Sensors and Actuators

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Lecture – 53
Flexible MEMS for phenotyping tissue properties - I

Hi welcome to this particular module, in the last module what we have done we have seen the fabrication of piezoresistive microcantilever and then the use of piezoresistive microcantilever; followed by a sensor or a biosensor fabricated on a glass substrate with interdigitated electrodes and SU 8 well. the interdigitated electrodes were inside the SU 8 well.

The use of the piezo resistor was to understand the mechanical properties of the tissue or can say elasticity or can say stiffness; while the use of the biosensor with interdigitated electrodes was to understand the electrical properties of the tissue. Now, when I say tissue, I can also study the change in the electrical properties that is the impedance of the cells. We also kind of glanced at we have to use impedance and not resistance. I told that to hold the tissue properties intact, as soon as we place the tissue we have to have some saline solution or a media.

And that will cause a parasitic effect on the overall bleedings and thus there will be a double air capacitance and many more such kind of things that will come into the picture. And that is instead of measuring resistance it is advisable to measure the impedance of the material.

we were able to understand that we can delineate or we can differentiate between the normal and the cancer tissue is not it; the same way we can differentiate between a normal cell and a cancerous cell. If see, if have cantilever and if I if this is a cell, and if this is a cantilever or let us say hand this portion is cantilever, this is a tip and if I press this cell I will be able to see the stiffness of the cell depending on how cantilever beam will bend. This bending depends on this stiffness of the cell, it is not it this is an example.

Same way if I load this cell on or group of cells or a few thousand cells on the interdigitated electrodes; like I said these are all digits, this is digits, interdigit. if this is metal, then if I place metal next to each other; but they are not touching each other, the impedance would be infinite, resistance would be infinite.

Now, if I place anything on this metal what will happen, depending on the impedance or resistance of the material we will be able to measure it; because now this metal will start it is shorted with the resistance or impedance of the material, is not it. the point that I am making is, that can go for cells, can understand the properties of cells, can understand properties of tissue; we are talking about breast cancer, but that does not mean that this is only related to breast cancer, can go for oral cancer.

Because when we are discussing or when we are developing sensors for non-communicable diseases like cancer; then we can take care of a lot of interesting properties, from oral cancer to breast cancer to cervical cancer to prostate cancer and then we can also locate stomach and liver cancers.

in principle any tissue related cancer, we can understand how it is property is changing from onset to the progression. that is the idea of teaching, the sensors for understanding tissue property. Now, if I can do mechanical or if I can measure the mechanical properties and if I can also measure the electrical properties; how about I measure both simultaneously.

can we design a sensor that can measure the electrical and mechanical properties of the material simultaneously With that concept, today we will see and MEMS-based electrochemical electromechanical sensor, fabricated using a flexible substrate?

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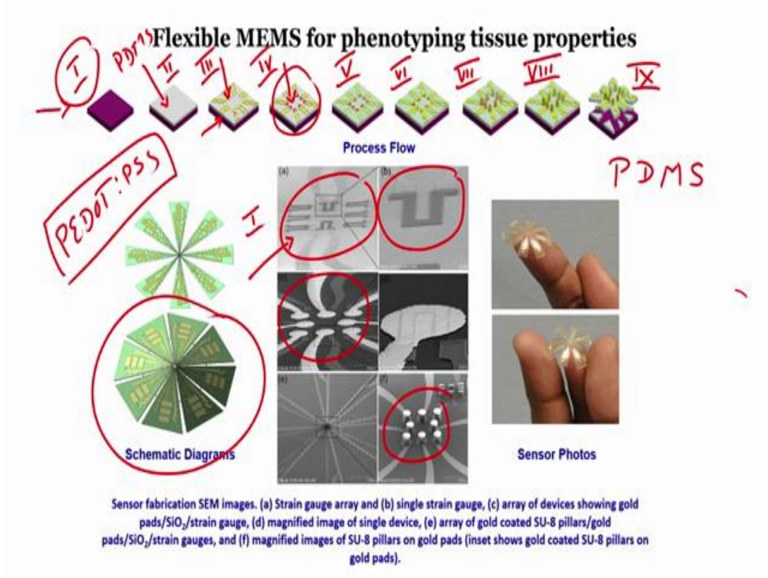

if see the screen and I will teach the process flow in detail, this is the process flow for fabricating the entire sensor and the sensor is fabricated on a substrate called PDMS P D M S . if start with, there is a silicon substrate here and then have a PDMS coated on the silicon substrate.

PDMS spin-coated on the silicon substrate; if see the third one, the third one would be the gold is deposited and is patterned in this particular region gold is deposited and pattern using photolithography followed by developing a piezo resistor. Piezoresistor is made out of a material quad P dot PSS PEDOT colon PSS; P dot PSS is a semiconducting material, is a polymer, not semiconducting material is a polymer which is a piezoresistive polymer.

this is a conducting polymer that is I was confused with a semiconductor. piezo PSS is a conductive polymer and it has a piezoresistive property. we will, after we deposit the chrome gold and pattern it, we will then deposit P dot PSS and form the piezoresistive sensors. Now if I want to see the piezoresistive sensors , can see here, these are all piezoresistive sensors ; this is one magnified piezoresistive sensor. these are all SEM images.

if I say if the first step is silicon, then the second step is PDMS, spin coating. Third step is chrome gold deposition and lithography to form pattern; fourth step is to deposit or spin coat P dot PSS and pattern it to form piezo resistors; fifth step is to grow or deposit silicon dioxide on the sensor; sixth step is to open the contact pads and to deposit a gold pad; the seventh step is to form the SU 8 pillars and then eighth step is to coat the SU 8 pillar tip with gold and ninth step would be to strip the PDMS from the substrate.

Now, a lot of steps I told and I am sure do not remember, is not it we will go one by one and I will tell how can it be when we fabricate such a sensor layer by layer. if see the screen, what see is; this is of this is one sensor or can say an array of sensors and these are all strain gauges, piezoresistive sensor. Then this is gold, these are all gold pads and then finally, these are SU 8 pillars which are coated with chrome gold using liftoff technique. we will go one by one to fabricate this particular sensor. Let us see how can we start.

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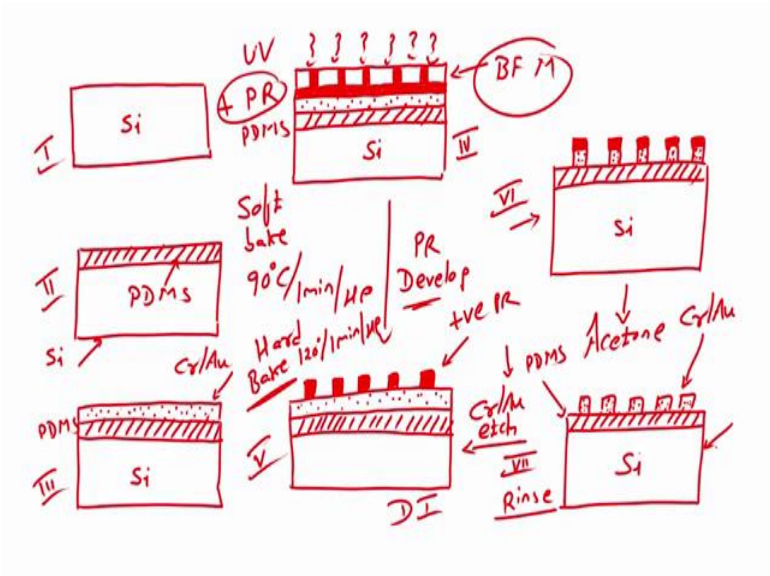

I will show the process flow in detail. The first step is take this silicon substrate, silicon; the second step is to spin coat PDMS on a silicon substrate. let us say this is r PDMS ; then the third step is to deposit. this one is PDMS, this one is still silicon, this substrate is still silicon; the third step is to deposit chrome gold on PDMS. let us say we have now silicon, we have PDMS and this one will be r chrome gold, .

The next step would be to pattern this chrome gold, is it not it for patterning what we will do, photolithography ; we will perform photolithography and to perform photolithography we had to first spin coat photoresist. this is r photoresist and this will be photoresist; I will say it is a positive photoresist.

After spin-coating photoresist; what is the next step, then the next step is I will go for soft bake, the soft bake is done at 90-degree centigrade for 1 minute on hot plate . After soft bake, I will load the mask to form chrome gold pattern and this mask will be b filled mask; mask would be b fill mask, .

if I take cross-section, see this particular first one, this step ok; silicon substrate, we can also have oxide and then we have PDMS, then we have to pattern this. If I take a cross-section I would be able to only see this kind of layers and that is we have been representing the mask, which is our b field mask in this particular format.

After that one, the next step would be to expose this photoresist with UV, UV lithography, ultraviolet light. When I expose its next step would be to unload the mask and perform for and dip this wafer in photoresist developer; when I dip this wafer in photoresist developer what will happen, the photoresist will get developed. Now, because it is a b field mask and there is a positive photoresist. what will happen what I was telling here is that what will happen when we expose the photoresist with a b-field mask and our photoresist is a positive photoresist.

as all know now that when we use b field mask and when there is a positive photoresist the area which is not exposed will get stronger, the area that is not exposed will get stronger. this is positive photoresist correct, this is a positive photoresist and can see that the area which is not exposed see this b field mask and the area which was not exposed got stronger.

Now, after this the next step would be, hard bake correct; hard bake 120 1 minute hot plate. A favor from a hard bake next step would be dip this wafer in chrome gold etchant; first chrome etchant then wash it, then gold etchant, again wash it. washing is called rinsing, to rinse it.

chrome gold etchant. If I dip this wafer in chrome gold etchant what will happen; I will have a substrate, which is silicon substrate on which there is a PDMS on which chrome and gold will get etch from the area which was not protected by positive photoresist. This area like have seen here is not protected by positive photoresistor; so the area which was not protected by photoresist that will get etched in the chrome gold etchant, correct easy.

Next step would be, I will dip this wafer in acetone; if I dip this wafer in acetone what will happen, we will have silicon with PDMS and chrome gold pattern, is not it, chrome gold pattern. now, this will be chrome gold, this is PDMS, this one is silicon, . if see here, let me just wrap things up. it becomes a little bit easier for to understand, ok. what we have done, we have.

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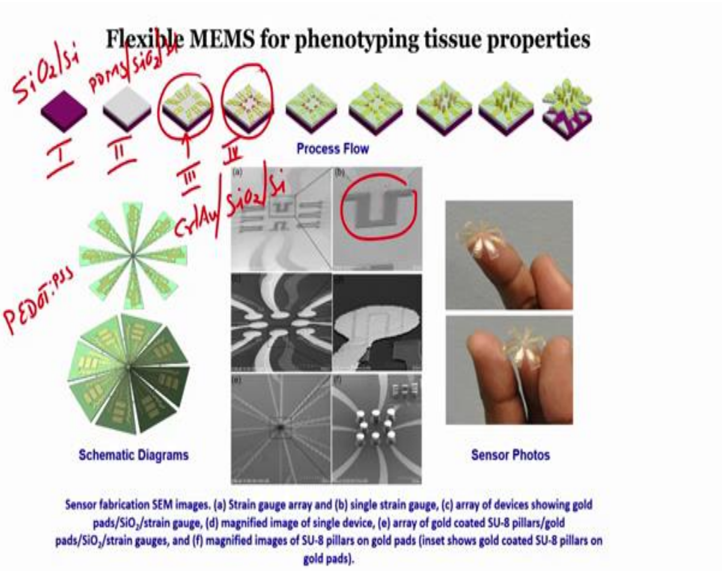

We have taken a silicon substrate; we can take an oxidized silicon substrate, on which we have spin-coated PDMS . Silicon or silicon oxidized silicon then we have PDMS on the silicon, ; this one which is step number III is r chrome gold pattern on silicon dioxide or oxidized silicon substrate, .

to come to this particular step which is step number III, we have to perform the photolithography process, so this is how we have done. Again I am repeating; the first step is to take a silicon substrate; the second step is spin coat PDMS; the third step is deposit chrome gold using physical vapor deposition, it can be an E beam evaporator, it can be thermal evaporator.

the fourth step is that we have to spin coat a positive photoresist, which is shown here and then perform soft bake at 90-degree centigrade 1 minute on the hot plate followed by loading a mask, this is our b film mask and then exposing the photoresist with UV light.

Then in the next step would be photoresist developer; the unexposed region would be stronger because we are using positive photoresist. After this the next step would be to dip this wafer in chrome etchant; when dip this wafer in, there is a chrome gold. gold is at a top and chrome is at the bottom. first we dip the wafer in gold etchant; once the gold is etched, we rinse the wafer with DI water.

Then we will dip the wafer in chrome etchant; once the chrome is etched we will dip the wafer in the DI water. Followed by the next step; after the photoresist developer, had to perform hard bake, which is over here . photoresist developer, hard bake, then a gold etching, then rinse, then chrome etching, then rinse, rinsing with DI water; and after that, can see this particular step. this will be our Vth step and in the VIth step what will be able to see is that chrome and gold have been etched from the area which was not protected by photoresist.

After this the next step will be to dip the wafer in acetone; acetone will act as a photoresistor stripper and then we have step number VII or step number III which is shown in this particular slide . Next step, if see the next step; next step are we are looking at this particular step which is step number IV. In this step what are looking at, are looking at a strain gauge and this strain gauge we had to fabricate using a conducting polymer like I have discussed earlier called P dot PSS , can Google it, it is called PEDOT colon PSS .

let us see how can we spin coat this material and form a strain gauge; it is exactly similar to what we have been discussing on this particular platform. we will start from here and to make things easier, we will just show two contexts , just to make it easier we will just show two contexts.

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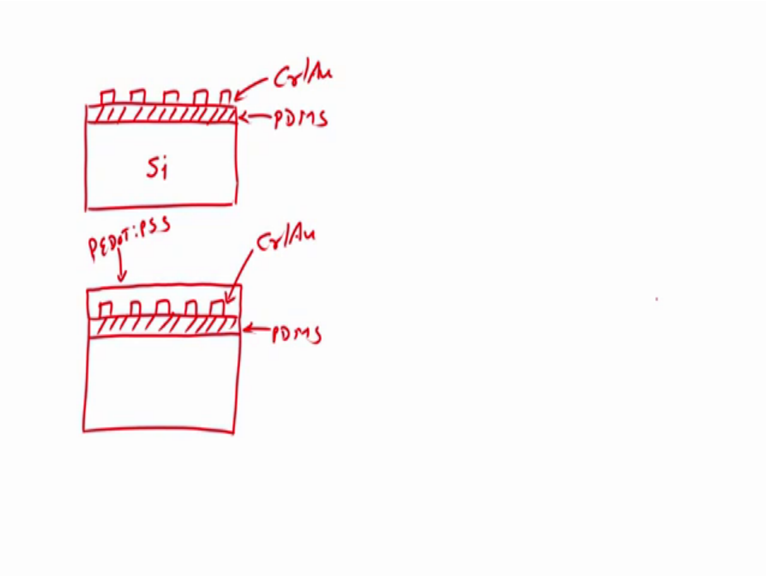

if see the slide, have this particular substrate ready with r gold pattern on the PDMS, is not it; silicon, this one would be PDMS and then have r gold patterned in this way, is not it. now, what we will be doing in the next step is; the next step we will spin coat, we will spin coat P dot PSS on to this chrome gold or on the wafer, which has PDMS, this is P dot PSS . After this, the remaining steps are exactly similar to these slides, see I will show it to .

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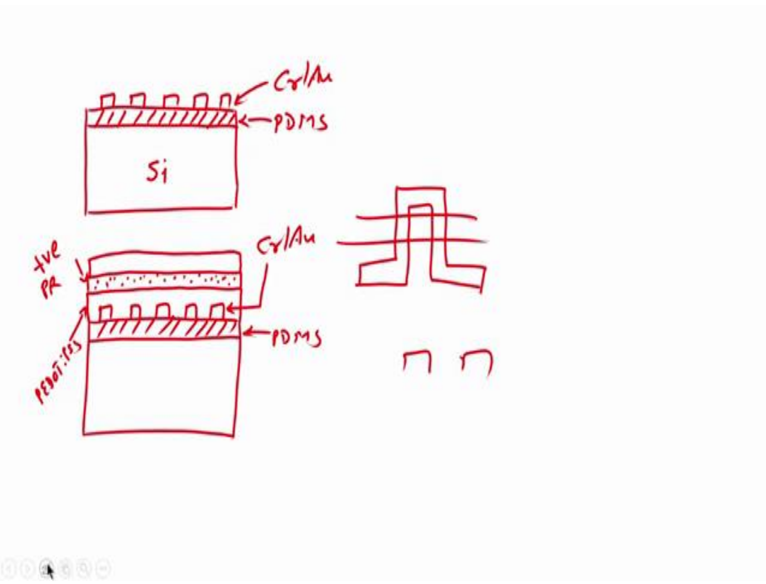

The next step would be to spin coat photoresist. we have photoresist, spin coat, and this photoresist is again a positive photoresist. After spin-coating positive photoresist next step is soft bake. Soft bake 90 degrees 1-minute hot plate followed by a mask, load the mask and then form the piezo resistor. if piezo resistor looks like this , if I take a cross-section of it ; like this, if I take a cross-section, I can only be able to see, if I only two pillars like this , two subs like this, is not it.

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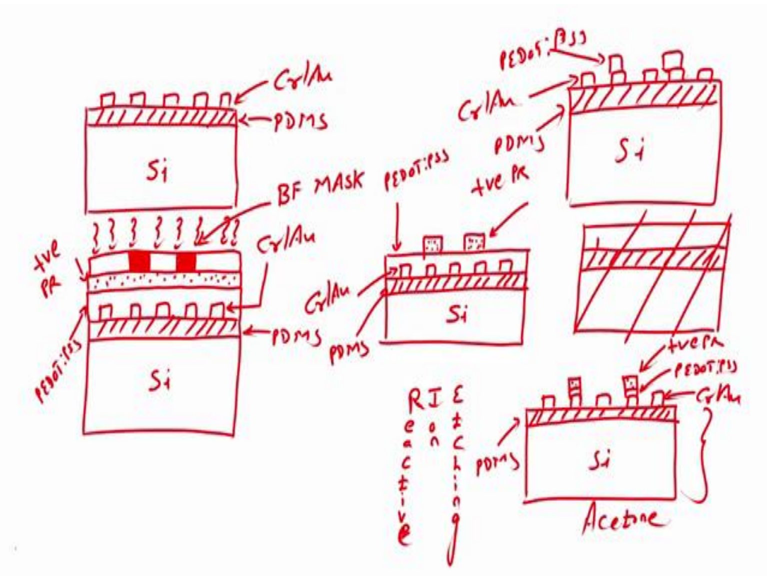

if I take a cross-section of this particular piezo resistor which is made out of a P dot PSS, then for that the mask that I am showing here will look like this and this is a b field mask . A photoresist is a positive photoresist and mask is a b field mask, . The next step would be exposed to UV light.

exposing with UV light; when I perform exposure the next step would be, photoresist developer. When develop this wafer in photoresist developer what will happen, will have r photoresist protected in the area which was not exposed by UV light. have here positive photoresist, this one is r P dot PSS, this we have spin-coated, here have chrome gold; then have PDMS, then have silicon, .

Now, I have to remove P dot PSS. I will use RIE to remove P dot PSS. RIE stands for Reactive Ion Etching, Reactive Ion Etching. if I perform RIE on this wafer what will happen, I will have; I will have wafer which will look like ok, let me redraw it. it becomes easier, let me redraw it here, I will have wafer. that let us not consider this particular diagram, this is PDMS, then interdigitated electrodes, and then I will have strain gauge, .

what I have here positive photoresist, then I have here P dot PSS, I have chrome gold, then I have PDMS and there is silicon . The next step is, if I dip this wafer in acetone what will I have; I will have PDMS on which there are interdigitated electrodes, on which there is a P dot PSS strain gauge, . If I dip this wafer in acetone, this wafer, then acetone will get stripped off, I will have P dot PSS, chrome gold and I have PDMS, and this is silicone.

where we have reached, we have reached this particular point; where have r piezo resistor pattern; piezo resistor pattern, . now, have the piezo resistors which are fabricated out of P dot PSS . understand until here, that now we have a P dot PSS. what will happen, if I apply pressure to this particular substrate, If I apply pressure to this particular substrate, to this one; then because there is a piezo resistor, it will bend and that will cause a change in resistance, .

we will stop our module here. And in the next module, I will tell how to coat an insulating material on this piezo resistor. Then I want to make it short so that can understand just a fabrication of piezo resistor; then fabrication of electrodes on this piezo resistor, ok. I will catch in the next module, till then take care, bye.