Lecture 19
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, were fabricated on a silicon dioxide material. And that silicon dioxide acts as an insulator, between a micro heater and inter-digital electrode. So, just to help you out, what we have studied? We have studied, how to fabricate a heater, on oxidized silicon substrate how to deposit an insulating layer, open the context of the heater, then 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 ID is, using two techniques. One is the standard lithography technique and second one, which I will teach you today, which is called, 'Lift Off'. Okay?

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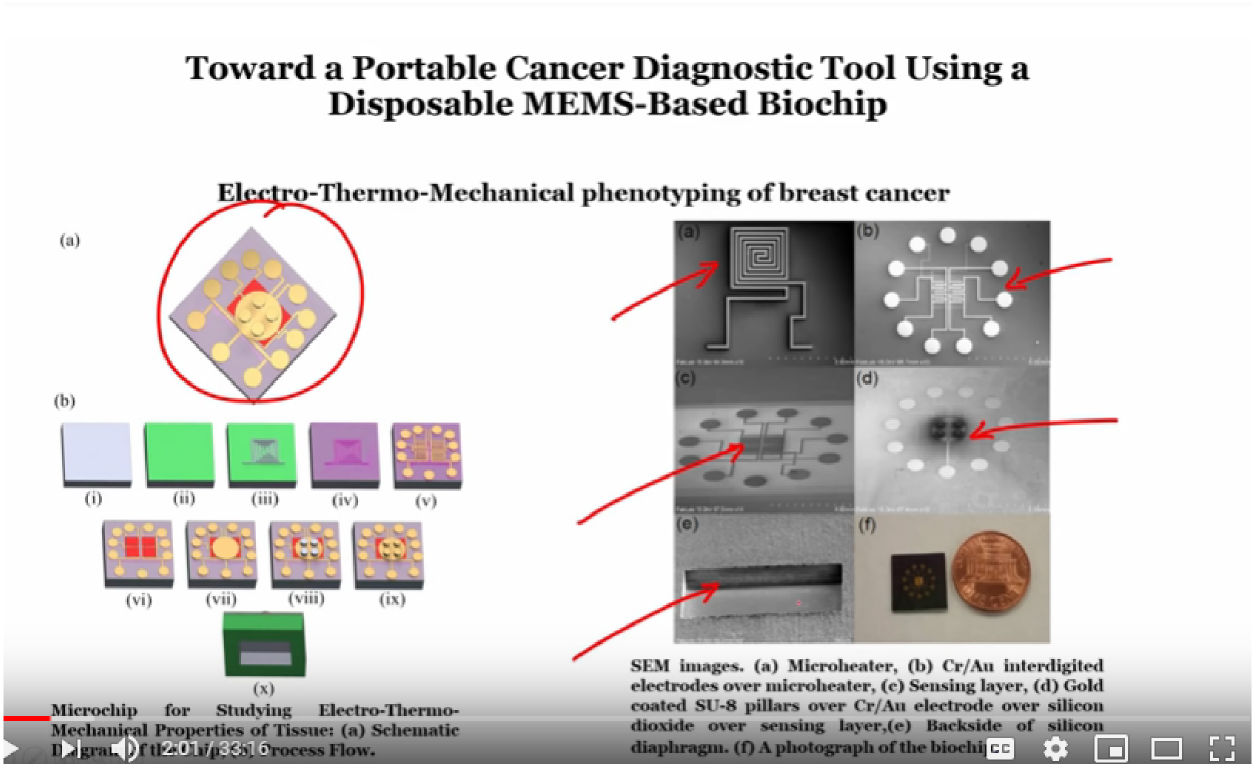

So, if you see the slide as you know, our goal is to understand, how can we fabricate this particular chip. When you want to fabricate this chip, like I said, this chip is indicated with a micro heater, the strip is indicated with interdigitated electrodes, on interdigitated electrodes there are Piezoresistive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

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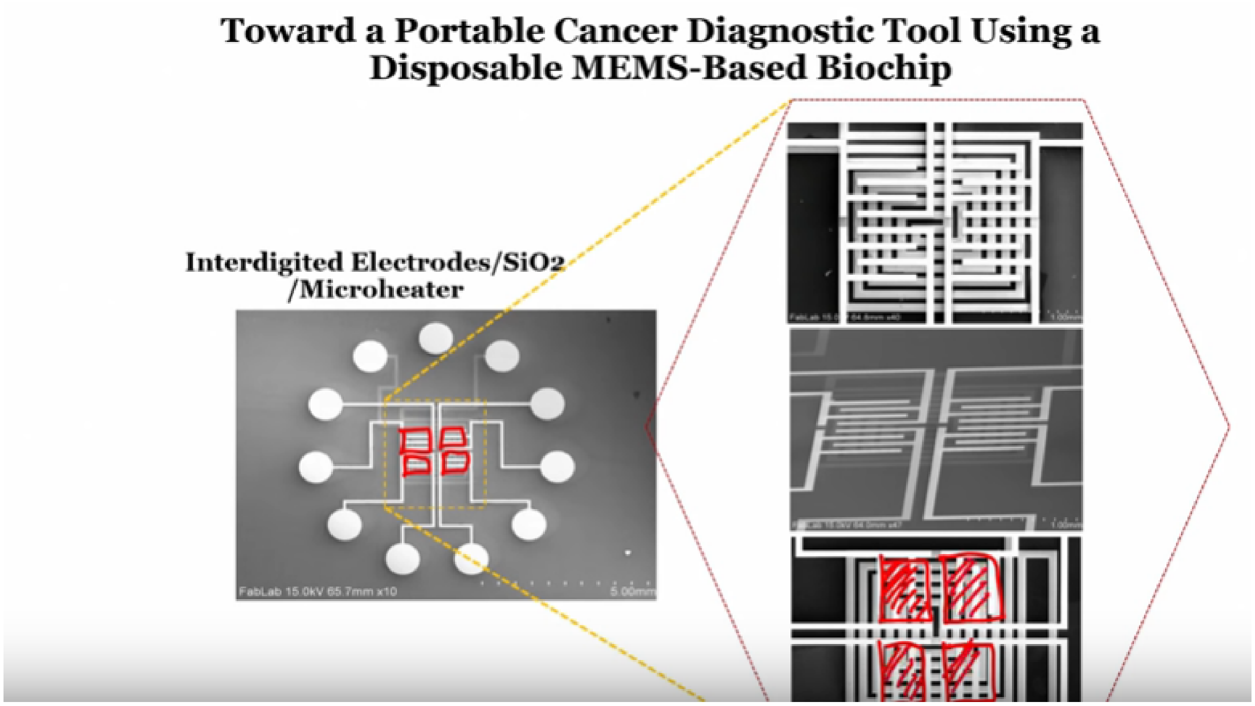

So, this we have seen, this we saw in the last module correct. Now, we will continue from this process, onwards to deposit, a Piezoresistive material, in this region. 1, 2, 3 & 4. Okay? So, this is just a magnified view, this is what I want to, do today and to teach you, fabrication of Piezoresistive sensors on the, interdigitated electrodes. Al Right?. Let us see the process flow.

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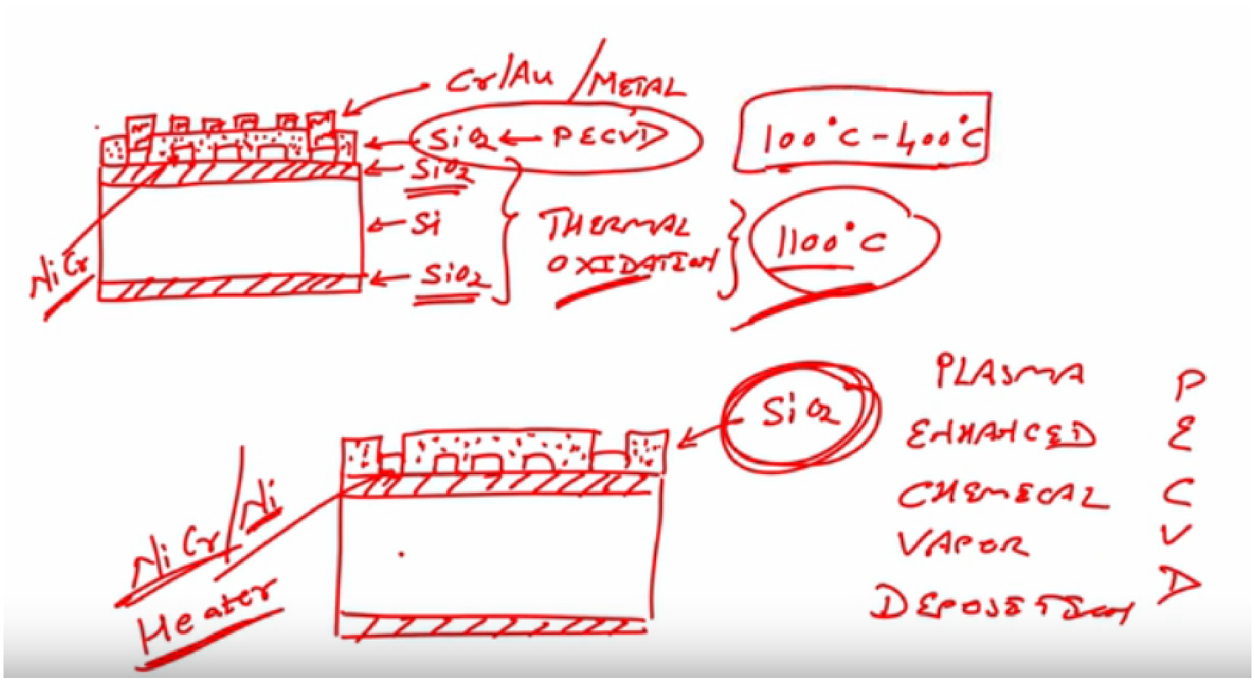

So, let's see how can we fabricate, the Piezoresistive sensors, over the interdigitated electrodes. For that, what we will do? We will first take, the oxidized silicon wafer and we have seen that our oxidized silicon wafer, is integrated with micro heater. Right? And then, we have opened the contact, 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 one, silicon dioxide 2, silicon dioxide 3, silicon and then we have, over Nichrome, this is a heater material, hey! Over that, what we are 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, interdigitated electrodes. Now, over this, I want to deposit, a Piezoresistive material. So, there are two ways, now this interdigitated electrodes, we have used chrome gold. Right? But, you can also use any other metal. Right? In either metal. Alright? The silicon dioxide, let this one and this one is grown, using thermal oxidation, while his silicon dioxide, is deposited using PECVD. So, let me first explain you, why we have not grown silicon dioxide using thermal oxidation like, like this, to thermal that like this oxidized or silicon dioxide layer: that we used, thermal oxidation, why? We have not used thermal oxidation, for this the Condi oxide, why we have used PECVD. Okay? 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 vapour deposition, thermal oxidation the temperature, temperature is 11 degree centigrade, again you can vary from thousand, to twelve hundred, generally it is there under degree centigrade. Okay? Now, you have Nichrome. So, I'll just draw quickly, a heater, on oxidized silicon wafer, right see, please understand that term, this is a silicon wafer, when you grow silicon dioxide, on silicon wafer, it becomes oxidized silicon wafer, oxidized, oxidized silicon wafer. Al right? So, oxidize silicon wafer, we are 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 and deposit my silicon dioxide, on the heater. Right? So that, I can further process my wafer, to fabricate interdigitated electrodes and other materials. Now, if I use thermal oxidation, to grow this silicon dioxide, the temperature that is used as level hundred degree 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, 1100 degree centigrade. Right? If it cannot withstand, this high temperature, then what will happen? It will melt. Right? It will melt and that's 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, 1100 degree centigrade and that temperature the material below it that is the, material below silicon dioxide, which is mine 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 PE e C V D. Right? And the advantage is that, we can deposit at a lower temperature, you got it? That's why?

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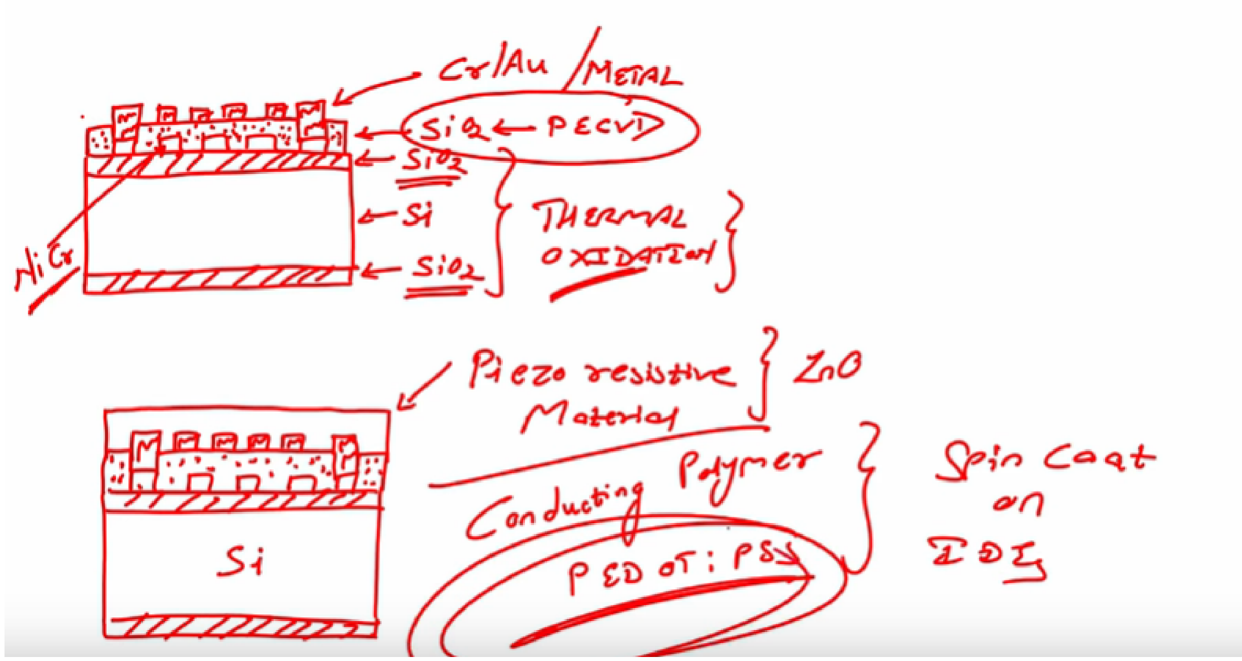

 I say that for, insulating layer over heater, we will go for PECVD. Right? So that is the reason of using PECVD, instead of the thermal oxidation. Okay? Guys easy, very easy. Right? Once you understand fabrication, it becomes very easy to design the chip and once you are design the chip, then we will go for this system design, system design. Alright? Now, this is the material, over that what we have to do? So, I again draw the schematic, where we can see what? Silicon dioxide, silicon heater, insulator, interdigitated electrodes. Right? Interdigitated electrodes math silicon dioxide, on this, I will deposit sorry, on this, I will deposit a Piezoresistive material, Piezoresistive material. Now, there are Piezoresistive materials, which can be deposited using PVD, PVD stands for physical evaporation, physical evaporation, three types, thermal evaporation, E-Beam evaporation and sputtering. Alright? Physical evaporation, thermal evaporation, E- Beam evaporation and sputtering. So, using E-Beam evaporation or sputtering, will deposit, Piezoresistive material. Okay? Now, there is an alternative material, which is a conducting polymer, now this can be zinc oxide. Right? Or any other piece of this 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, PE dot: P SS and for using period P SS, I have to spin coated, spin coat on interdigitated electrode. This is also visually this tube material. Okay?

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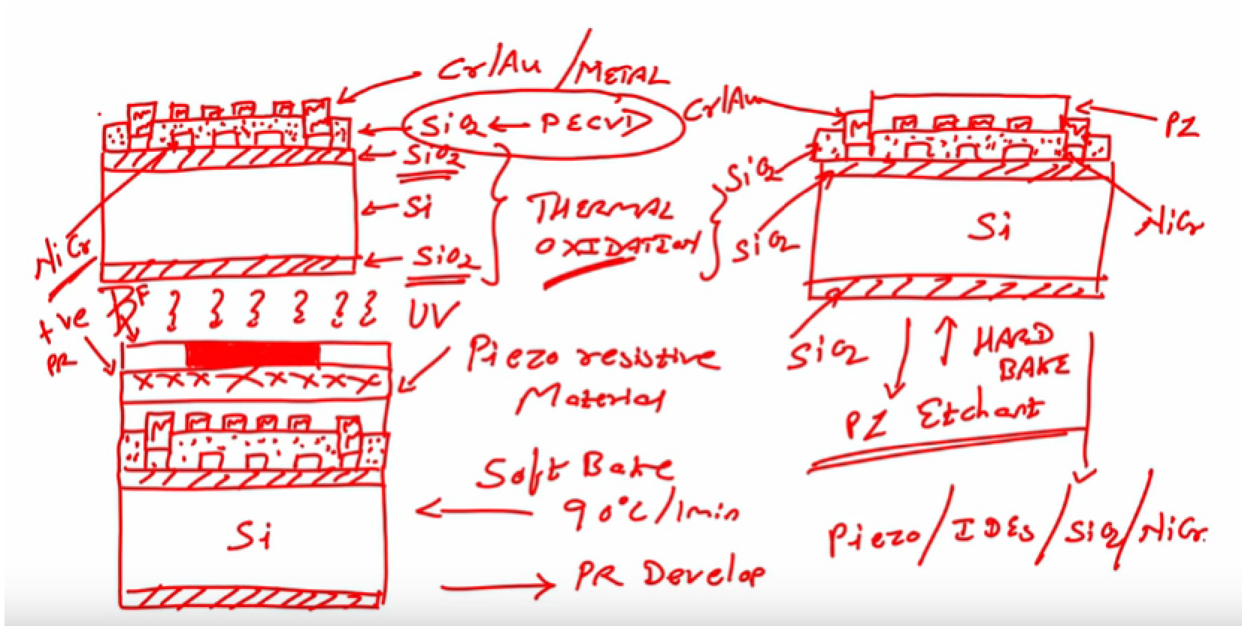

So, point is that we will, deposit or we will spin coat, Piezoresistive material. Right? Using either PVD or, or using spin coating. Right? Once you do that, what you do? Here to perform lithography and all of you know, how to perform lithography, we will take, we will spin coat, positive photo resist. Right? Let me, put checks for positive photo resist, what after that, what is the step? After positive photo resist, I will soft baked, soft baked the wafer, soft bake the wafer at 90 degree centigrade for one minute. Alright? And after soft bake, next step is, to load the mask and we only want, 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'll also show it you two different ways, if I use bright field mask, bright field mask like this one. Right? This is my bright field mask, 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 don't have bright field mask and I have a dark field mask, if I do not have a bright field mask, mask and I have a dark field mask. Right? In that case, my dark field mask, will look like this. Right. So, in this case, if I use positive photo resist then, the region which is unexposed, will be stronger, which we don't want, we want our Piezoresistive material, to be on this area. Right? Only on this area, we don't want on the contact, so if I use dark field mask, switch positive photo resist my problem, will not solve. So, what I will do? If I have sorry, let me just select the red color. Okay? If I have dark field mask then, I will change my positive photo resist, instead of positive or resist I will spin coat negative photo resist, you got it?

Because, if in negative photo resist, the unexposed region will be weaker and the exposed region, which is this region, will be stronger. So, finally what we'll 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 field mask, I'll go for negative photo resist in this case, but if I have a bright field mask, if I have a bright field mask, then I'll go for a positive photo resist. So, you have to select the recipe, according to the design of your mask and the ability of a photo resist. Right? So here I'll use, positive or digest, this is my bright field mask, easy after exposing what will happen? We have to, we have to develop the photo resist, PR development. Right? See if I did the wafer in photo resist, which is photo resist developer, then what will I have? I will have, my oxidized silicon wafer, on that there is a micro heater, on that there is an insulating material, which is my silicon dioxide, on that I have interdigitated electrodes. Right? On there, there is a Piezoresistive material, 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 photo resist only, in this region, only in this region. Okay? Why because? I have used a bright field mask, with positive photo resist and the unexposed region, will be stronger and that's why I can see that the unexposed region, is stronger, hmm! The next step is we'll go for a hard baked, hard baked, hard baked is done it, 120 degree centigrade, one minute on hot plate. After this, the next step would be, next step would be to, H Piezoresistive material. So, we have to dip this wafer, in a Piezoresistive material Etchant, write wet etching, if I do that, what will happen? The material, which is protected by the Piezoresistive material , which is protected by the photo resist, will not get etched, by the Piezoresistive material, which is not protected by Photo resist, will get Etch. So, I'll have Piezoresistive material in this area. Alright? You got it? Because there is no photo resist that can protect the Piezoresistive material, in this region and this region, hmm! So, once I deposit the wafer or once I dip the wafer, in a Piezoresistive Etchant I'll Etch my Piezoresistive material , which is not protected by photo resistor. 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 photo resist, if the dip, if I dip the wafer in acetone, will strip the photo resist, if I strip the Photo resist, then what will I have? I'll have a Piezoresistive material over interdigitated electrodes. Right? I will have, a Piezoresistive, likes a Piezo resistive material, over interdigitated electrodes, over sio2, over NiChrome heater. And then, this will look like, you got it?

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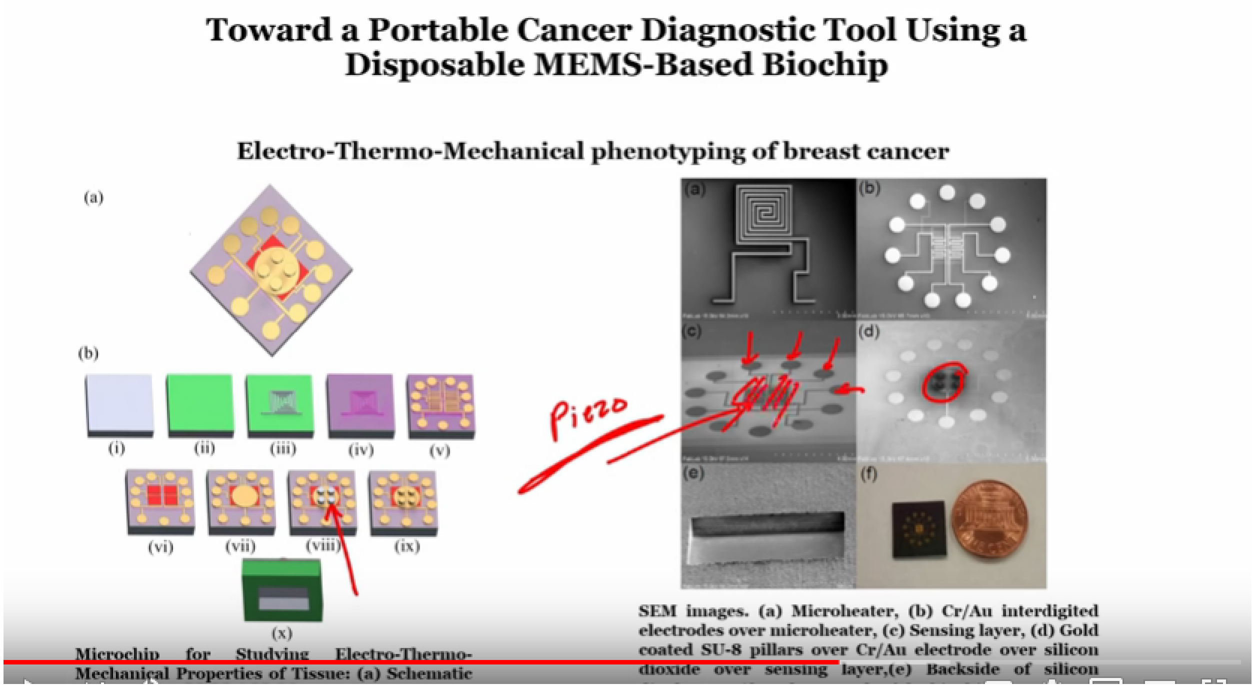

Easy so, what is our next step? Our next step is, to have a gold pad. Right? Which is in the center? Okay? This one, gold pair and on that gold pad, we require su-8 pillars, on that goal pad, we require su-8 pillars. So, can I deposit the gold directly on Piezoresistive material, this is Piezoresistive material. Right? This for black squares, in center or gray, gray squares in the center, are Piezoresistive material. But, can I deposit a gold which is a metal, on Piezoresistive material, it will get short. Right? So, what we had to do? After this we had to grow our silicon dioxide layer. Right? Open the context, 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 now, let us see in this particular module, what we have learn? You'll learn 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, if I want to use liftoff. So, what exactly liftoff means and why we had to use liftoff. Right? So, let us understand, if you go back to the slide,

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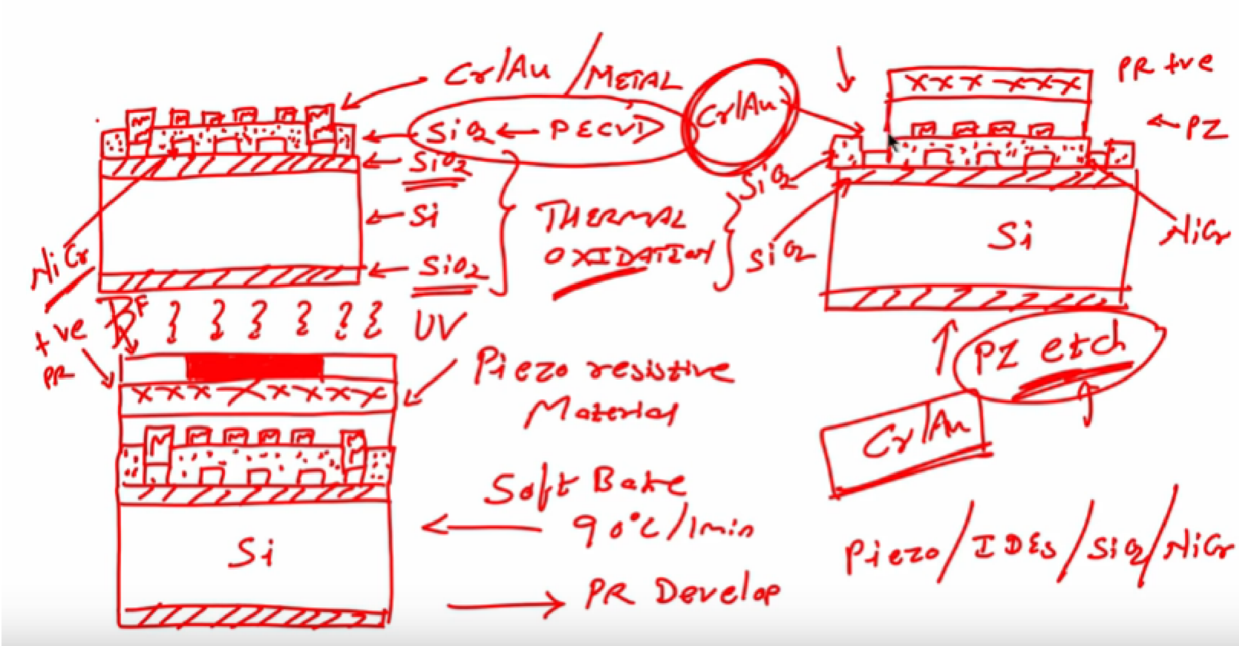

What you see here? Is that we have done, a standard lithography technique, where we have Piezoresistive material. So, if I just continue from this section, it will be easier, for you to understand why we will go for liftoff. Okay? So, the point is that you know: that we had, a Piezoresistive material, all over the interdigitated electrodes and then, we are protecting the Piezoresistive material in this area. Right? This one see we all know, this is positive Photo resist. This is Piezoresistive material. Alright? 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 Piezoresistive material suppose, 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 photo resist, which is not protected by photo resist, 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 add chrome gold. In this case, what will what will happen? The chrome gold here and here. Right? Will be Etch if there is a case, we will lose the contact to the interdigitated electrode, correct, we lose the contact to the interdigitated electrodes and what's the purpose of fabricating interdigitated electrodes no purpose, it was gone, there's 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 Piezoresistive material, which is called, 'Lift Off'. So, let me show you, interesting if you see the slide.

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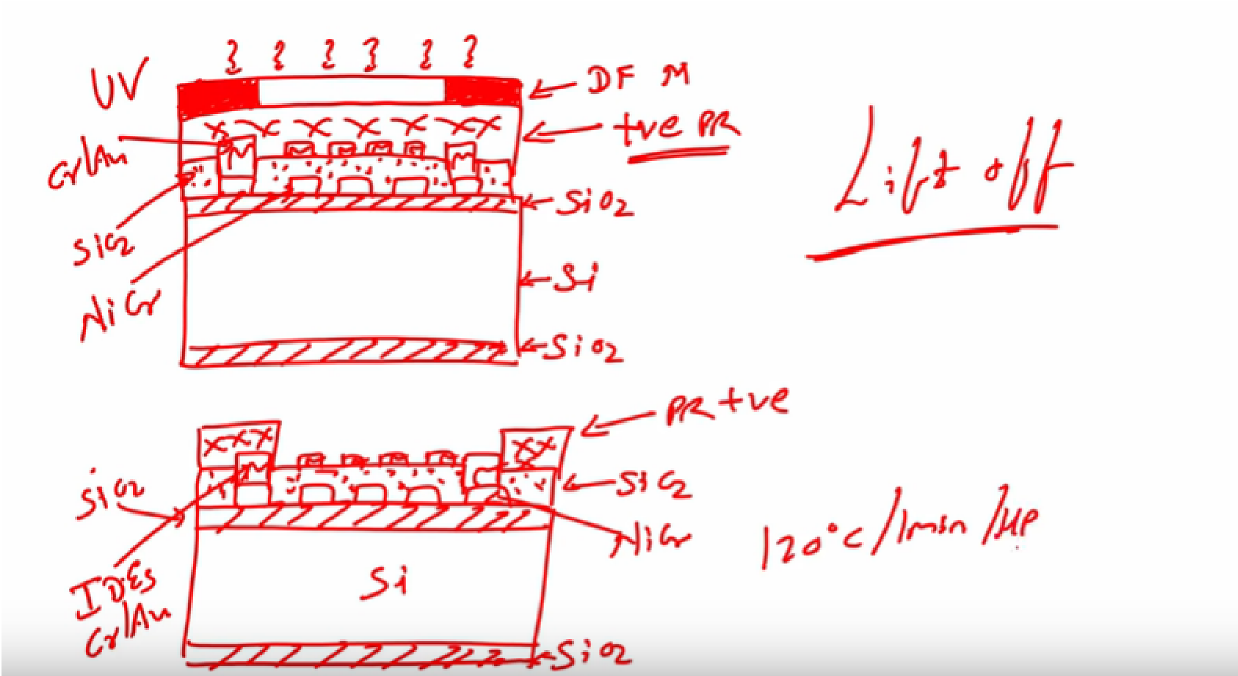

I will show you, how to do lift off. Okay? Very interesting technique, very easy, focus on the schematic that I am drawing. Right? I always write down, even you know that, what are the patterns here? What I am showing in the design, is always a good practice to write down as many times as you can, so that you remember. Okay? This is using thermal oxidation, over that what we have? We have a heater, order what we have? We have a silicon dioxide, grown using PECVD or that, what we have? We have interdigitated electrodes, correct. ,Now, over this, we want to, we want to pattern the, 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, we will spin coat positive Photo resist. Alright? Spin coat, positive Photo resist, then we'll use a, dark field mask, a dark field mask. Of course after positive photo resist spin coating, what is the next step? Next step is of course, the soft bake. Right? So, spin coating, soft bake, at 90 degree one minute hot plate, will lower the dark field mask and I have positive Photo resist. 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'll have an oxidized silicon wafer, oxide silicon wafer with heater, insulating material, interdigitated electrode . Right? And photo resist. So, let me draw photo resist like X, so photo resist in this region. Right? So, if I use positive photo resist, if I expose the wafer, with UV and if I develop the wafer and if I develop the wafer, what will I have? I'll have photo resist, in this region there is nothing you can see, there is no photo resist. Right? There is no photo resist. But, here there is photo resist and we know, what is this one? Introducer 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 back, hard-backed 120, 1 minute hot plate hmm! After hard back, after hard back.

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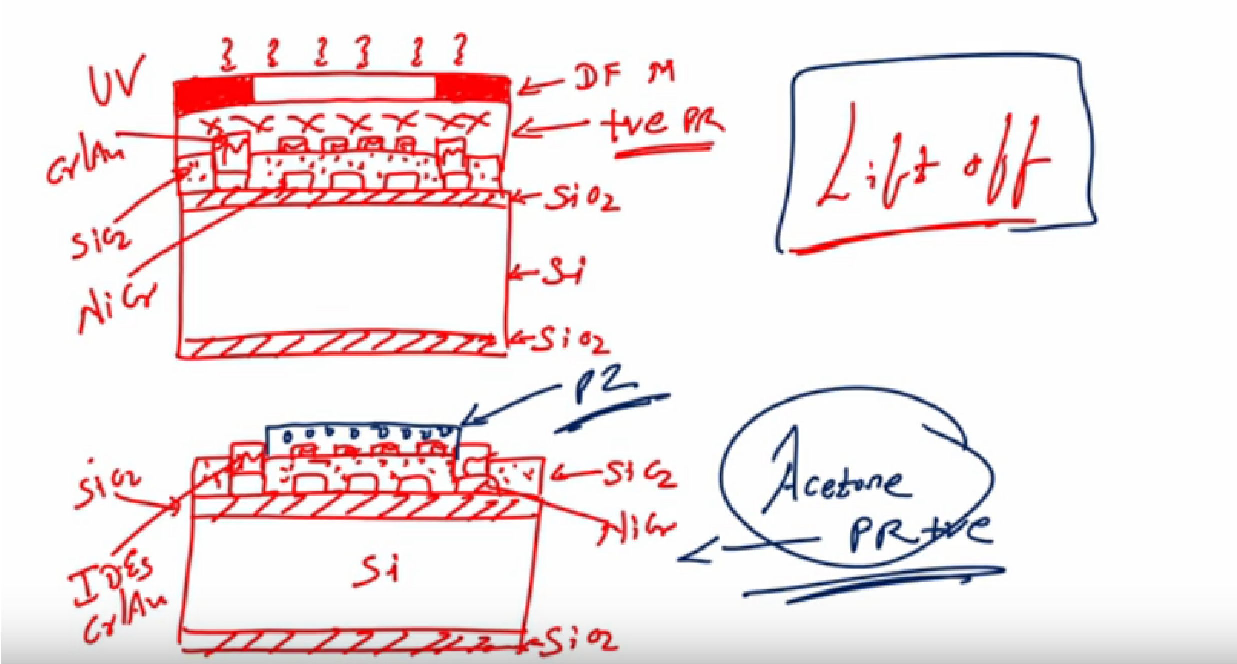

Next step is, I will deposit, I will deposit a Piezoresistive material, Piezoresistive material will be deposited like this. Right? So, let me just draw the Piezoresistive material with a different color. So, you understand this is the Piezoresistive material. Right? What I have done? On the positive photo resist which after the hard back, have deposited a Piezoresistive material . Right? Over the photo resist. The next step is, after this, I will dip the wafer, in acetone, I'll dip the wafer in acetone, if you dip the wafer acetone, what will happen? The positive photo resist, the positive Photo resist, will be stripped off it strips off. Right? So, if the positive photo resist 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 did this wafer, with a Piezoresistive material, deposited on positive photo resist and if I dip this wafer in acetone, then what will I have? Is what will I have is this structure, you got it? Why because? The positive photo resist, will lift off the material, when you strip off when you strip it, in acetone, you got it? So, why and now you have to do a liftoff 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 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 deep we are dipping the wafer, in acetone, which will strip of the photo resist and the fall the Piezoresistive 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 technically. Right? In the next slide, 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'll see you in next module. Take care. Bye.