Fabrication Techniques for Mems-based Sensors: Clinical Perspective

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Lecture - 20
Process flow for Fabrication of interdigited Electrodes (contd)

Welcome to this module. And in our last module, what we have seen? we have seen how we can fabricate an interdigited electrodes over an insulator. And below the insulator, there was a micro heater. The idea of learning this particular topic is to understand, how we can fabricate devices or chips for biomedical applications in particular to understand cancer and other than understanding cancer, to diagnose cancer at an early stage.

So, can we add modalities other than optical modality or biomarkers so that is what we have discussed last time that if you take a tissue from a breast right, so breast cancer, then the generally how it is identified that the a woman has to go to a hospital, where a MRI or mammography is performed. And then, if the area is suspicious, then the tissue is taken out from suspicions region and we sent to the path lab, where they understand the biomarkers present in the tissue. What are those biomarkers? We discussed about those biomarkers, they were HNE, prostogene, estrogen, HER, B63, SME. These are several biomarkers.

Now, in particular breast cancer there is something or subdivision of breast cancer, which is called triple negative breast cancer. And in that none of the biomarkers are present, then how we can identify there is a cancer or not or even. If there biomarkers are present in other subdivisions, there are false positives and false negatives signals.

So, how we can reduce those false positive and false negative signals by taking the help of engineering. So, the idea here is that we will understand a mechanical property, a electrical property, and thermal property of a tissue that means, we are adding the different modalities to the existing modality. And we are creating a biochip that can aid a physician to take a correct decision right. For that correct decision, this device or the chip should be able to measure electrical, mechanical, thermal property.

So, in our last modules, we have been understanding how we can fabricate this particular biochip. And we talked about biochip, we also talked about heater. How we can design a process flow right, to pattern, a heater made up of either nichrome, nickel, platinum, chrome gold right. And once you have a heater, you wanted to have a interdigited electrodes, but you cannot have metal on metal that is why, there should be insulating material over which there where interdigited electrodes. And that was what we have seen in the last module, how we can design or pattern interdigited electrodes on insulator right.

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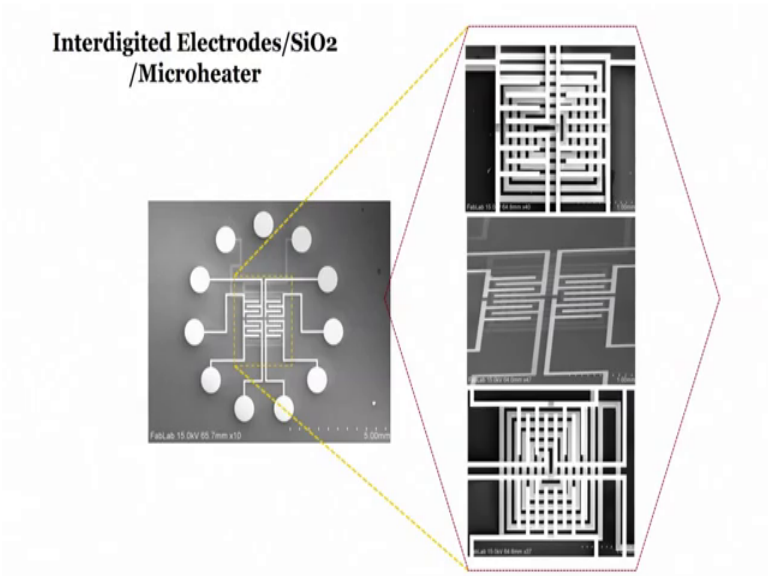

So, we see the screen, what we discussed last time, it was interdigited electrodes right over an insulator. And below the insulator, there is a micro heater.

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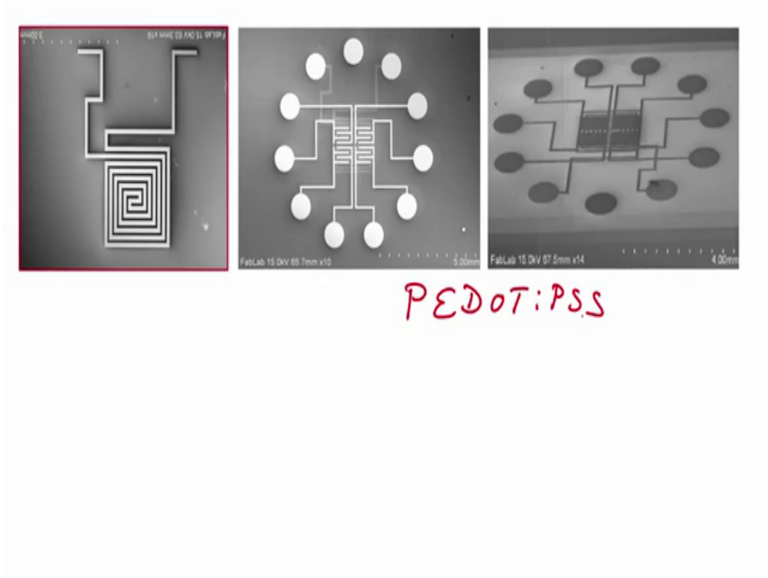

So, until now we have seen, how we can design a process flow for fabricating a micro heater. Then, we have seen how we can pattern interdigited electrodes on an insulator, over this there is an insulator, there is an insulator on which there are this interdigited electrodes right. And then, we also seen that we have to open this area, we have to create a window. To open this area right, and remove the insulator from that particular area, so that we can have a external contact, you can see here, contact pairs for the micro heater.

On this chip, next step is we want to have a piezoresistive material we want to have the piezoresistive material. So, how to pattern this piezoresistive material right how to first deposit, and then pattern this piezoresistive material. So, we can use several piezoresistive material including silicon, we can make a piezoresistive, it is a poly silicon right. And or we can use a conducting polymer conducting polymer call PE Dot PSS call PE Dot PSS.

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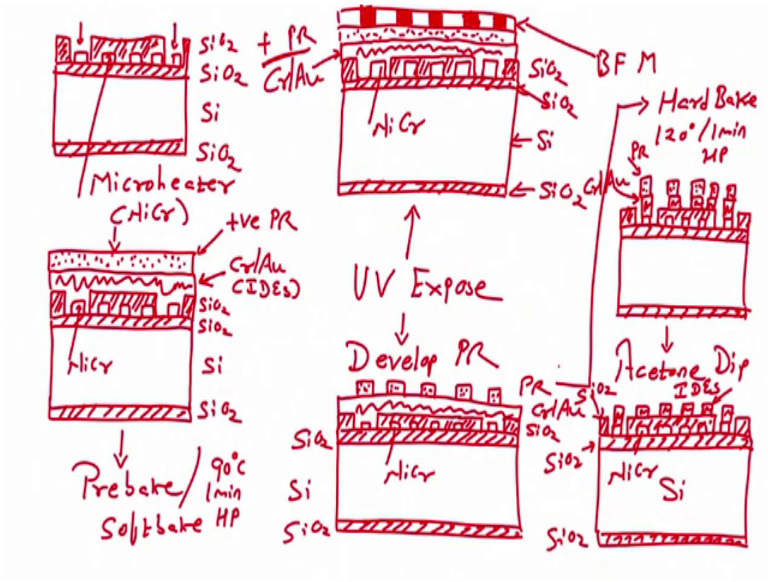

So, if you remember the last screen that we have seen right, which is our interdigited electrodes this one right. And below interdigited electrodes there is an insulator below, which there is a micro heater. So, we will start from here, and then we will pattern a piezoresistive material right.

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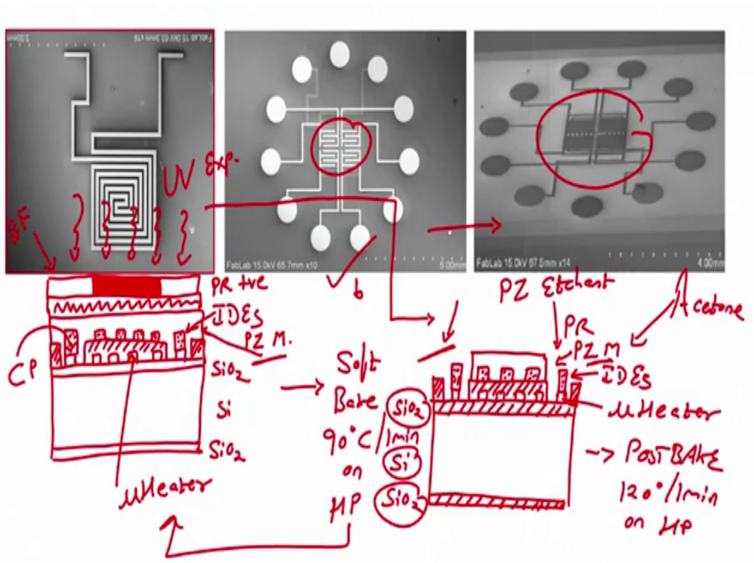

So, I have to draw that particular schematic diagram to start from this particular end right. And then, we will see from here, how can we reach to this particular chip. So, this chip let us say, I give a, b, and c. So, we are drawing b ok, cross section of b. So, I have insulator, which is my oxidised silicon substrate on which I have my micro heater on which there is an insulator right, let us say this is an insulator.

This is these are the contact context right contact pads to micro heater, this is your micro heater right micro heater. This is SiO2, silicon, SiO2 on this on this there were interdigited electrodes right this is what we have seen. So, I will draw interdigited electrodes in terms of like dots to just distinguish from the heater all right. So, this is my interdigitated electrodes.

So, what is the next step what is the next step next step is to next step is to spin coat spin coat a material, which is my PE Dot PSS. It has spin coat PE Dot PSS on the entire wafer right what is PE Dot PSS PE Dot PSS is conducting polymer, and it can also act as a piezoresistor. Instead of PE Dot PSS, I can use any other piezoresistive material and deposit it right. So, this is nothing but piezoresistive material property of piezoresistive material is when you apply pressure, there will be change in resistance right piezoresistive material.

On this piezoresistive material, what is the next step, after I deposit piezoresistive material on interdigited electrodes, I have to go for lithography right. So, first step is I will spin coat I will spin coat photoresist right as spin coat photoresist on this piezoresistive material right, this is my photoresist. Let us say, I am using positive photoresist. What is the next step, I want to create this particular chip you see here right.

Next step is after this we all know, we have to soft bake it soft bake right. After soft baking, soft baking can be done it 90 degree 1 minute on hot plate. After soft baking, I am coming back to this particular schematic. After soft baking, we have to load the mask we have to load the mask such that I can save my material, piezoresistive material on the interdigited electrodes right. I am just drawing cross section for one that is why I am drawing this particular schematic, where you can see that the piezoresistive material right is on this interdigited electrode. What is this mask? This mask is my bright field mask bright field mask right.

Next step, next step is we have to do UV exposure; we have to perform a UV exposure right. After this next step, so we go this way right, and we come here, after UV exposure you will unload the mask. And then, you will perform photoresist developing or you will dip the wafer in photoresist developer. After photoresist developer, what is the next step, after photoresist developer you will see that the wafer will look like the one that I am drawing on your screen right.

So, whenever I am drawing, you can also draw on your book notebook, and try to see whether you guys understand, how to draw it or not right. See, what I said, we have interdigited electrodes on which, we have a piezoresistive material. And on piezoresistive material, we have spin coated photoresist, which is positive photoresist. We have done soft baking, then we have loaded mask, which is bright field mask. They perform UV exposure, after UV exposure, you unload the mask and perform photoresist developing. After photoresist developing, what we get what we get is what we are drawing over here right.

So, you guys can also draw along with me right. And then, let see whether both of us are drawing similar thing, so that we understand that you as well as me, we both are drawing things that is similar and that should be correct right. If there is not correct, you can always you can always improve improve. So, photoresist developer, then we have on the photoresist developer, we have interdigited. After photoresist developer, how the schematic will move like schematic will look like the one that I am drawing on this particular screen. So, after this piezoresistive, and so this is my photoresist, this is my piezoresistive material right this one. Then this one is interdigited electrodes, then this one is micro heater. This we already know SiO_2, silicon, SiO_2 right.

Next step, what is the next step. After photoresist developer, next step is post bake post bake post bake is done at 120 1 minute on hot plate. After post baking, what is the next step after post baking? The next step would be to develop or to etch piezoresistive material from the area or from the unwanted areas. We only want piezoresistive material on this electrodes, we do not want on any other side of the chip correct, so that is why, we have used photoresist.

And we have pattern the photoresist in a way that it will protect the piezoresistive material below it only in the wanted area. And the unwanted area, you can see that if I put this, chip in a piezoresistive etchant right. Whatever the material that we are using, the etchant for piezoresistive material, what will happen that the piezoresistive material will get develop or will get etched right. You see this area will got etched rest of the the area, it got etched correct right easy.

After this, what is the next step? We have to dip this wafer we have to dip this wafer in acetone. Why, because we do not want photoresist. We have to strip of the photoresist. So, if I dip this wafer in acetone, what will I have, piezoresistive material on my interdigited electrodes right. So, if you see the entire structure silicon oxide, so we can say oxidised silicon on that there is there are there is a micro heater on which there is an insulator, the contact pads of the micro heater are opened on which there are interdigited electrodes on which there is a on which there is a piezoresistive material easy.

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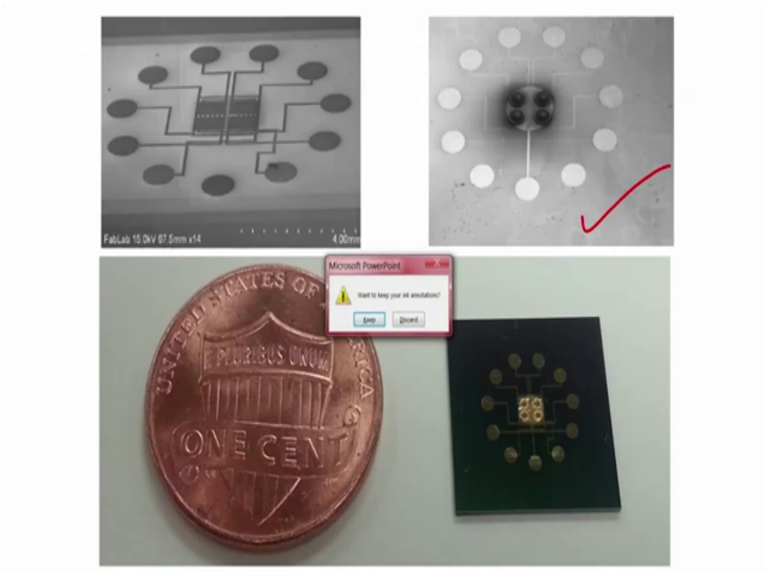

Now, what is the next step? Next step is next step is that we have to have a gold pad this particular chip right. We have to use this particular chip, what is this chip you see.

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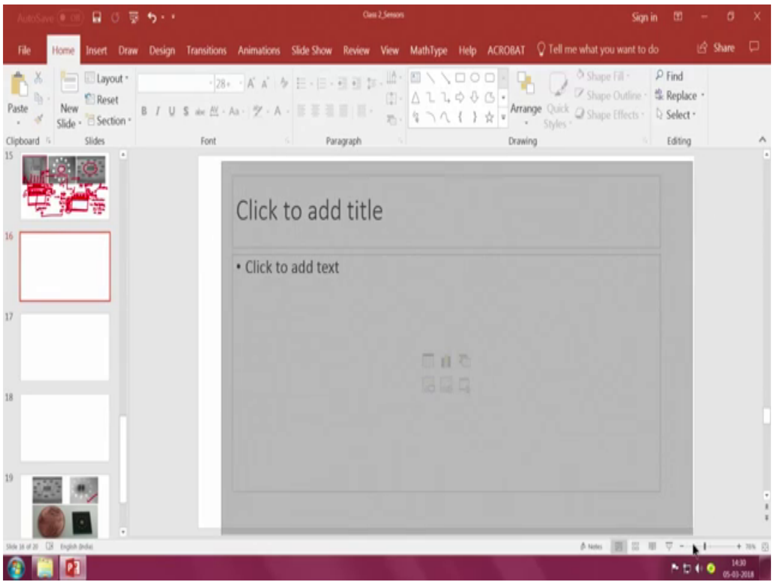

Let me just use this design right over here, so that we know what is the next step right or last step was that we created piezoresistive material on interdigited electrodes right.

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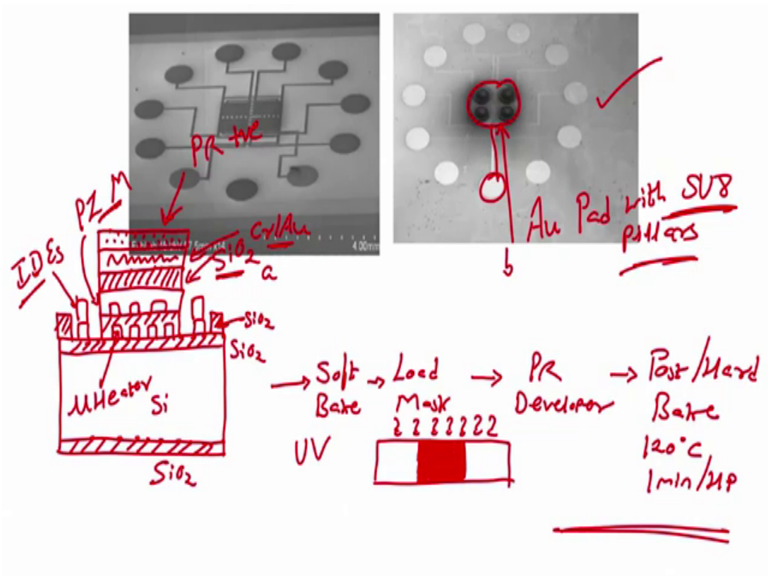

Our next step is that we want to have a gold pad with SU8 pillars. This is if you see this one right, this is your gold pad with SU8 pillars gold pad with SU8 pillars right. I will tell you what is the role of each material, you should you should also start guessing it right. So, heater for thermal conductivity of tissue, Piezoresistive material for understanding stiffness of tissue, electrode for understanding resistance of the tissue; so, we will see how we can use this biochip. Right now, we are on this stage.

From here, first step is we have to create a gold pad. To create a gold pad, you gold I can if I deposit gold directly on this particular chip, which is let say this is a, and this is b. If I directly deposit gold pad on a, then there will be shot between piezoresistive material and metal. And that is why, the next step after a should be that we have to have an insulating material we have to have insulating material.

So, what does it mean that we had oxidized silicon wafer oxidized silicon wafer on which on which there was a micro heater, on which there was insulator correct, on which there where interdigited electrodes, on this there was piezoresistive material right. So, I just draw it to just make sure that we both you guys and me we are on the same page. What is this? This is your SiO2 this is silicon, this is SiO2. Then what is this one, this is again SiO2 right insulator insulator here, here insulator. Then what is this one, this is our micro heater micro heater. Then what is this one? This is your interdigited electrodes. What is this one, this is your piezoresistive material correct, this is your a.

And next is we have to deposit gold, but like I said we cannot deposit metal on piezoresistor. So, what is the next step? Next step is we will we will deposit and pattern insulating material on the insulating material on the chip. Next step, after this, the next step would be we have to deposit gold. What is this material SiO2? What is this material? This is gold. I already told you that with some metals cannot be deposited directly on the chip. The reason is that these metals, they have pure adhesion to the substrate. And to improve the adhesion, we have to use a combination of another metal.

In case of gold, gold has pure adhesion to oxidize silicon and that is why, we have to use a thin layer of chrome along with gold right. This why we always write chrome gold, but the thickness of chrome is extremely thin compared to thickness of gold all right So, what is the next step? After this chrome gold after chrome gold, we have to create a pad. For creating a pad the, the next step would be we have to so what is this one, this is your chrome gold right.

After this next step is photoresist right. Now, after photoresist you already know, what is the process photoresist. Then we have to soft bake soft bake. After soft baking, you have to load mask load mask. How the mask will look like? mask will look like something that I am drawing right over here right. Mask will save my gold pad on the piezoresistive material right. It will be directly on pattern on the same area, where there are piezoresistive sensors. But the one thing that we have to remember is that below the metal, below gold pad, there is an insulating material all right.

You can see chrome gold is there, insulator is there, below insulator there are interdigited electrodes. And below above interdigited electrodes here, This is piezoresistive material ok. So, this is my mask. After my mask, I will perform UV exposure UV exposure. After UV exposure, you know what is next step photoresist developer.

After photoresist developer, what is the next after photoresist developer? The next step is that post or hard bake post bake or hard bake is done at 120 degree 1 minute on hot plate right post bake or hard bake 120 degree 1 minute on a hot plate. After post bake what is the next step? Next step would be I will etch chrome gold from the unwanted region. And what is the unwanted region unwanted region would be so if I complete this many steps, how a wafer will look like? So I will draw it right over here. Now wafer will look like what I have drawn right over here right.

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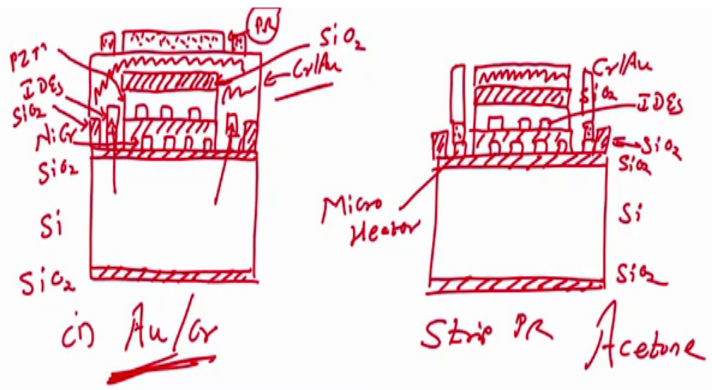

And so let us let us draw on the next slide, so it is easy right. I will draw two schematics here, and you see what is the difference what is the difference. For first schematic first schematic should be an oxidize silicon substrate on which there is a micro heater. So, let us draw micro heater. On micro heater there is an insulator we all know, we are discussing this from 2, 3 modules right on insulator. So, insulator we can draw similar, which is silicon dioxide. There are interdigited electrodes correct.

On this there is a piezoresistive material on piezoresistive material, we have silicon dioxide. On silicon dioxide, we have chrome gold chrome gold. On chrome gold, after we perform the lithography step. On chrome gold, we can we can pattern the photoresist in this particular fashion. This is your photoresist all right. And if I did this wafer, so if I write down SiO2, silicon, SiO2, micro heater is nichrome, then SiO2, then interdigited electrodes, then piezoresistive material, then SiO2 sorry SiO2 right on which there is a chrome gold, on which there is photoresist.

So, if I did this wafer in a photoresist, in a in a chrome gold etchant, first I can dip in gold etchant followed by chrome etchant right. What will I have? I will have correct I will have chrome gold in this particular fashion. If I etch chrome and gold right from the unwanted area, which is not protected by my photoresist right. Chrome and gold will be etched from this region right, and what will I have, I will have a chrome gold pad that is just a schematic to show it to you. Right, you can also have photoresist in this particular fashion, so that so that your pads below the photoresist will not get etched. This should not get etched right, this one, and this one, they directly expose and they are also interdigited electrodes, which are made up of chrome gold.

So, chrome gold can get etched, if this is not protected with the help of photoresist. So, we can draw a schematic which is similar to schematic one right. And when you perform lithography when you perform lithography, you can save the area with a photoresist or you can mask the area with the help of photoresist, so that when you dip the wafer in chrome and gold etchant. The chrome and gold will get etched only in the region, which is not protected by photoresist right. And the region, which is protected by photoresist, you can see here, you you can you can save the region, which was protected by photoresist this is your photoresist right.

This is the chrome gold, and chrome gold over chrome gold there is a photoresist, right over here and probably right over here right or you can just say that you have a thicker electrode, which is even better thicker electrode, because you are depositing chrome gold every time, you have thicker electrodes. And on thicker electrodes, you have your photoresist right.

Now, what is the next step, next step is that you have to strip strip photoresist by dipping the wafer in acetone, we all know by dipping the wafer in acetone. If you do that what will happen, the photoresist will get stripped. And you will have and you will have a chip with a gold pad on interdigited electrodes. So, what will have, you will have this particular chip, but without SU8 pillars without SU8 pillars ok.

So, if you perform this process flow what you are getting, you are getting a gold pad. The circular gold pad, you can see right over here, which is connected here and here right. And this gold pad below, this gold pad there is a insulating material, which is SiO2, which below insulating material. There is a piezoresistive material, below piezoresistive material there are interdigited electrodes, below interdigited electrodes there is another insulating material, below that insulating material there is a micro heater correct.

So, what is the next step, next step is that we have to now pattern SU8 to form, this particular structure which are like a pillars of SU8 right. So, how we can do that? After this particular step, how we can make SU8 pillars or how we can pattern SU8 to form pillars? This will see in the next module, till then you just look at whatever we have done here. Understand see, I am going little bit slow, so that you guys do not get confused. Once you understand the process correctly, it becomes very easy.

But, but the chip that we are designing is really complex. If you now have noticed that we started with just a heater, and then we have insulating material over which we have interdigited electrodes, over which there was piezoresistive material, over which the another insulating material on that there was gold pad. On this, now we are looking at SU8, and then SU8 is polymer, which is non-conductive polymer. So, we have to make it conductive, because SU8 pillars along with gold pad will act as a one single electrode. How to do that? That is the next step.

Once you do that, you have to perform front to back lithography to create a diaphragm. And then, you have to use this chip inside a tool, so that you can measure the properties of a tissue. So, it is complex, but it is not so difficult that nobody can do it. Every one you guys can do it, once you understand process flow. You understand process flow, you understand recipe you can design any sensor.

So, let us talk about how we can spin coat SU8, and SU8 is nothing but negative photoresist. Now, you all remember right what is the characteristic of positive and negative photoresist. Positive photoresist the unexposed area, the unexposed area will be stronger. Negative photoresist the unexposed area would be weaker, SU8 is negative photoresist. So, if I want to create SU8 pillars, I have to be smart to understand what kind of mask I have to use, so that I will have the pattern on gold, which are my SU8 pillars. And then in this we will see a very interesting technique called lift off technique lift off technique to make this SU8 pillar conductive right.

Till then you just go through this lecture, and I will see you in next module. Bye.