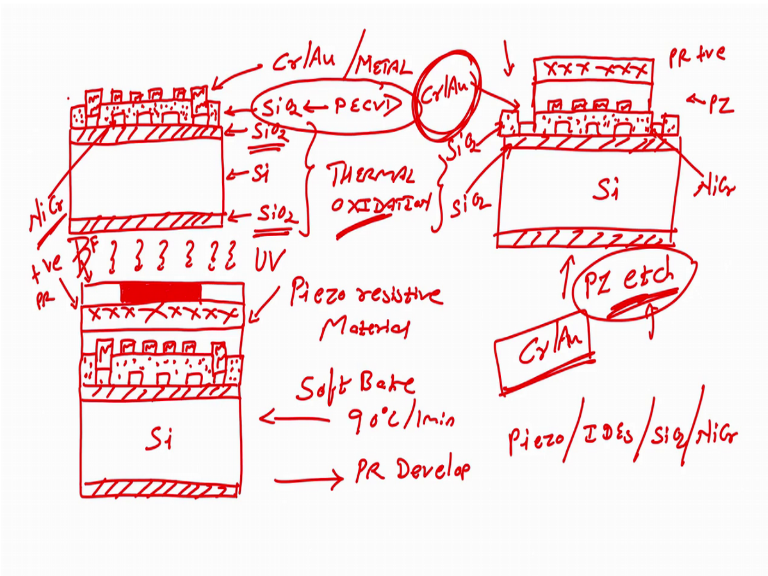

So, the point is that you know that we had a piezoresistive material all over the interdigitate electrodes and then we are protecting the piezoresistive material in this area right this much we all know, this is positive photoresist this is piezoresistive material all right this is of course, chrome gold and the main section you know. So, now, if I dip this wafer in piezoresistive material etchant, in piezoresistive etchant what will happen it will etch the piezoresistive material right it will etch the piezoresistive material.

Suppose, the etchant of the piezoresistive material also affects the chrome and gold then what will happen, once the piezoresistive material is etched from the area which is not protected by photoresist, which is not protected by photoresist it will start etching chrome gold, it will start etching chrome gold why? Because the piezoresistive material that we have used the etchant the chemicals that are used to etch piezoresistive material will start affecting chrome gold because the material or the chemicals are such that it can also edge chrome gold.

In this case what will happen the chrome gold here and here right will be etched, if that is a case will lose the contact to the interdigitated electrodes correct we lose the contact to the interdigitated electrodes; then what is the purpose of fabricating the interdigitated electrodes? No purpose, it is gone there is no point of continuing with the fabrication right. So, if this case arises when you are fabricating a device what you have to do you have to think of an alternative technique to pattern piezoresistve material this is called lift off. So, let me show you interesting if you see the slide.

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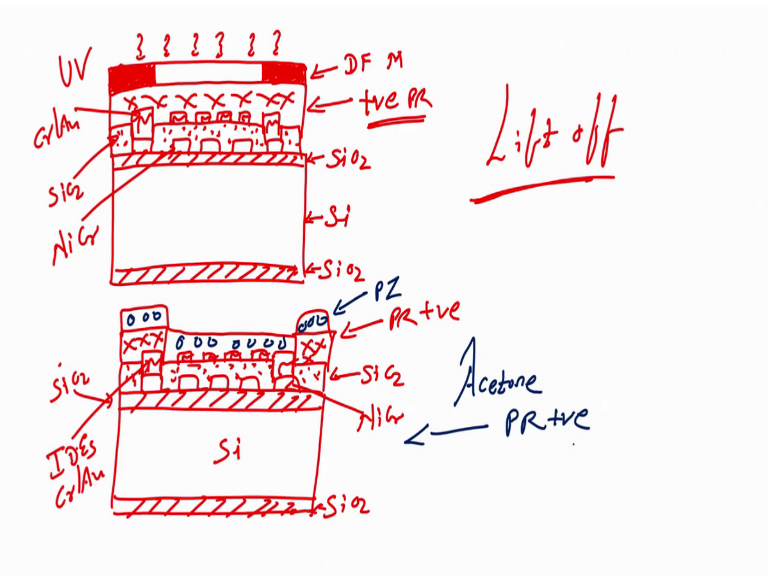

I will show you how to do lift off very interesting technique, very easy focus on the schematic that I am drawing right. I always write down even you know that what are the patterns here, what I am showing in the design is always a good practice to write down as many times as you can. So, that you remember this is using thermal oxidation over there what we have? We have a heater; over there what we have? We have a silicon dioxide grown using PECVD; over that what we have? We have interdigitated electrodes correct. Now, over this we want to pattern the piezoresistive material.

So, for patterning the piezoresistive material what we will do, we will use a technique called lift off; what is this technique lift off? So, we will first instead of depositing piezoresistive material, we will spin coat positive photoresist alright in spin coat positive photoresist. Then we will use a dark filled mask because after positive photoresist spin coating what is the next step? Next step is of course, the soft bake. So, spin coating soft bake at 90 degree 1 minute hard plate we will load the dark field mask, and I have positive photoresist. So, if I expose dark field mask with UV what will happen the unexposed region will be stronger an exposed region would be weaker.

So, what will I have? I will have an oxidized silicon wafer with heater insulating material interdigitated electrodes right and photoresist. So, let me draw photoresist like x so, photoresist in this region right. So, if I use positive photoresist, if I expose the wafer with UV and if I develop the wafer and if I develop the wafer what will I have?

I will have photoresist, in this region there is nothing you can see there is no photoresist right there is no photoresist, but here there is photoresist and we know; what is this one? Interdigitated electrodes right interdigitated electrodes made from gold or you can say chrome gold, nichrome silicon dioxide, silicon, silicon dioxide, silicon dioxide right. Now I will go for hard bake; hard bake 120, 1 minute hard plate. After hard bake next step is I will deposit a piezoresistive material this material will be deposited like this right.

So, let me just draw the piezoresistive material with different color. So, you understand. This is a piezoresistive material right. What I have done on the positive photoresist which after the hard bake I have deposited a piezoresistive material right over the photoresist. The next step is after this I will dip the wafer in acetone, I will dip the wafer in acetone. If you dip the wafer in acetone what will happen the positive photoresist the positive photoresist will be stripped off, it strips off right. So, if the positive photoresist strips off it will lift off the material over it, it will lift off the material over it. So, what does that mean? If I dip this wafer with a piezoresistive material deposited on positive photoresist and if I dip this wafer in acetone then will I have is this structure.

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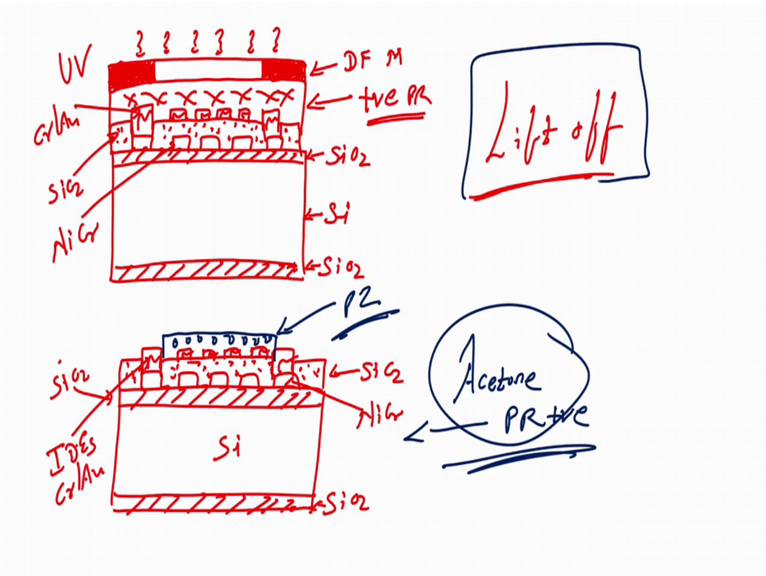

You got it why? Because the positive photoresist will lift off the material when you strip it in acetone, you got it.

So, why and now you have to do a lift off because, then this way you are not using an etchant for the piezoresistive material and that way if my etchant is or the piezoresistive etchant or the material etchant is affecting chrome gold which is right below it, now in this case it will not be a problem because we are dipping the wafer in acetone which will strip of the photoresist and the fall the piezoelectric material will stick to the interdigitated electrodes right.

So, this is the last slide for this particular module and what we have seen? We have seen how can we deposit piezoresistive material right on interdigitated electrodes which are on silicon dioxide which are on micro heater right. So, if you go from the bottom oxidized silicon substrate, micro heater silicon dioxide interdigitated electrodes piezoresistive material, piezoresistive material either using the standard lithography or using lift off technique right. In the next slide in the next module in fact, what we will see? We will see how can we deposit a gold pad on a piezoresistive material and like I said that if you want to deposit a gold on piezoresistive material you again had to form an insulating layer right. Till then, just go through this particular module and I will see you in next module take care bye.