Electronic Systems for Cancer Diagnosis
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Lecture - 15
Fabrication of SU-8 pillar on Piezoresistive Sensor

Hi welcome to this module and in this module what we will look at? We look at how can we create or fabricate SU-8 pillars on the gold pad that we have seen the process flow of fabrication in the last module and then, we will also see how to create a diaphragm. So, there are two process and once we finish that two process, you will see how can you have a chip indicated with lot of sensors, ok.

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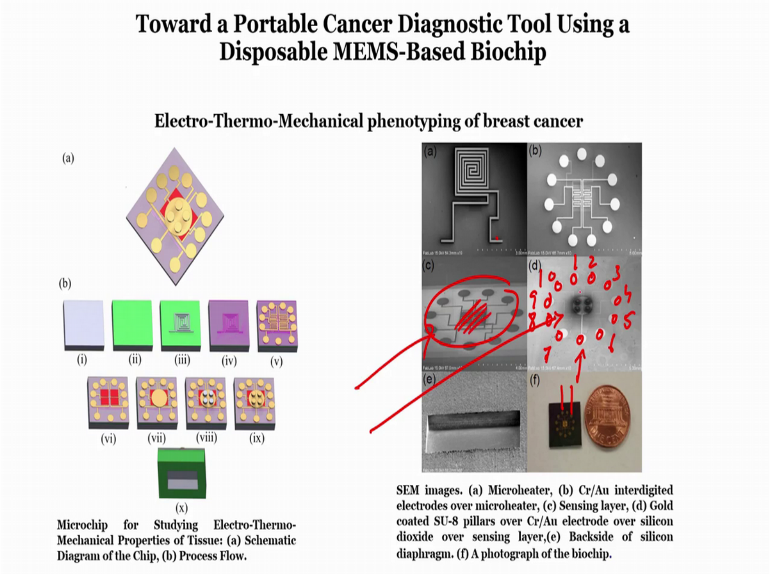

Toward a Portable Cancer Diagnostic Tool Using a Disposable MEMS-Based Biochip

Electro-Thermo-Mechanical phenotyping of breast cancer

Microchip for Studying Electro-Thermo-Mechanical Properties of Tissue: (a) Schematic Diagram of the Chip, (b) Process Flow.

SEM images. (a) Microheater, (b) Cr/Au interdigited electrodes over microheater, (c) Sensing layer, (d) Gold coated SU-8 pillars over Cr/Au electrode over silicon dioxide over sensing layer,(e) Backside of silicon diaphragm. (f) A photograph of the biochip.

So, if you see the slide in the last module we have seen how can we create the gold pad on the piezoresistive sensors, right and we have seen how can you do that? We have to deposit an insulating material oh and then, we had opened the contact and then, we can deposit gold and pattern the gold such that we have a gold pad and the gold context would be on each contact pad. These contact pads as you can see if you see this piezoresistive material or sensor, there are four of those each sensor you will have two pads

So, 8 for that, 2 for heater will be 10 and 1 for the gold will be 11. So, one if I say from here, 1 2 3 4 5 6 7 8 9 10 and for a gold 11, ok. So, 11 pads we have opened after we have in deposited insulator on the piezoresistive sensor and then, open the contact area for depositing gold and in the center there is an insulating material on that we have a gold pad. So, let us see how can we deposit or fabricate or draw the process of a fabricating the SU-8 pillars.

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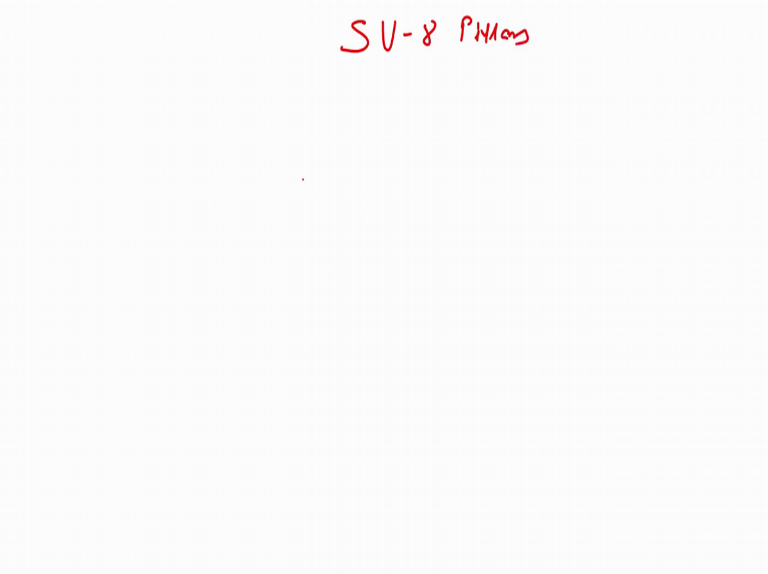

SU-8 Pillars

Now, we have to have SU-8 pillars right. So, for SU-8 pillars let us see how can we further process.

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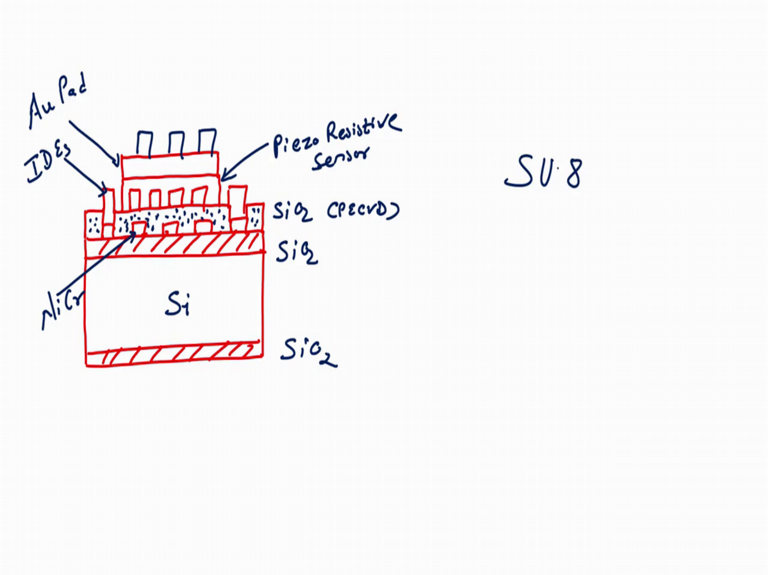

So, if I draw the wafer it is an oxidize silicon wafer, right. We all know on the oxidize silicon wafer we have a heater, right. On heater we have insulating layer except on the heater contact on that we have interdigitated electrodes, right. On this we will we have piezoresistive material and on that we have the gold pad.

So, let me use different pen. Color of this pen is dark blue. That is fine. So, here is our PECVD silicon dioxide. Let me write it down. Silicon dioxide with thermal evaporation and a thermal oxidation silicon wafer silicon dioxide silicon dioxide using PECVD, right. We have nichrome heater, then we have interdigitated electrodes on that we have piezo resistive sensor, on this we have gold pad, ok. Now, what we want? We want SU-8 pillars; we want this structure, right. These pillars are SU-8 S U 8.

So, let us see the process of how can we fabricate this SU-8 pillars or pattern SU-8 pillars on this particular chip So, for that what we have to do? So, I will just like remove this thing for a while, so that we can understand it properly AU pad you just delete it now we know,

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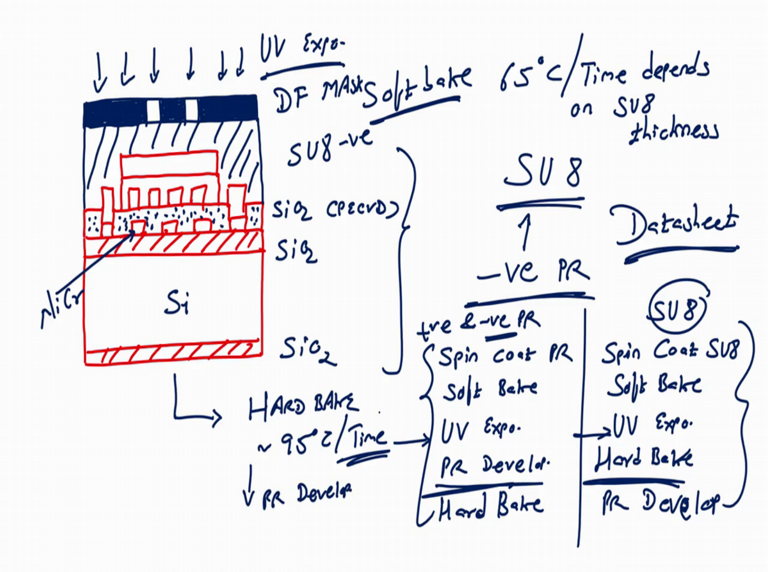

So, if I want to fabricate or pattern SU-8 on this chip on this chip, then I will spin coat I will spin coat this SU-8 material spin coat SU and there are several kind of SU-8 and depending on the viscosity, we can have different thickness of a SU-8 material, right. So, right now we are interested in having SU-8 pillars with 50 microns thickness, 50 micron thickness. So, we will deposit a SU-8 which can give us 50 micron thickness by controlling the rotations on the spin coater.

So, once I spin coat SU-8 on the chip, what is the next step? Next step is prebake or soft bake. Soft bake now in this case soft bake is done at 65 degree centigrade and the time depends on time for baking depends on SU-8 thickness, time for baking depends on SU-8 thickness, all right. So, after spin coating on the chip, this SU-8 material we will do the soft baking. After soft baking the next step is mask, right. So, let us see and understand this thing SU-8 is the negative photoresist.

It will behave as a negative photo resist, all right. So, if I want to have a mask on this, right my I want SU-8 pillars only on two places and remaining places I do not want SU-8 pillars. So, what kind of mask I can use if SU-8 is a negative photoresist? That means, area which is not exposed right, area which is not exposed will be weaker, right area which is not exposed will be weaker.

So, I will have a wafer, a mask which is my dark field mask, dark field mask. So, in dark field mask as you can see the most of the area in the mask is dark and the area which one we want to expose does not have any chrome material, right. It is a chrome mask is a chrome mask. So, you can see here, here and here UV can go and remaining area you will not go.

So, from here and here the UV can pass through the remaining area. UV cannot pass through,. So, this after loading this is a dark field mask will go for UV exposure UV exposure. So, even we do the UV exposure what happens? The area which is not exposed the area which is not exposed will become weaker because this is negative photoresist and the area which is exposed will become stronger, right. So, if you see the slide after UV exposure, the next step will be the next step in reality should be. So, if I draw the photolithography process, then it is spin coating spin coat photoresist. Next step is soft bake soft bake, right.

Next step is UV exposure, next step is photoresist developer, next step is hard bake, right. This is in case of photoresist positive and negative photoresist in case of SU-8 which behaves as negative photoresist. The process is like this spin coat spin coat SU-8. Next step is soft bake like I said 65 degree. Time depends on the thickness UV exposure.

Next step is hard bake. This is done around 90-95 degree centigrade. Again time depends on the thickness.

Now, when I say time depend on thickness, how you will know using the datasheet data sheet for SU-8 after hard bake you have to go for PR develop PR developing, ok. So, in positive negative photo resist, these are the steps in SU-8 these are the steps. So, what is the change in the process flow? If you can see the slide the change in the process flow is that after UV exposure instead of going for photoresist developer, you have to go for hard baking. So, when I say that UV exposure we have done, the next step is hard bake and hard baking for SU-8 is around 95 degree centigrade. Again for how much time depends on the thickness of SU-8 material? After hard bake photoresist developer, right.

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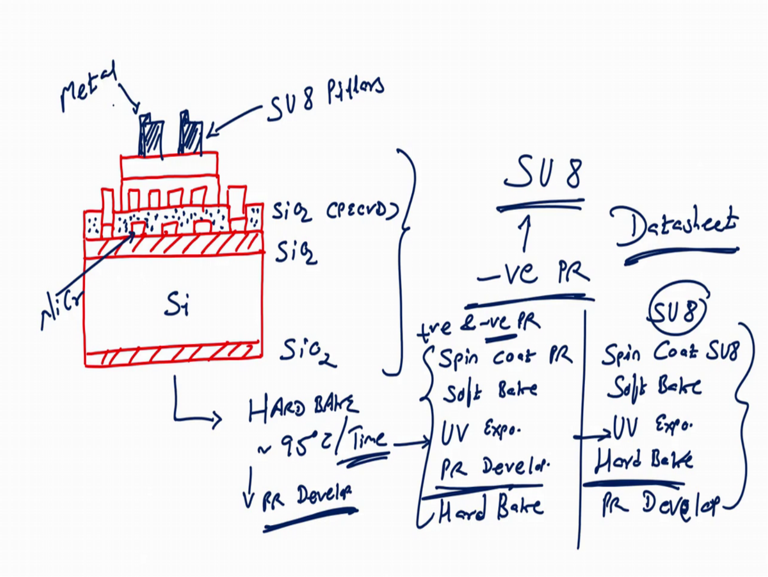

So, when you develop your photoresist after hard baking what you will find is, what you will find is that the SU-8 will only be in this region and remaining region SU-8 it would be will get developed in remaining region, the photoresist that is your SU-8 will get developed. So, these are my SU-8 pillars, all right. These are my SU-8 pillars.

Now, I will place this wafer. So, now you understand that this is a wafer for example and I have SU-8 pillars on the wafer right vertical pillars on the wafer. If you understand the physical vapor deposition, there is a shadowing effect. So, because of that if I have a pillar let me explain you little bit if I can help you outok. You understand do not consider this top surface like let me say like this, ok. Now, this is the wafer, this is the wafer and this tip this tip that comes out here right this much this tip either SU-8 pillar do not consider the top section of the pen.

Now, if I place the wafer like this, I cannot quote on the side, I cannot quote on the side so, but if I tilt the wafer, then I can coat on the side, right. At least one side we can coat it, right. So, if I tilt the wafer at 45 degree angle in there PVD which is Physical Vapor Deposition, then I would be able to coat this SU-8 pillar with a metal. That means, SU-8 pillar will have the conductive line because at least one side of the SU-8 pillar will be coated with metal.

So, SU-8 metal coating will be the next step. How can we do that? We can place the wafer, we can do the lithography. So, if you see again I will do the lithography and I will only open I can do either lithography or I can just save the protect only half of this and remaining. So, once we if you till the wafer anyway even you if you till the wafer, then you will have SU-8 only. The material would be only deposited in this area in both the cases, right. So, I will have a conductive value. So, this SU-8 pillar will have a metal contact all right.

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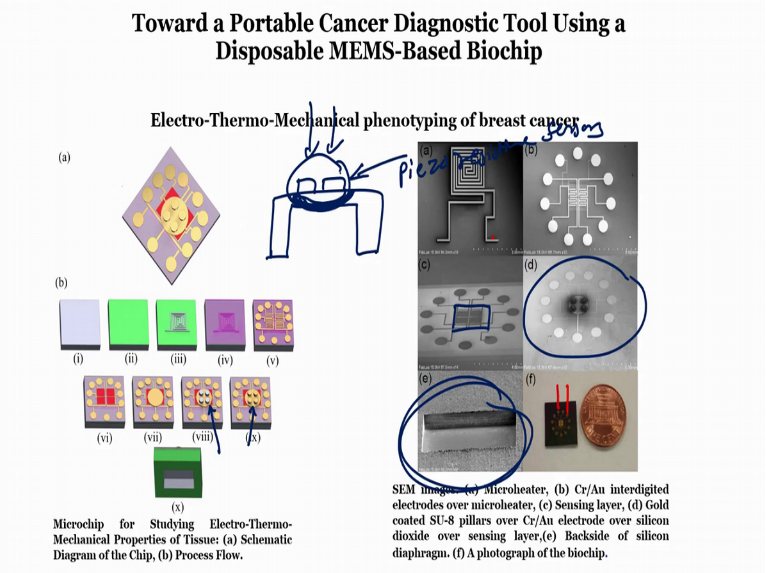

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So, if I go back and you see what you see here? You see that you have a chip; you have a chip, right with SU-8 pillars coated with metal. That means, till last module we saw this gold pad on the piezoresistive sensor. In this module we see the SU-8 pillars right without coating an SU-8 pillars with metal coating. Now, what is the next step? Next step is we have to create a diaphragm on the backside of the silicon wafer. This diaphragm will be exactly on the backside of this.

So, if I have a wafer and these are my piezoresistive sensor, my diaphragm would be like this. Why we have to create this diaphragm? Try to create this diaphragm because these are piezoresistive sensors, right. These are piezoresistive sensors. So, if I apply a pressure or force, then if I apply a force or pressure what will happen? This diaphragm will bend and depending on how much the diaphragm is bending this there will be change in the piezo resistivity, their piezo resistance, right then which is in the resistance.

So, thinner the diaphragm, better the sensitivity, but we have to optimize the diaphragm thickness because then the mechanical stability will reduce. So, in this case we are creating SU-8 pillars and below the SU-8 pillars there is an electrode which is gold pad, below that there is insulating material, below that there is a piezoresistive material, below that there is a again insulating material, below that there is a micro heater.

Micro heater is on the oxide silicon substrate and on the back said we have to create a diaphragm, so that when we apply pressure onto the SU-8 pillars, the applying pressure will change the piezoresistivity of the piezoresistor depending how much diaphragm will bend. So, to create a diaphragm we are etching silicon from the backside of the wafer, right. That is the idea.

That is why we are creating the diaphragm on the backside. So, if you go to the slide and if you see what I want, I want to now so let me just rub this down. It becomes little bit easier in that way. The only thing tricky about SU-8 is that after UV exposure it to go for hard bake. So, if you remember that much, then your life becomes easier ok.

So, now if I want to create a diaphragm on the backside of this chip, so that whenever I apply pressure the piezoresistor would change its resistance, right.

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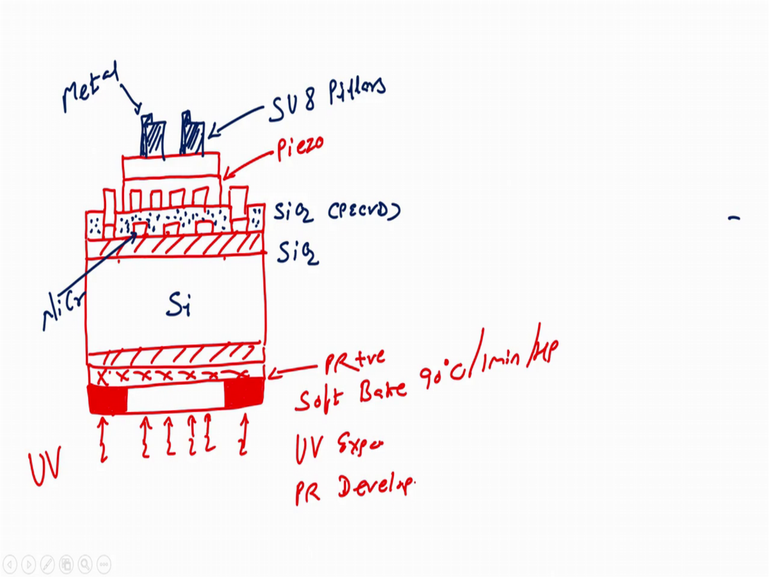

What should I do? I should do the lithography, but on the backside of the wafer. So, in that case I will deposit a photoresist. This will be my positive photo resist, right positive photoresist. Then, I will do positive. After that I will go for soft bake which is 90 degree. 1 minute hot plate after that, I load the mask and I want to etch the region which is below this piezoregistive region, right. This is piezo etch.

So, piezoresistive region, so I want to etch my wafer like here and this area I want to protect, this area and this area I want to protect, this area I want to etch. So, I will design my mask for positive photoresist. So, positive photoresist the unexposed region will be will be stronger, right.

So, I have a bright filed mask as you can see and in this will have we have unexposed region because this photoresist will be unexposed in this particular blocks while it will get exposed in this block, right. So, if I go for UV exposure if I go for UV exposure what will happen? The unexposed region will be stronger, right. So, the after this soft bake I will load the mask and go for UV exposure. When I do that followed by developing photoresist right in PR developer what will I have? I will have photoresist only in this area and the remaining area photoresist will be etched, right.

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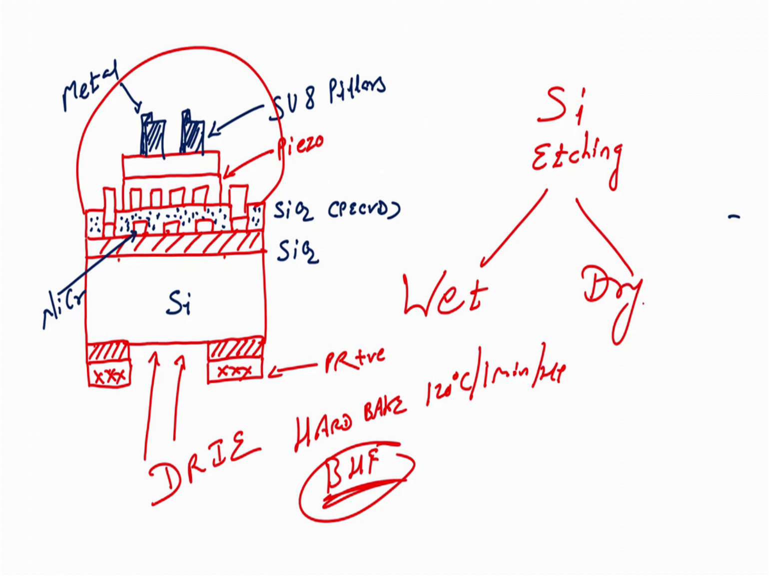

Now, next step is hard bake. Next step is hard bake. Hard bake you all know positive photoresist 120 degree centigrade 1 minute hot plate after hard baking we have to remove the silicon dioxide from this region. So, we have to go for buffer hydrofluoric acid or BHF, right. So, what will happen? Silicon dioxide will get etched right because of the buffer hydrofluoric acid. What is a next step? I will protect the front side right either mechanically or using the photoresist and back side of the wafer. Please look at this slide. The backside of the wafer I will etch using deep reactive and etching this is a dry etching. When you go for silicon etching, there are two types wet etching and dry etching.

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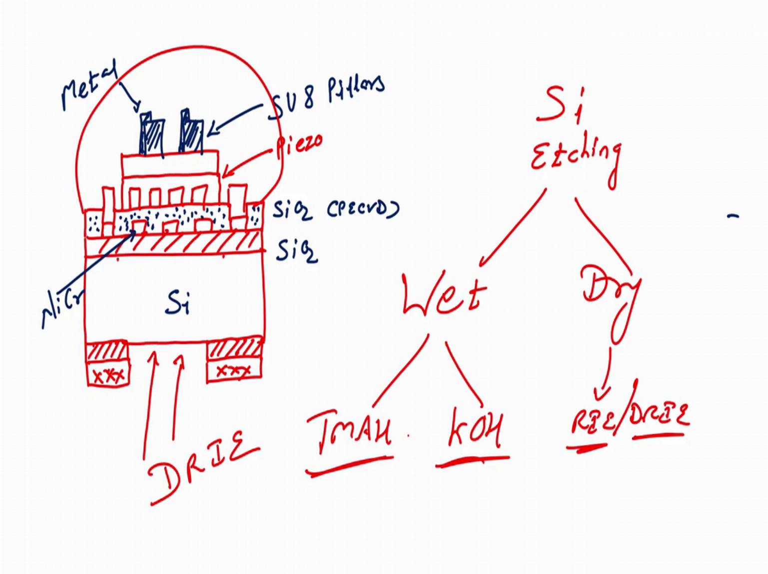

In wet etching you can use two different chemicals TMAH and KOH. Dry etching is RI or DRIE, right.

There is an anisotropic etching; there is a isotropic etching reactive ion etching, deep reactive ion etching potassium hydroxide tetra methyl ammonium hydroxide. Now, there is advantage disadvantage in both the cases. When you see your different lecture in which somebody teaches you or may be in my earlier lecture you will see how when you we were looking at the bulk micromachining probably at that time I have taught you that how can we use dry or wet etching and what is the difference, right.

So, if not just go through YouTube videos where you can see how DRIE works how RIE works, how KOH works and what is the what happens when we use TMAH, right. TMAH is also neuro toxic. It has to be used at 25 degree centigrade, KOH you have to use at 80 degree centigrade DRIE will give us a vertical wall.

So, if I use DRI and if I etch the silicon wafer and what will I have? I will have a die diaphragm.

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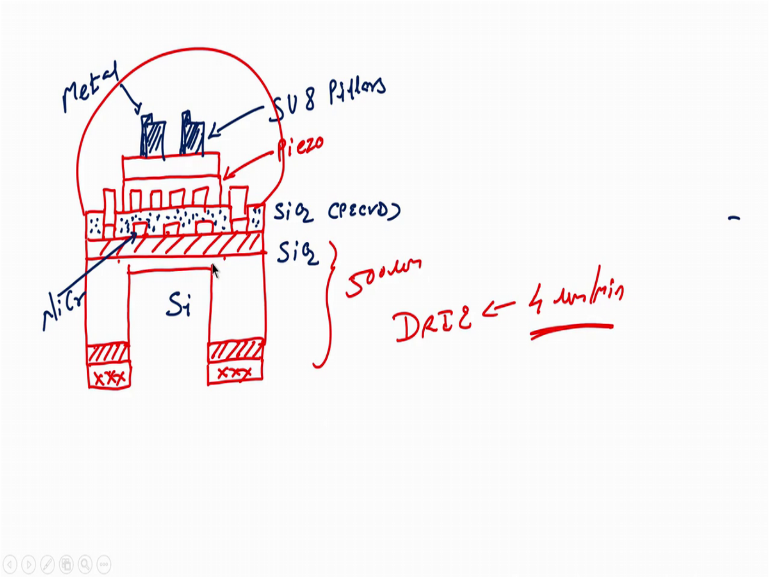

If I use DRIE then I will have diaphragm like this. Now, I know the rate of etching of DRIE. Suppose DRIE etch rate is 4 micrometer per minute and if the thickness of this wafer is 500 microns, then I would know how many minutes I need to create a diaphragm of 100 microns, correct simple. So, I had to etch 400 microns if I want to create a diaphragm. Diaphragm is this region.

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And let us say that this region is about 100 micrometers. You depend like I said thinner the diaphragm, better the sensitivity. Thinner the diaphragm, better the sensitivity.

Now, what you have? Definitely you can remove this what you have is a complete chip integrated it. So, the first the bottom layer, ok. Bottom layer is heater over heater that is silicon dioxide, insulator. Over insulator there are interdigitated electrodes made up of chrome gold. Over this there is again oh over this there is a piezoresistor, over this insulator over that gold pad, right. Over gold pad we do not have slides. I will write down this is on the gold pad, you have SU-8 pillars and then, we make this pillars we coat metal and below heater there is silicon dioxide on silicon wafer and this is my diaphragm as well right this is my chip, this is my chip. This is what we have learned in all the modules together how to make this bio chip.

Now, you can see that you are learning so many things, so many different sensors onto one chip, but the idea is what to do with this sensors and how can we use these sensors for the given application that is to understand the properties of tissues properties of a tissues.

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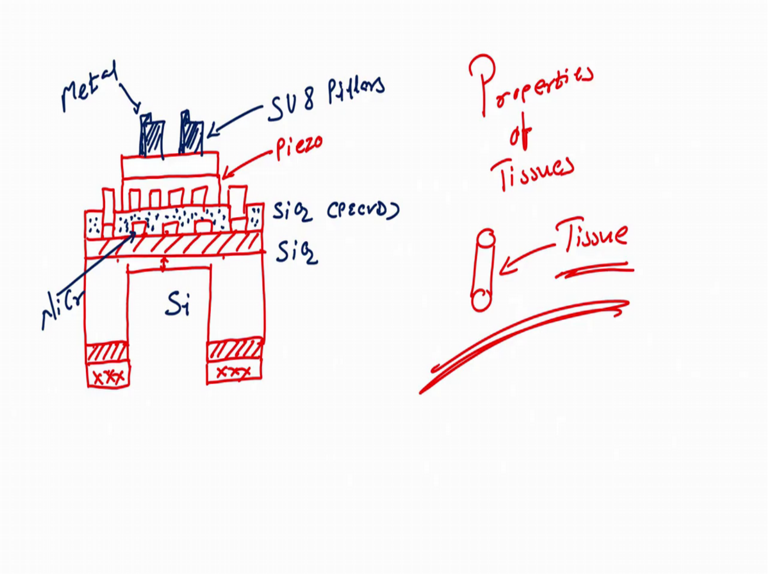

Suppose tissues from the biopsy is given to you, what are the properties that we can understand. So, using this chip let us see how can we use different or how can understand different properties of tissue, ok.

So, let us keep this slide as a last slide for this module and let me teach you how can you use this slide or use this chip which is a biochip mems based biochip for understanding the change in the tissue properties. When I said change in tissue properties, there are several changes right from electrical to mechanical to thermal to ph, right several thing changes and that changes when the tissue is diseased. That is if we take the tissue from the breast cancer area depending on the stage or as the stage of the cancer progresses, there is a change in the tissue properties.

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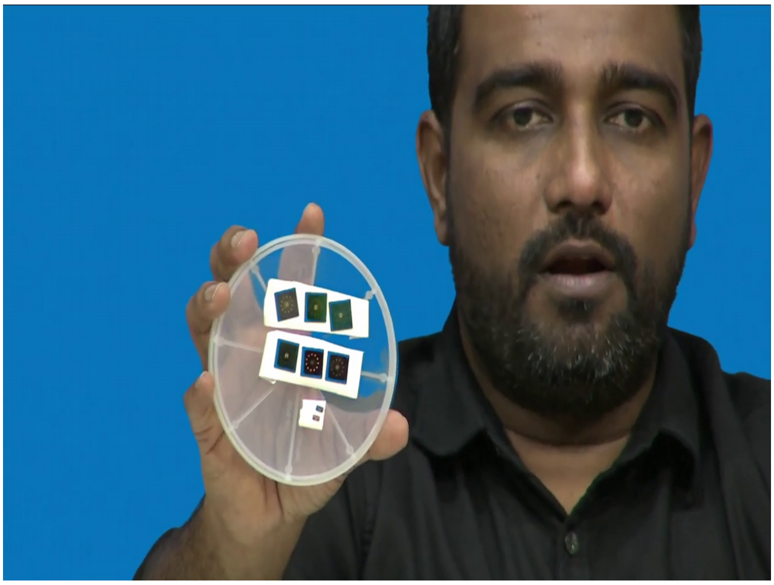

So, let me show you let me show you before we end this slide I have something for you in my hand and that is your bio chip, Ok. These are the chips, these are the chips in my hand right over here and these chips are the one that you have seen on the glass light on the in the modules, right. All the modules including today this is the chip that we want to design. Is it possible to zoom little bit? So, you can see here, right. You can see that I am holding several chips here in my hand. If you can just focus on one which is right over here right and you can see that this chip has all the sensors that we are talking about in this particular module, all right.

So, these are the chips that we will be using for understanding the tissue property. These are oxidized silicon wafer on that like I said there is a heater insulator, ide is piezoresistive material insulator, gold pad, SU-8 pillar metal on the gold pad, on the back there is a diaphragm, all right. So, let us see how can we use this chip to understand the tissue properties in the next module, all right. So, till then what you have to do? you are to understand this particular module in detail what I have talked particularly in this section. We have seen SU-8. SU-8 has a little bit of trick like I said when you take a photoresist which is positive photoresist or a negative photo resist, the standard step of photolithography is spin coat, the photoresist soft bake it then load the mask UV expose photoresist development and hard bake in SU-8. What is a difference? You spin coat it, then soft bake it, then expose it, then hard bake it, then you have to go for photoresist development, right. Easy and if you want to make the photoresist even harder that the SU-8 even harder after hard baking and the photoresist developer hard baking exposure and the photoresist development of course after hard.

So, that is spin coat, soft bake, expose hard bake, then photoresist developer in case of SU-8 and then after that you can bake this wafer with SU-8 at little bit higher temperature let us say 130 or 140 degree centigrade to make the SU-8 pillar stronger and then, what we have seen that how can we deposit metal and how can we create a diaphragm for diaphragm we have used deep reactive add etch like I said there are several techniques to etch the diaphragm.

Now, since bulk of the material is etched in this particular step, we will consider this as a bulk micromachining, right. I have taught you what exactly bulk micromachining is in my earlier modules, right. So, let us see how can we use this chip that I have shown it to you in the next module for understanding the tissue property. Till then you take care. I will see you in the next class. Bye.