Lecture 40:
Fabrication Process for Gas Sensor

Hi welcome to this particular lecture. Now if you see, what we had to do is that I'll show it to you, how can we design a gas sensor and what are the process flow, for designing that particular sensor. Okay? So, let me show it to you, on the on the slide. Suppose I want let me get first show it you here, if you can come back to the screen, I'm holding a sensor, yeah suppose I want to fabricate this sensor. Now III I'm not interested in understanding the casing, I am interested in understanding, what is within the sensor.

Okay? So, here we are looking at the video, which will help us to understand, what is there within this particular sensor. So, let me just show it to you again if you can go back to the slide.

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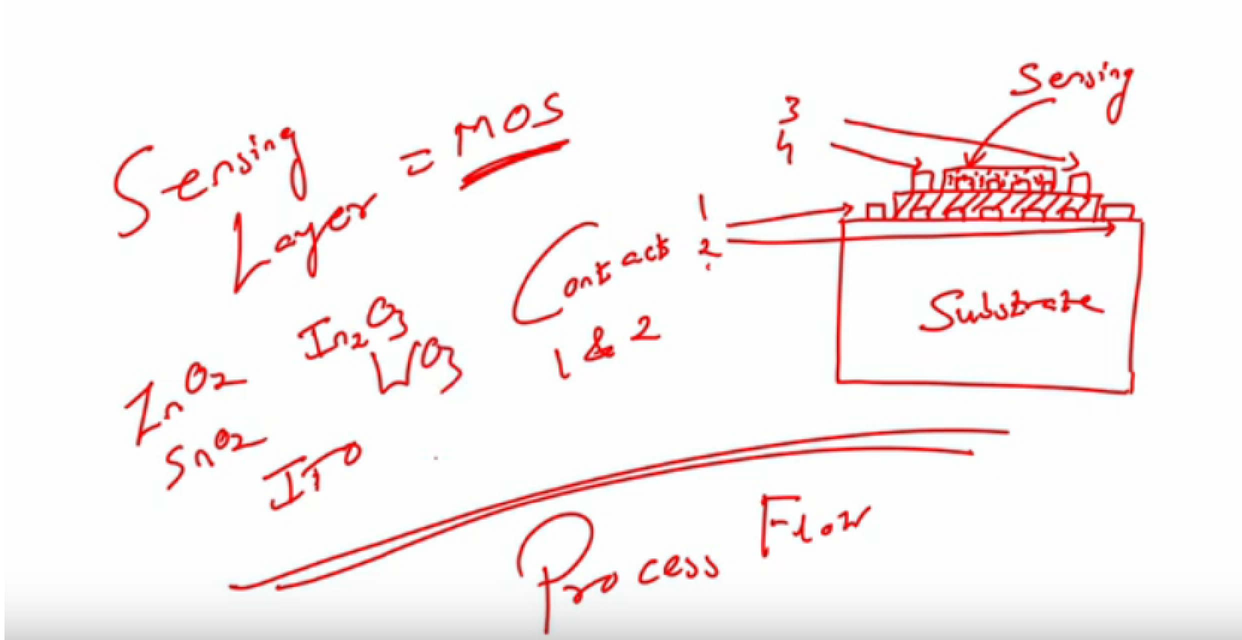

So, what are we were talking about we're talking about that, we have a sensor. And sensor has four points. So, the first point should be a heater, first two points should be heated. Right? These are the context, to the heater, hater contact one and two. Right? This is what in these two then on this heater, there should be some kind of oxide or insulating material, on this insulating material that should, be a sensing layer. But for sensing layer, there should be again a, electrode. So, this one would be our, sensing layer this one and this one would be over three and four these are electrodes, this is sensing layer, sensing layer. Right? This is our substrate. Alright? So, I want to design a process flow, I want to design a process flow, to fabricate, this particular sensor, the sensing layer, sensing layer, should be metal-oxide-semiconductor. So, I can use zinc oxide, I can use tin oxide, I can use indium oxide, I can use indium tin oxide, I can use tungsten oxide. Right? Several really. Okay?

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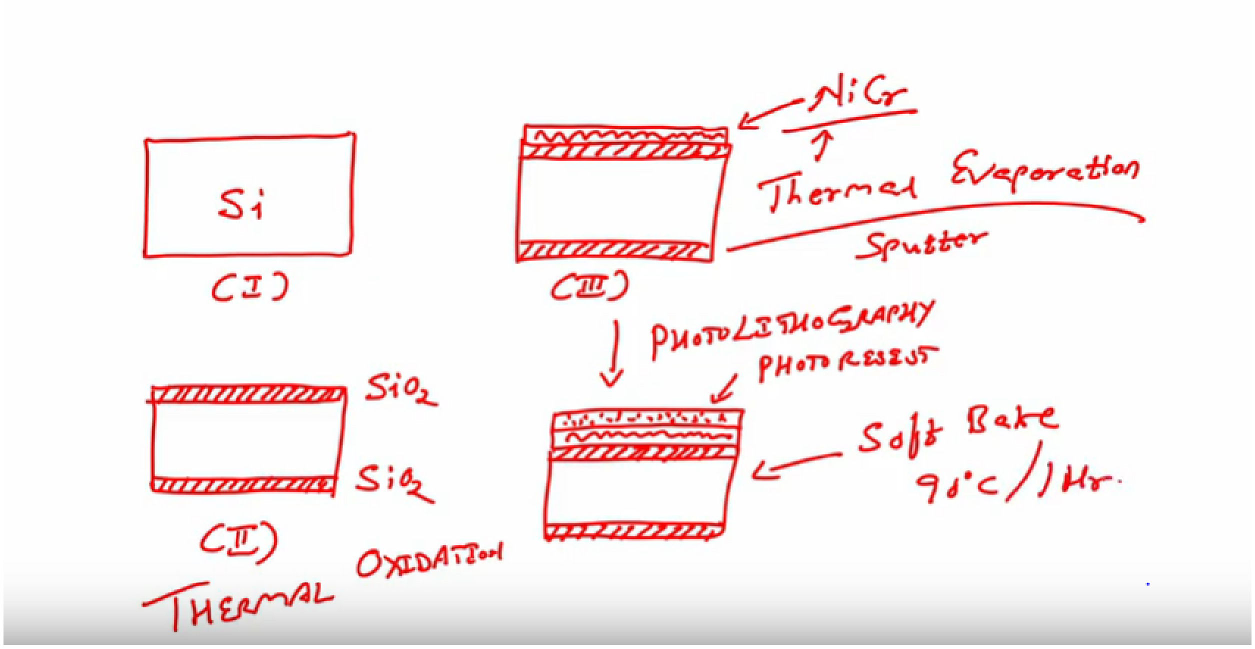

So, let us see the process, we start with, a substrate start with a substrate, which is silicon, then we grow oxide. So, this is stage 1, stage 2, stage 3, how you grow oxide. We grow oxide with the help of thermal oxidation. Alright? This is what stage three, stage three what we do? We will deposit a metal this metal is for our heater. So, I will say nichrome. Alright? Let me give some design to this so, that we can understand, the difference after this, I need to perform a photolithography technique, photolithography, technique, to fabricate a heater. So, what I will do is the first step, after this would be, I take a substrate, which is already having a metal, I will deposit nichrome. We deposit this nichrome, using thermal evaporation or sputtering, sputtering. Alright? So, we have this metal, on this metal I will spin coat Photoresist Perl do ask pin code Photoresist, after spin coating Photoresist, I will bake this which is called,' Soft Bake', bake this at 90 degree centigrade, for one hour. Okay?

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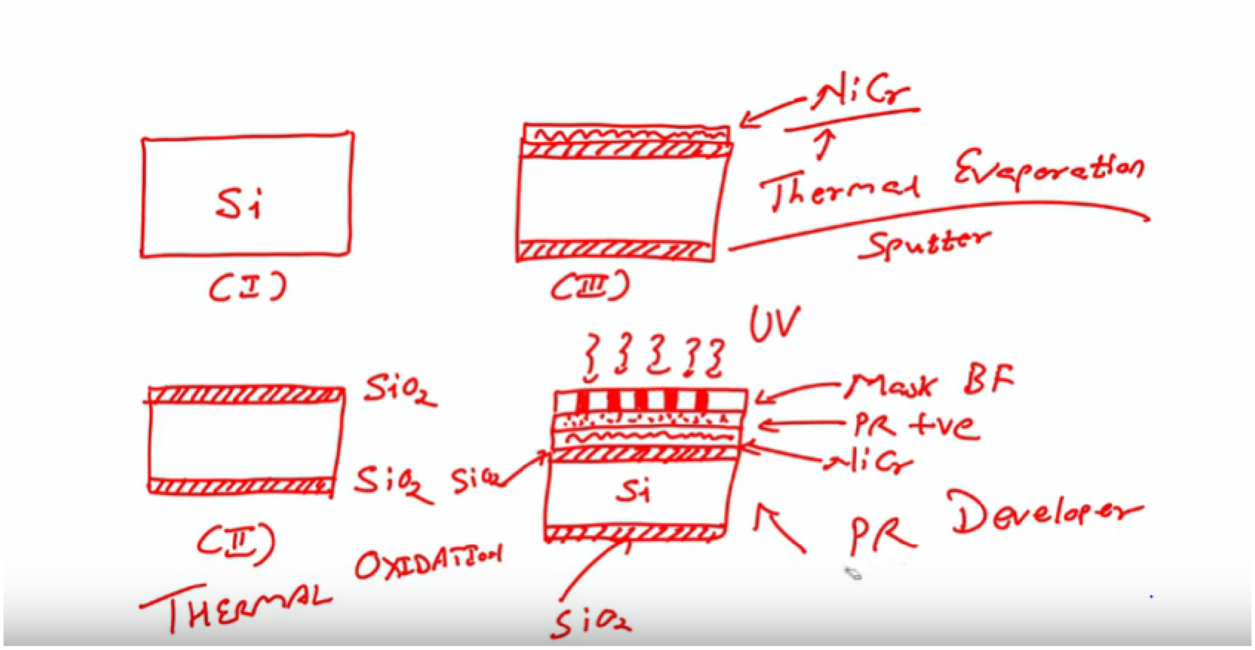

Next step is so; you let me know down here, this is my Photoresist. Right? This is my nichrome, this is silicon dioxide, this is silicon dioxide, silicon and on this and have a mask and that mask is my bright field mask, you have seen in the little graphic section. Right? What's the importance of bright field? What is the importance of dark field? Right? So, this is my bright field mask and this poor Photoresist is positive Photoresist. Okay? Next step is I will expose this wafer, with UV with UV light that's why it's called,'UV Lithography'. Alright? Expose this wafer with UV light, after exposing the wafer, I will dip this wafer in Photoresist developer, after exposing their fur I'll leave this referring Photoresist developer. When I dip this wafer in Photoresist developer.

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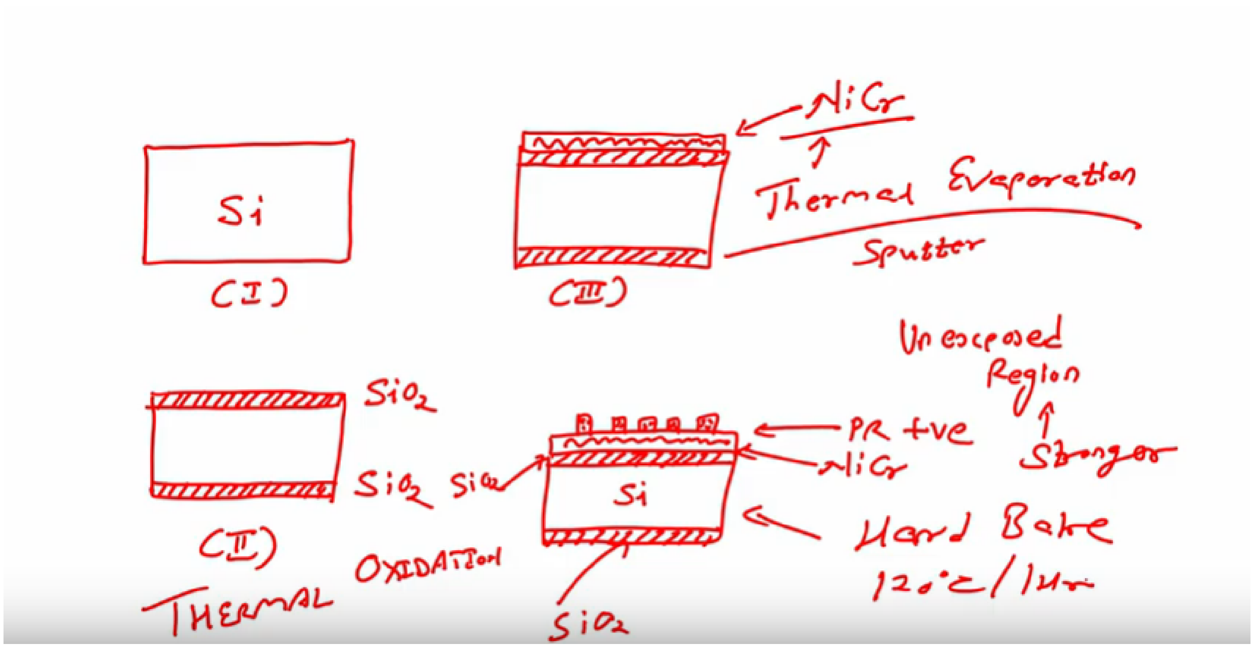

What will happen? That the unexposed area unexposed area, will become stronger. And the exposed area will become weaker and get developed. Why because the positive resist, for the positive PR the unexposed, region becomes stronger we know that. Right? So, this Photoresist is here. Now after this, I will do a herd bake I'll perform herd bake herd bake is done it 1:20 1 hour, when I perform herd bake.

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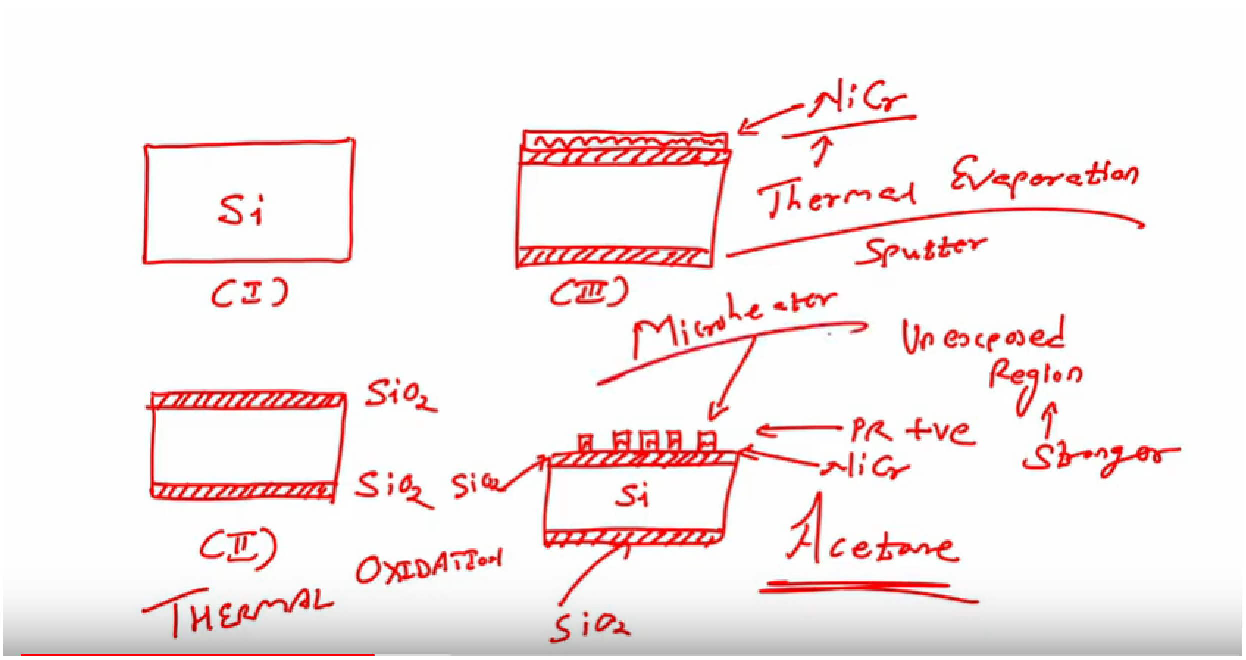

After this I will dip this wafer in nichrome Etch, nichrome Etch when I dip this referee nichrome Etch, what will happen? The area which is protected by Photoresist area, which is protected by Photoresist, will remain and the area, which we is not protected by Photoresist will get etched. Alright? After my chrome edging next step is I'll dip this wafer in acetone, I'll leave this wafer in acetone. Why because when I dip this wafer in acetone, I will strip off my Photoresist, I'll strip of my Photoresist. Now what I have is a sensor or as a with a substrate, with a micro heater, I have a substrate with micro heater. But what I want I want.

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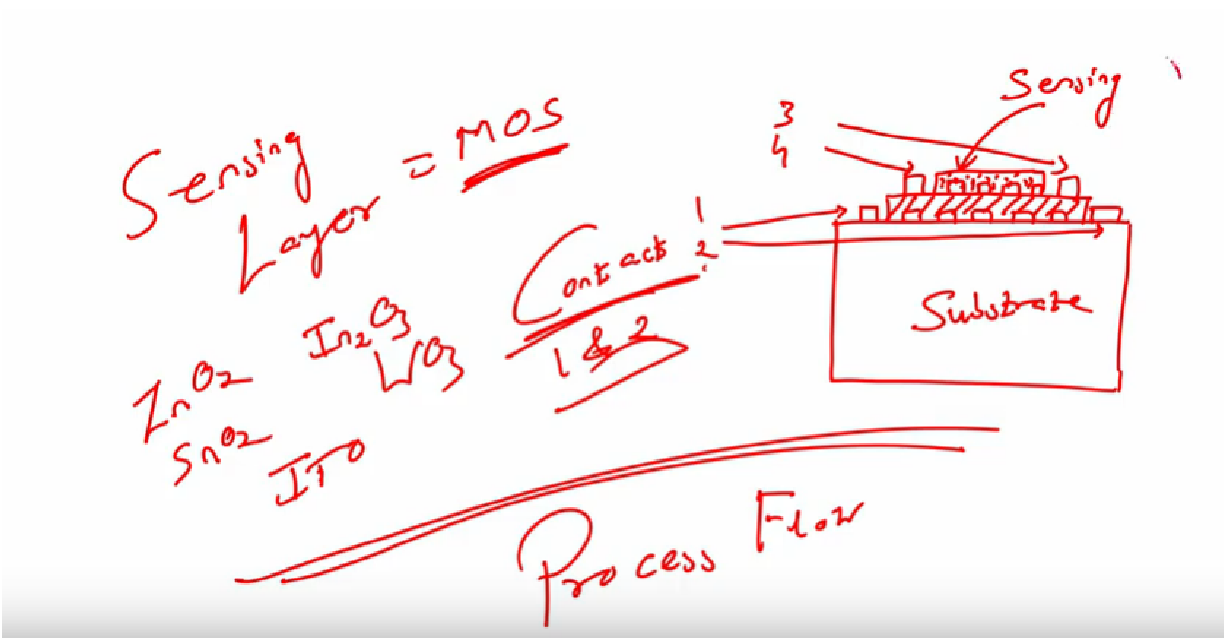

A substrate, with micro heater, this is your heater context, 1 and 2. Right? And a sensing layer and electrodes. Right?

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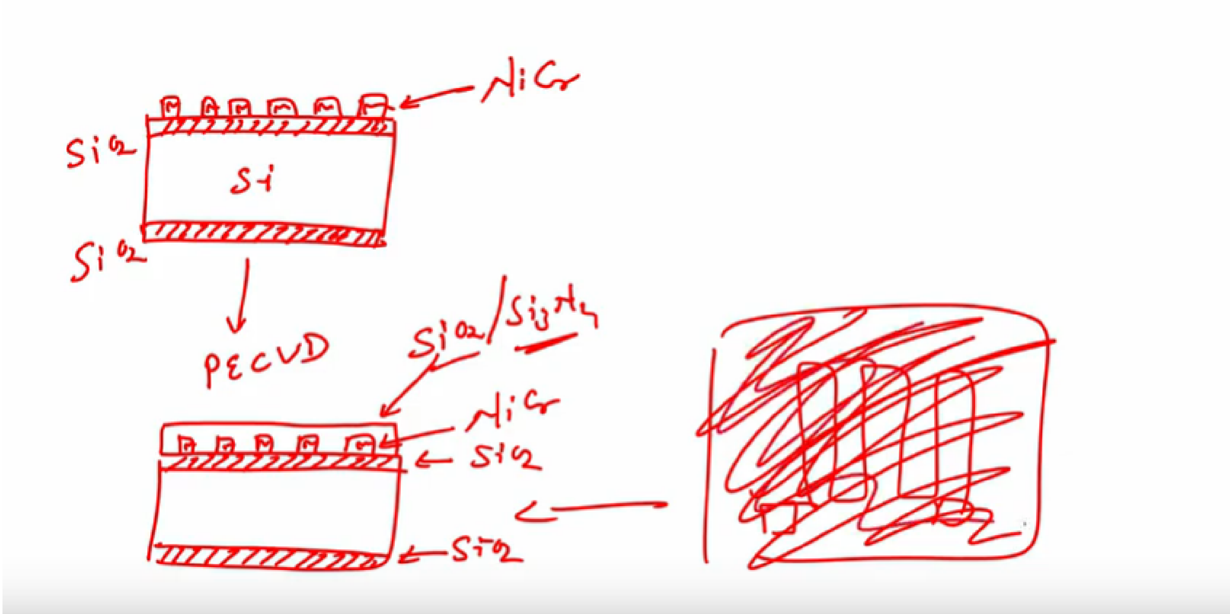

So, once I have a substrate with micro heater. Let me draw it here. Alright? This is all silicon dioxide, this is silicon, silicon dioxide, silicon dioxide, this is our micrometer. Okay? Now what we will do? We have to have insulator, because we cannot directly deposit, metal oxide semiconductor, on the micro heater. So, for having insulator, we have to use PECVD, PECVD if I use PECVD what will I have I'll have my heater, with an insulating material. So, there will be insulating material, on the heater. Okay? This insulating material can be, Sio2 or si 3 and 4 silicon dioxide or silicon nitride, this is my nichrome, this is my silicon dioxide, this is my silicon dioxide. Now can I directly deposit, my semiconducting material, on this particular insulating material, sio2 si3 or 4 no why? Because I am NOT able to access the contact area, of the heater, if I draw the top view of this particular slide, my top we will look like, I have a heater. And everywhere there is a oxide, everywhere there is oxide. So, I cannot hit the heater.

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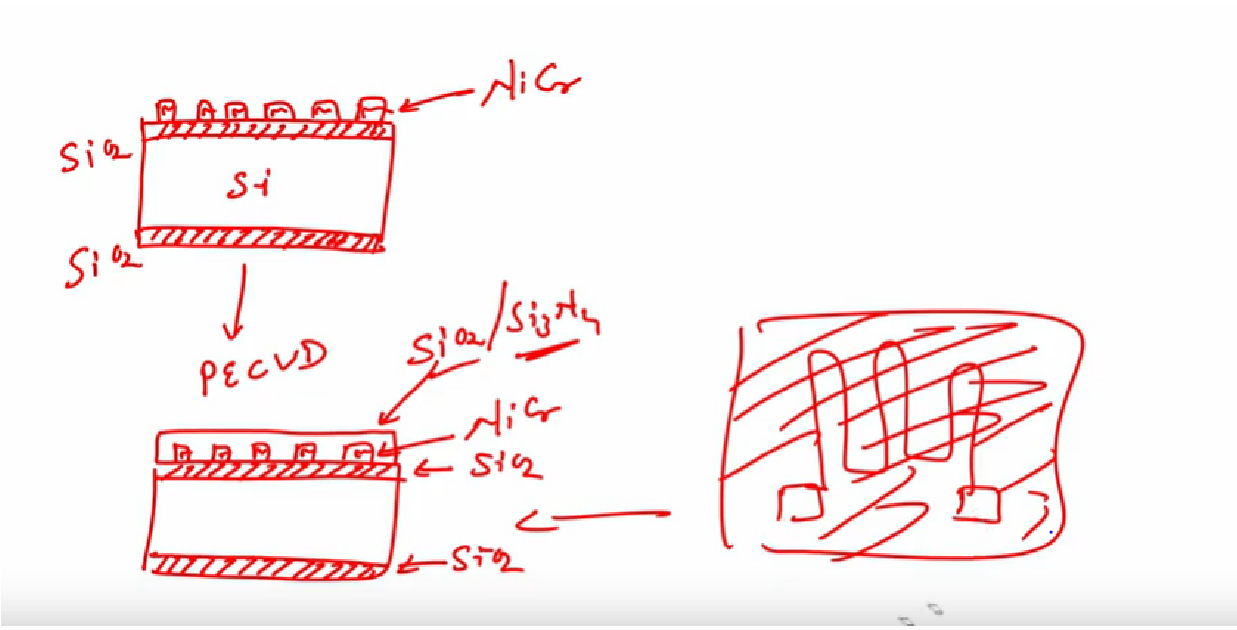

So, for that what I have to do? For that I have to open, the contact of the heating material. That means that, everywhere there can be silicon dioxide, except on the heater contact, except on the heater contact except 1 & 2, everywhere should be silicon dioxide. So, for that what we need to do? We have to perform again a photolithography. So, that we can open the contact or heater context. Right? You can open the window and we can have the heater context. Let us see how we can do that. Alright?

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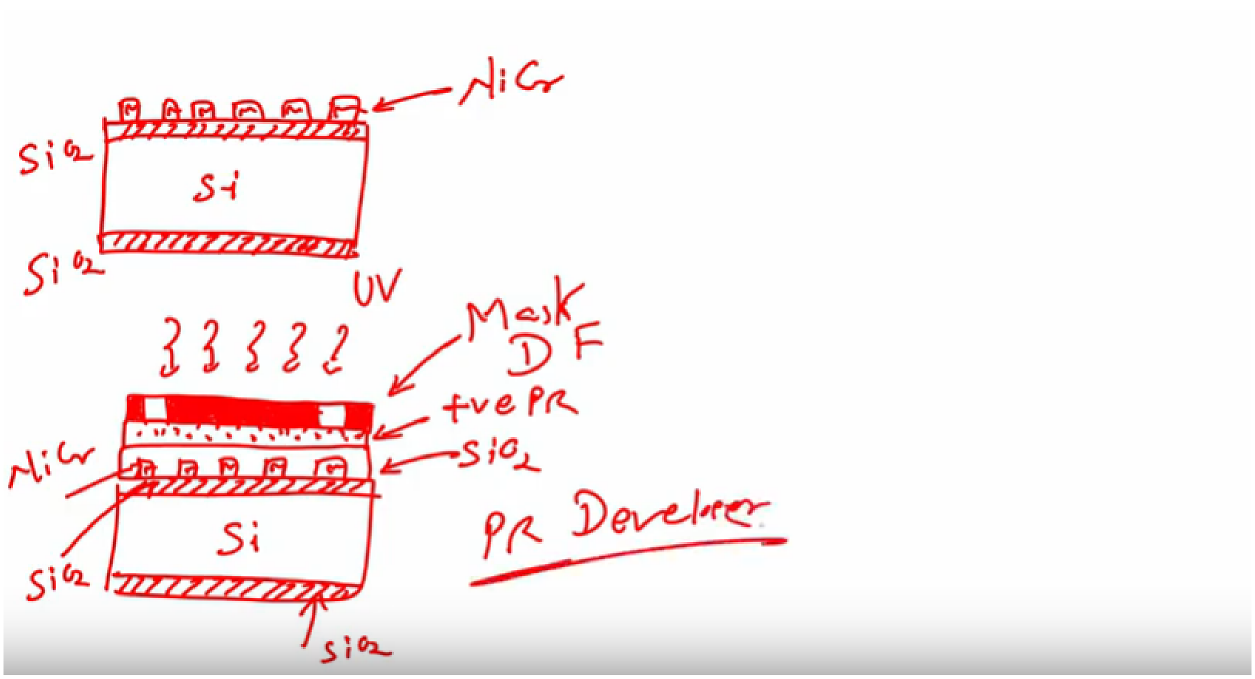

So, after this we'll have Photoresist. So, if I write it down so, you don't get confused this is my insulating material let's say silicon dioxide. This is my heater, which is my Chrome this is again silicon dioxide, which is thermally oxide, this is silicon dioxide, again thermal oxidation, this is my silicon, which is my substrate and this is my positive Photoresist. Right? Now I will after positive Photoresist, pin coating is positive resist what I will do? I will soft bake, don't forget the steps. Okay? Soft bake, soft bake is at 90 degree, for 1 minute, if I have written somewhere, 1 are it's not correct, just understand and the degree 1 minute, 120 degree 1 minute. Okay? Not ours 90 degree 1 minute, 120 degree 1,minute after this I will lower the mask and this time my mask, should be my mask should, be such that I want this area to be opened, which area the contact area, of the heater. Right? The heater windows, the contact area to the heater windows, it should be opened. So, this is my mask, what is this mask? This is dark field mask dark filed mask. Alright? Next step is I will expose, this wafer with UV light, after exposing, my next step would be I have to develop the wafer. For developing wafer, we had to use Photoresist developer. Right? So, if I dip this wafer in Photoresist developer, after low unloading the mask and after you exposure what will I have.

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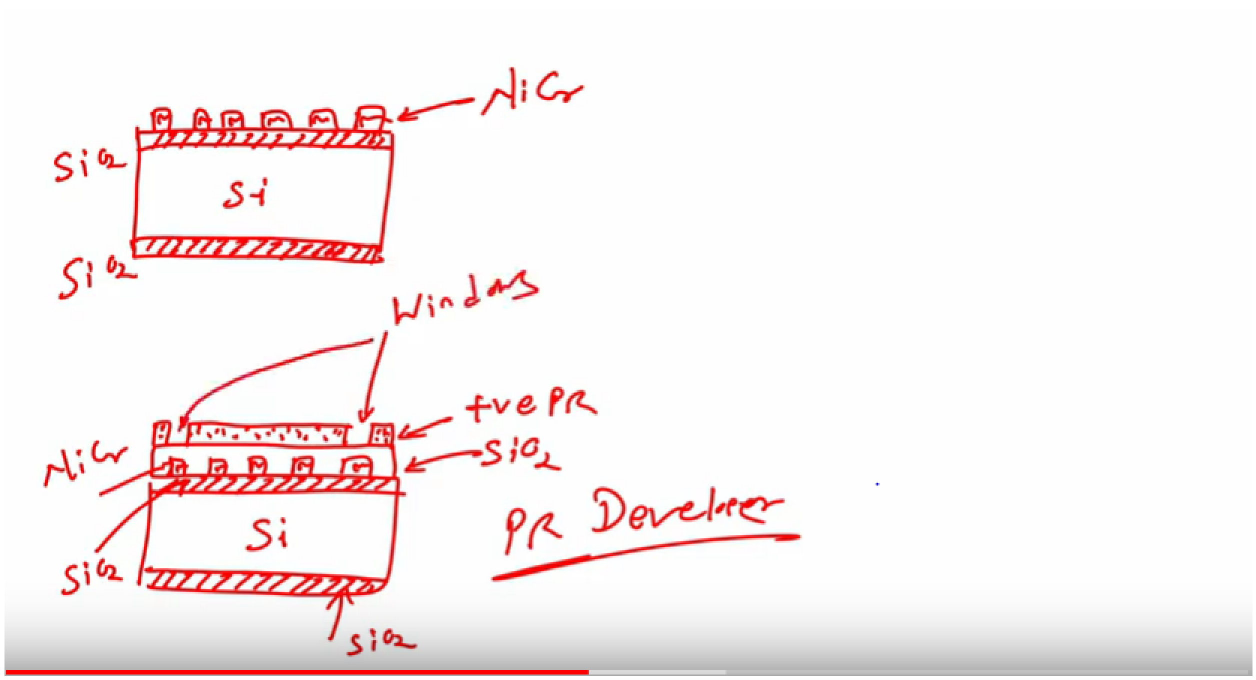

I will have my Photoresist in the area, which was not exposed by UV. And you can see here, the windows for the contact to the micro heater are opened.

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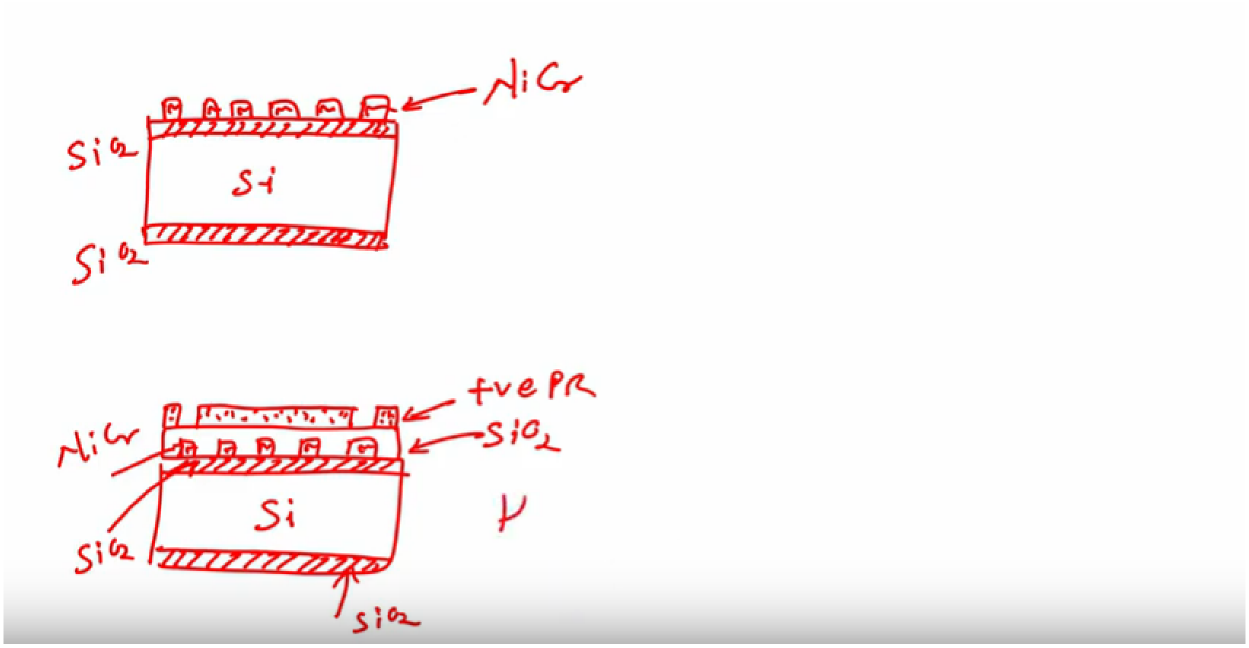

So, what's the next step, once I have this, my next step is I'll go for herd bake.

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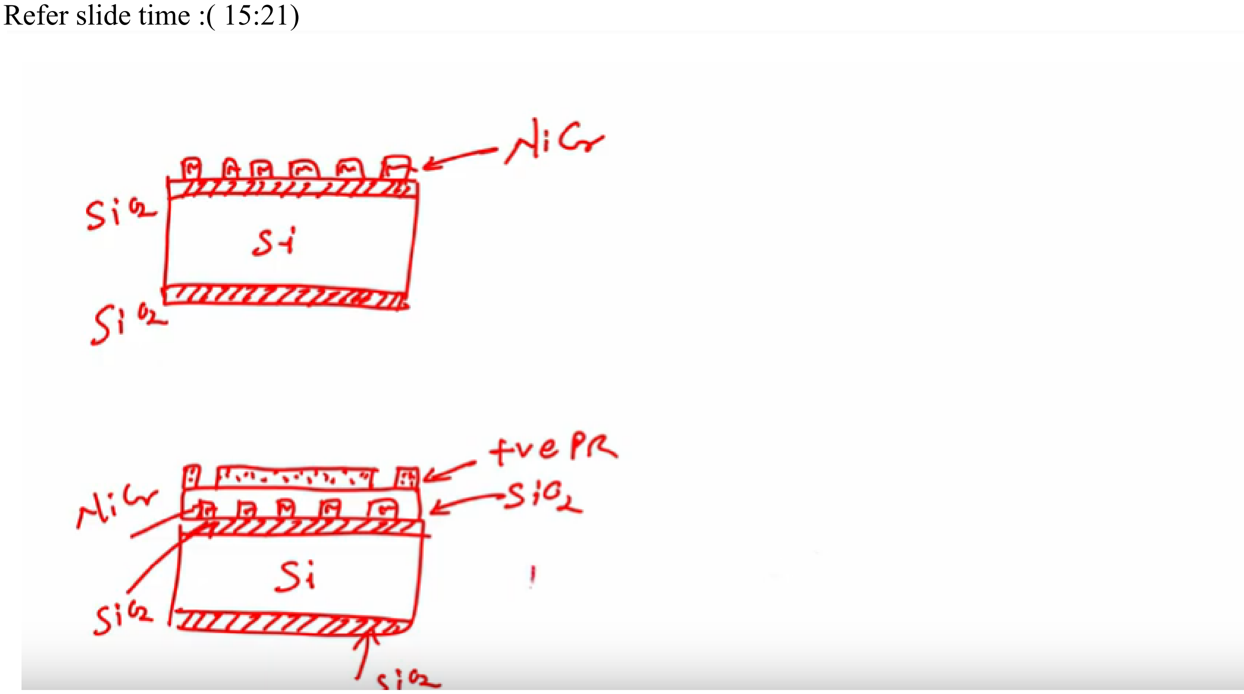

Herd bake is the net 120 degree, for one minute correct. Okay? If I go for herd bake, the next step would be I will dip the wafer in BHF, BHF stands for,

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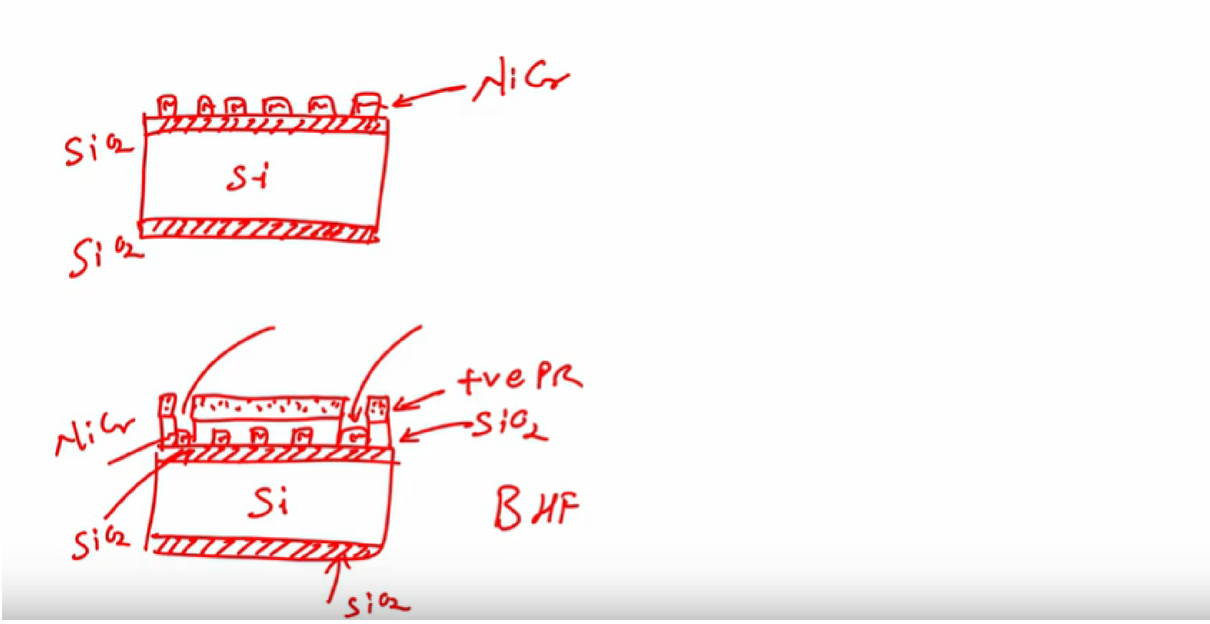

buffer hydrofluoric acid, if I use BHF what will happen? I will etch the silicon dioxide, from the contact region, from the contact region, which is my heater contact, see there is no silicon dioxide, you know there is no silicon dioxide, in this particular area. Now I can access my heater. Right? Now I can access my heater.

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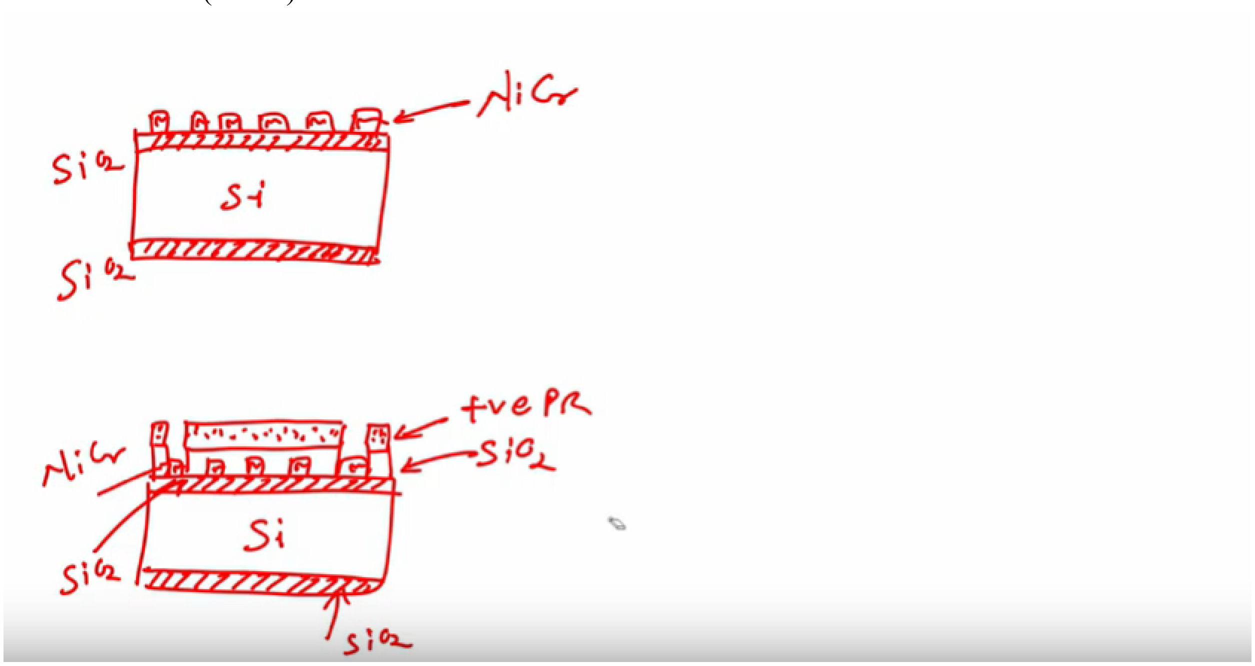

But what I should do with this Photoresist I have to strip off the Photoresist. So, after BHF F after I rinse it every step understand that you are there is a rinsing. Okay? Here to wash the wafer,

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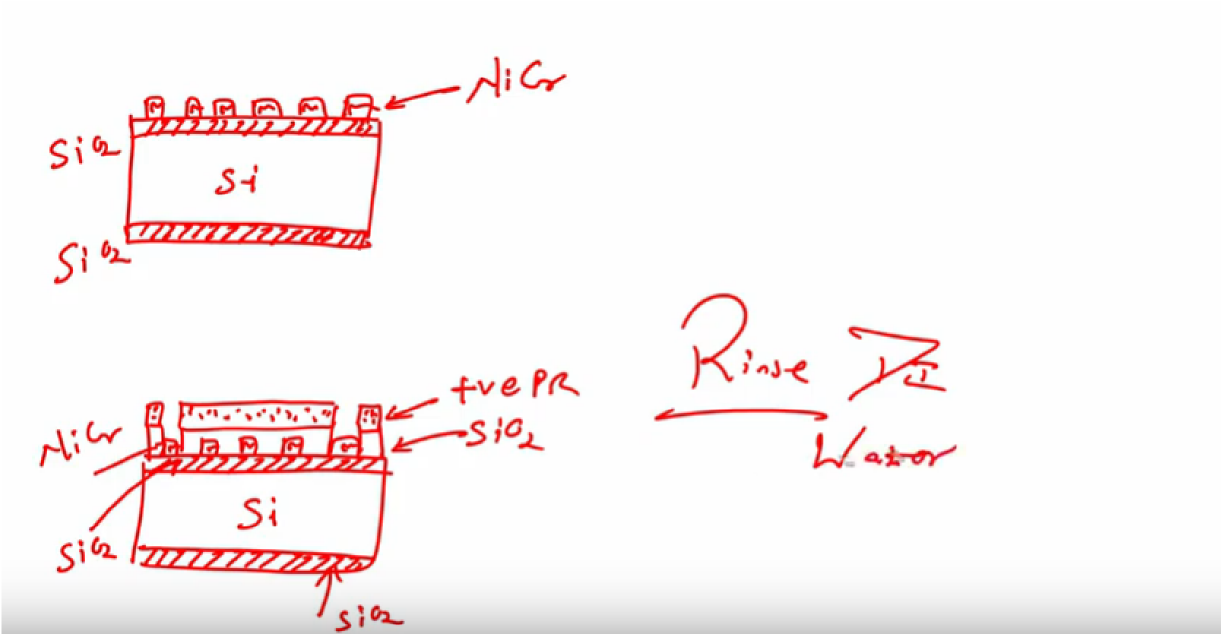

with DI water, you to rinse the wafer rinse means wafer with, DI water. DI water for every step, you have to go for rinsing with DI water.

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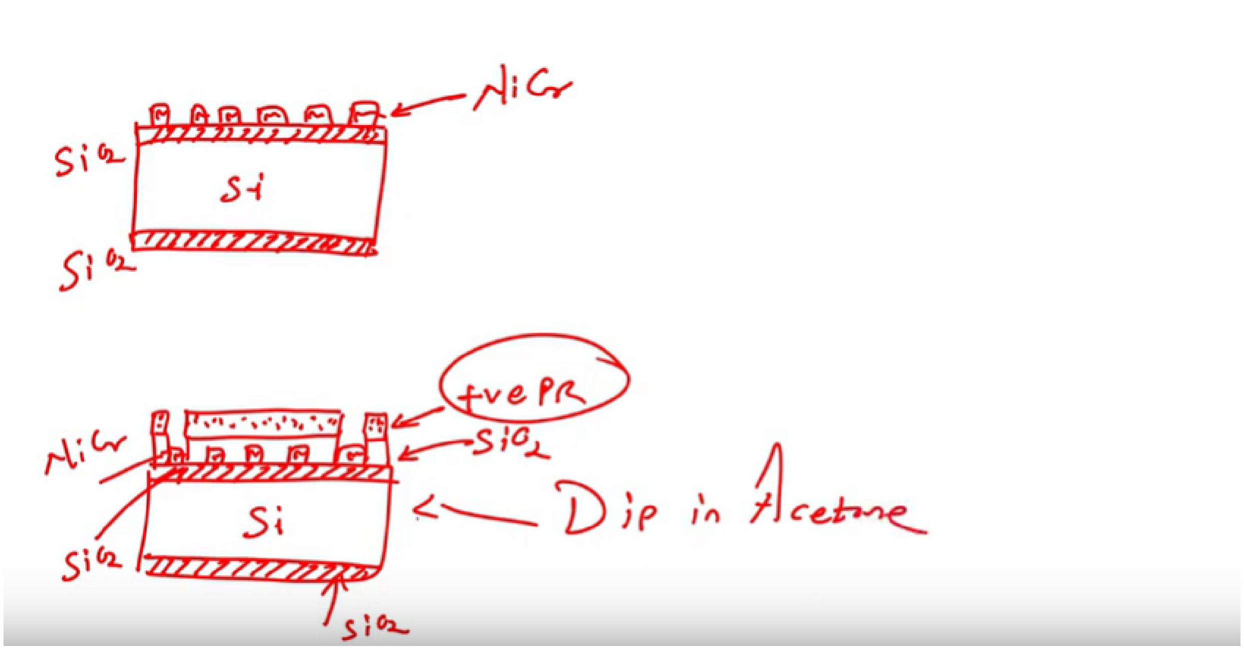

Now after this, we need to step off the Photo resistor, what we should do? We should dip this wafer, in acetone, if I dip this suffer in acetone1 my Photoresist will be stripped, off where forward this is stripped off then what will I have I'll have,

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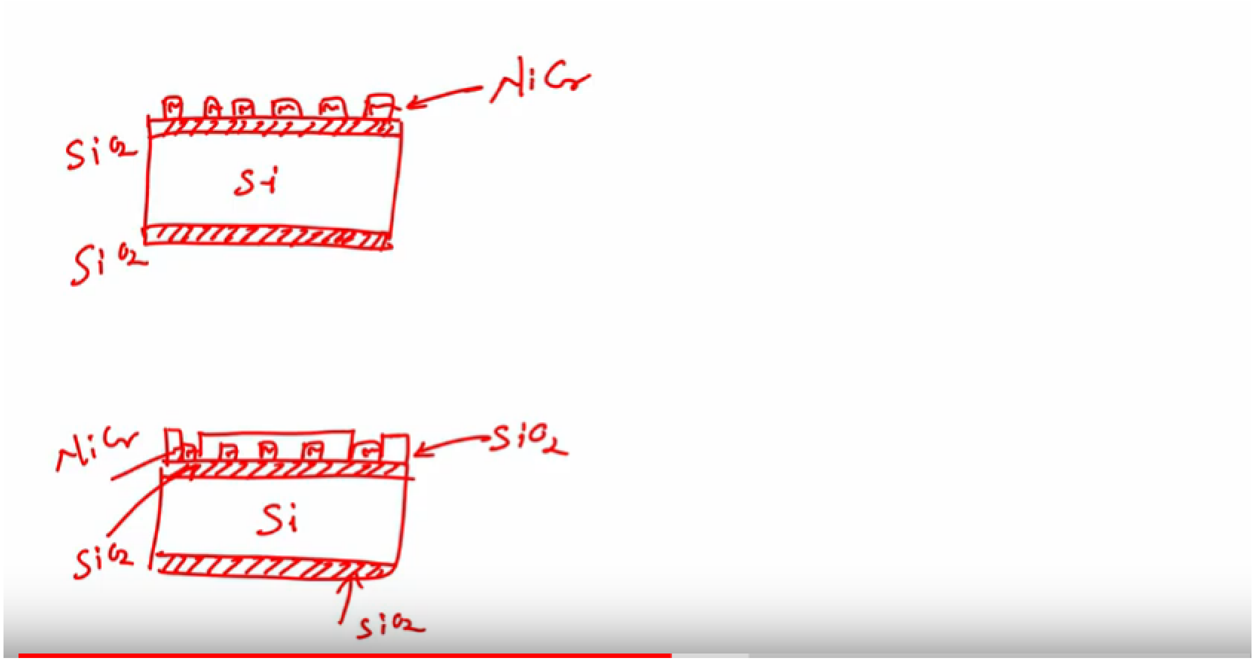

a micro heater, with silicon dioxide, except on the contact pad. Right? What is the next step G, now whatever are we if,

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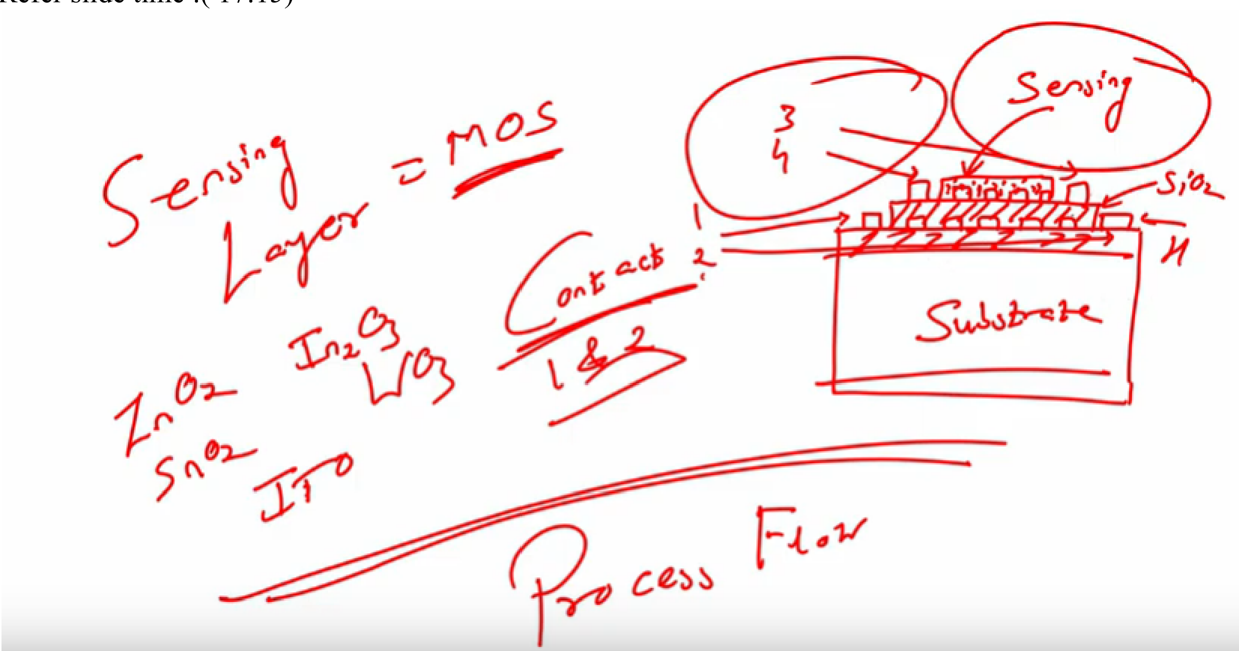

I show it to here, this is silicon dioxide. Right? And this one is silicon dioxide, this is my heater. Now on the silicon dioxide what I have, I want to have, sensing layer.

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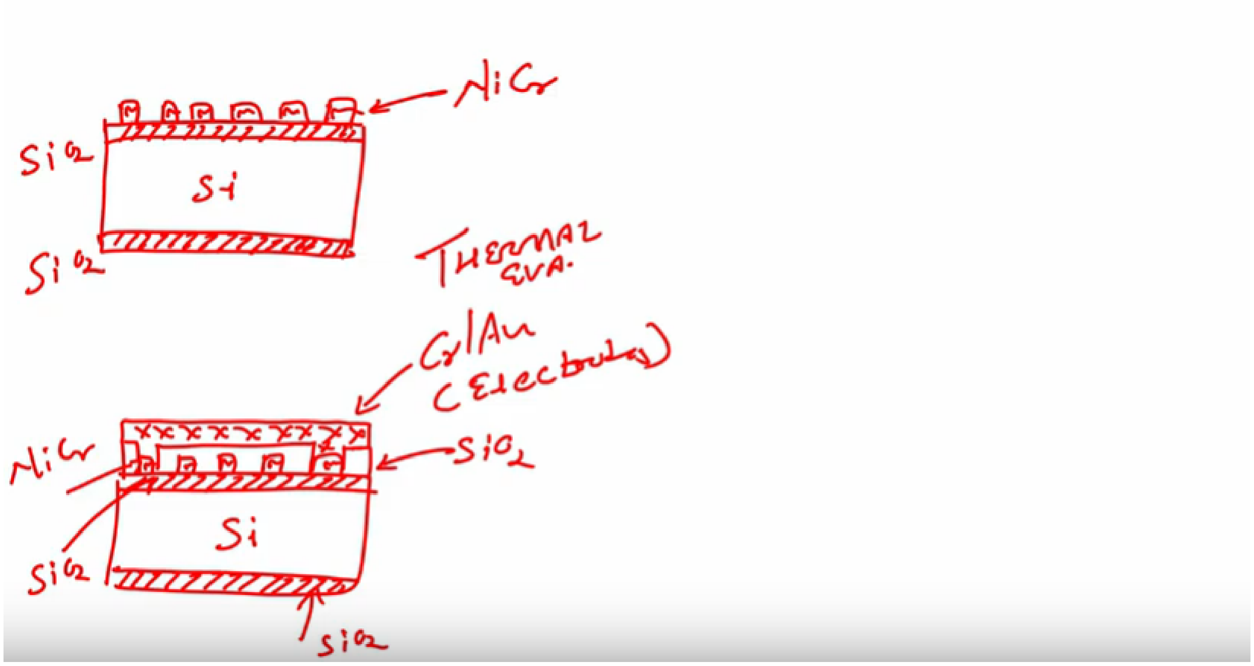

And electrons so, on this what I will do I will, after this the next step would be I'll deposit a metal. So, let me have pattern for metal as xx, this metal is for less this is chrome gold, this chrome goal, is for electrodes, you can see. Right? There are two heater context, now I end want to have electrodes. So, four electrodes, I will first deposit the metal using thermal evaporation, evaporation. Alright? After depositing metal, the next step that I will perform is, photolithography, now you guys know. Right? For photography what we need to do? We have to deposit.

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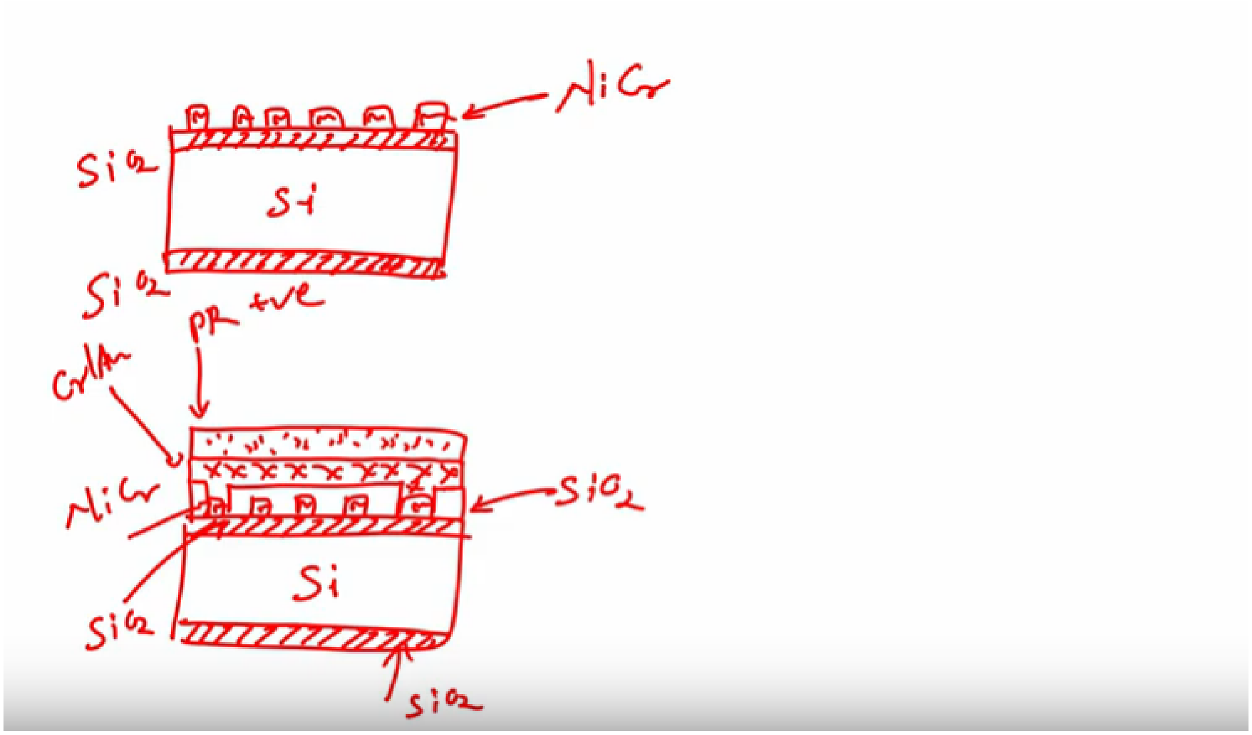

So, this is my metal of course gold and here is my Photoresist. Right? Positive soft bake after Photoresist spin coating. We have to have soft bake, soft bake eater 90-degree one minute, followed by loading the mask.

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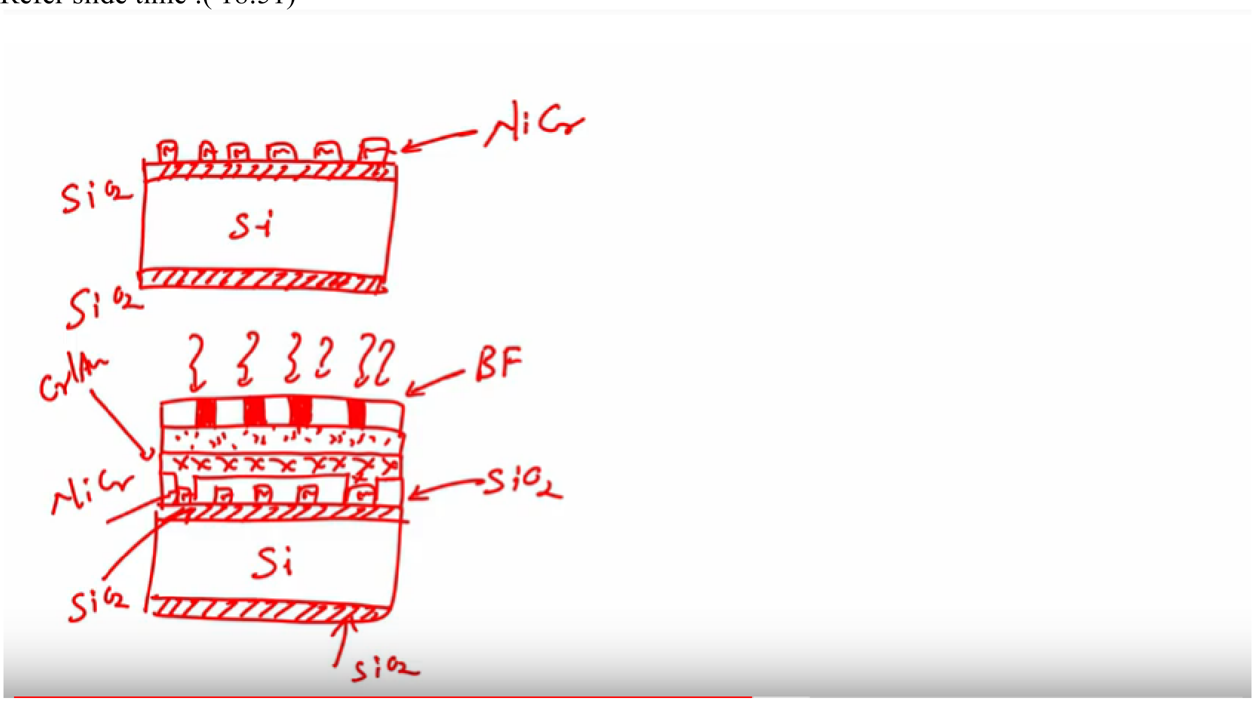

Followed by loading the mask and this mask is bright field mask, this mask is bright filed mask, after this UV exposure, after you exposure. We had to develop the wafer when you develop, the wafer what will happen the Photoresist, which was not exposed.

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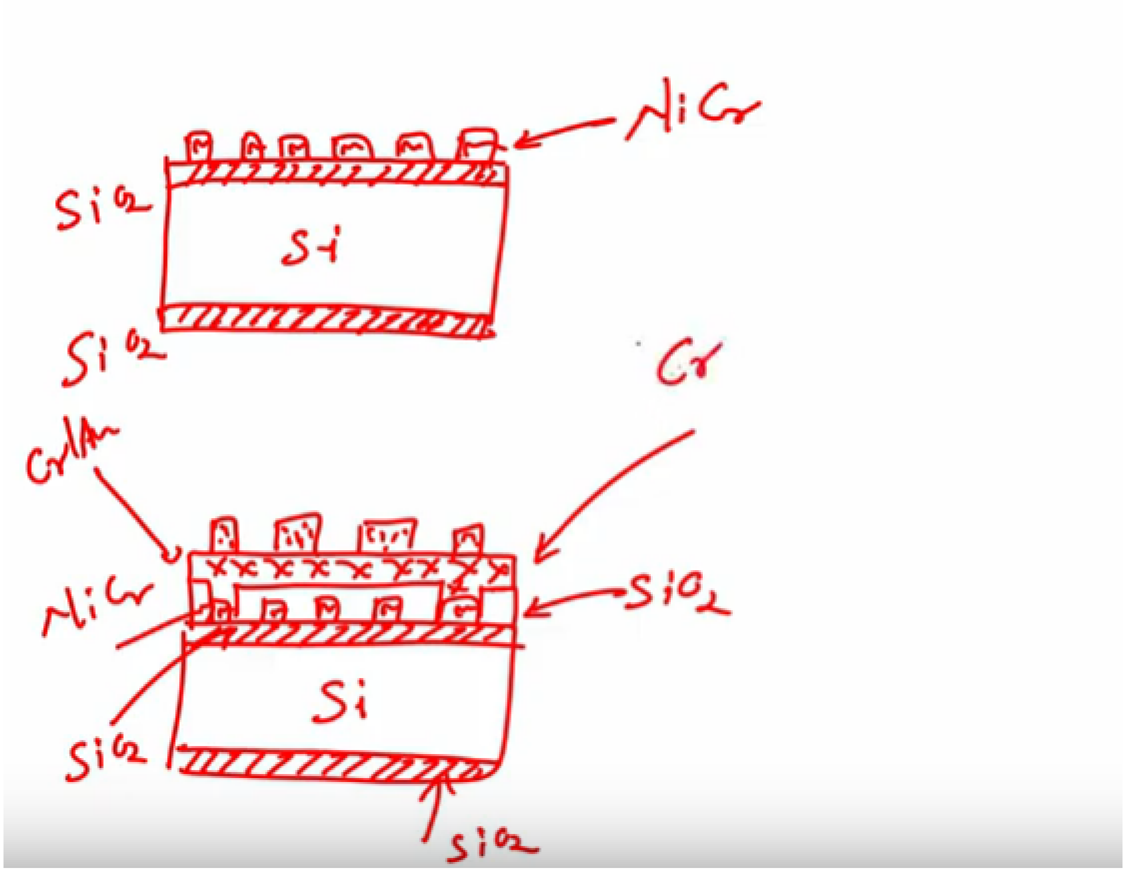

A stronger Photoresist is this area and then. Right? After this, if I develop I edge, this wafer edge chrome and gold by dipping the edge in chrome edge end first is gold edge end and followed by chromatin because chrome is at the bottom.

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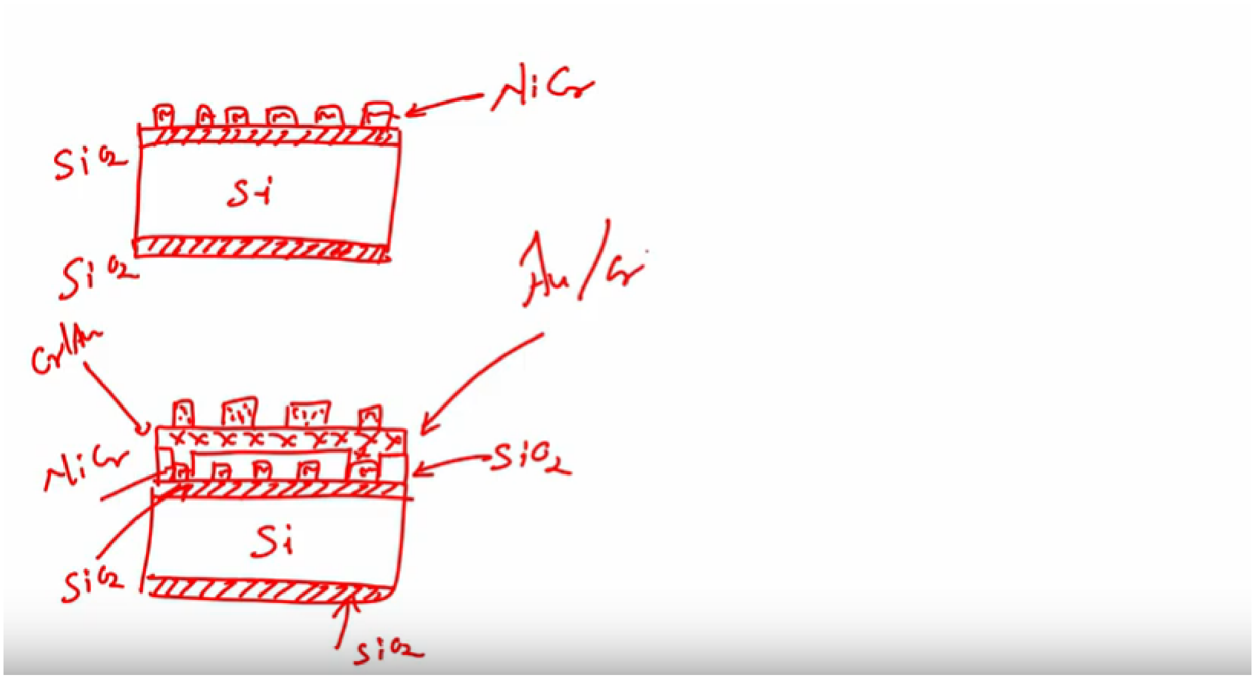

So, first I will dip this FR in gold edge end followed by chrome edge end what will happen? The Photoresist the area, which is protected by Photoresist, will remain as it is in the area, which is not protected by Photoresist will get etched. Alright?

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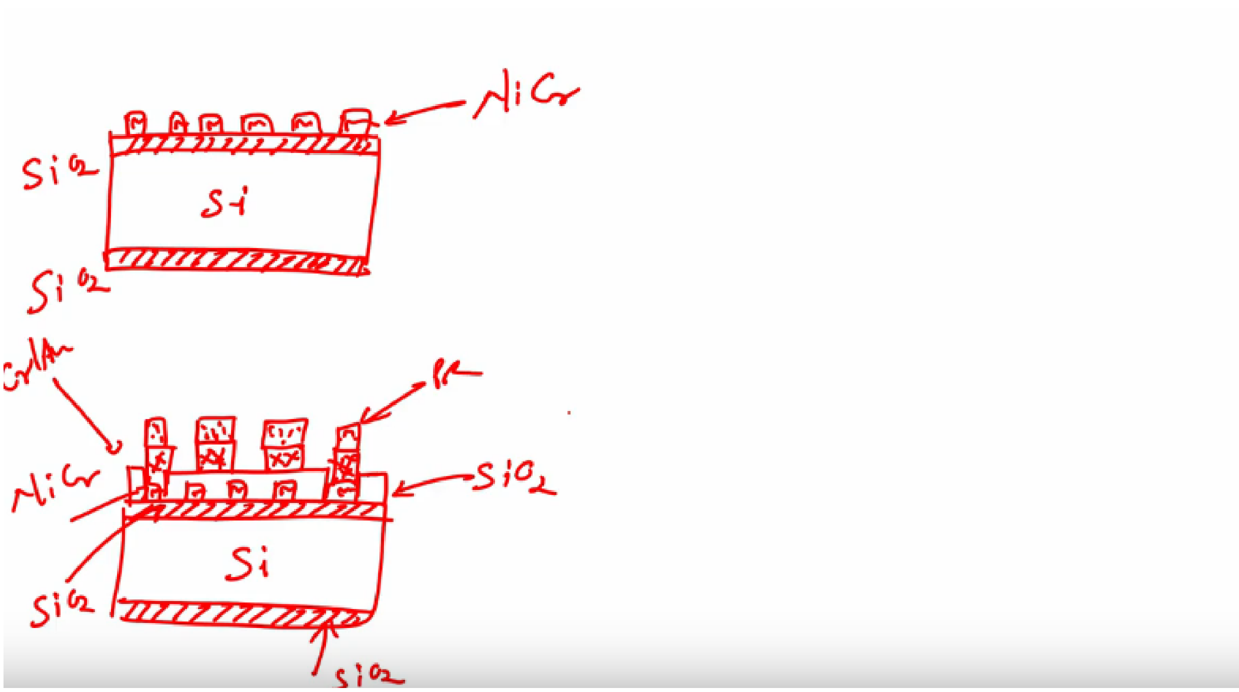

So, area which is protected by Photoresist, a stronger area, which is not protected by Photoresist. Right? You'll get etched, after this I'll dip the wafer in, acetone before that of course after developing the

Photoresist we have to do herd bake don't forget that. So, after this if I dip the wafer in acetone, I will strip off my Photoresist, if I strip of my Photoresist, what will I have?

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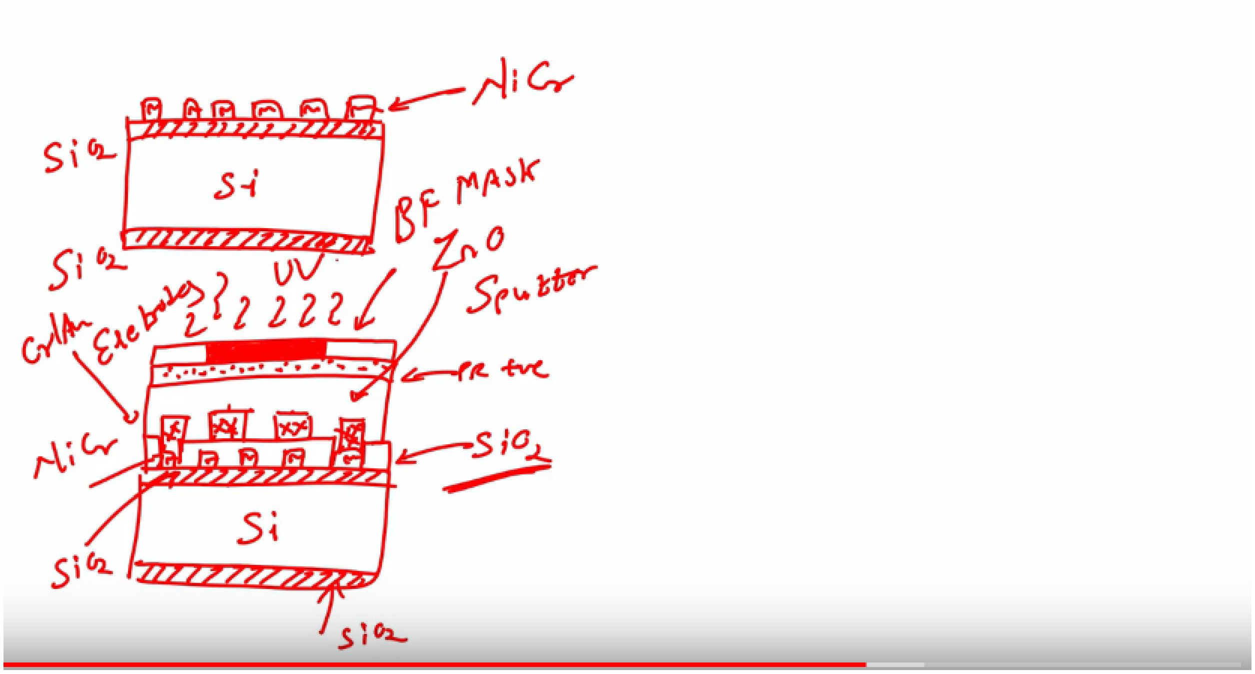

I'll have chrome gold electrodes; over my chrome heater and in between there is a insulating material, which is sio2, what is the next step? Next step is I will deposit my sensing layer, which is my metal oxide, semiconductor. That says that I know sensing layer. Alright? However I deposit my sensing there, by sputtering, you take a zigzag oxide target and then sputter it to form a film of zinc oxide. But do we require film of signals everywhere, no we only want him to be on this, particular electrode and the context should be, open. So, after this the next step would be, spin coat, Photoresist, perform soft bake, load mask bright filed mask, we only want to protect the Photoresist or the electrodes and not on the contact area, as we only want to protect, the sink oxide only on the context only on the electrodes and not on the contact, area of the electrodes. So, we have at this Bright filed mask. Right? This is zinc oxide is here. Alright? And this is our bright field mask; next step is will expose with UV. Right? After this exposure, if I develop the effort what will happen? If I develop the effort then I will have,

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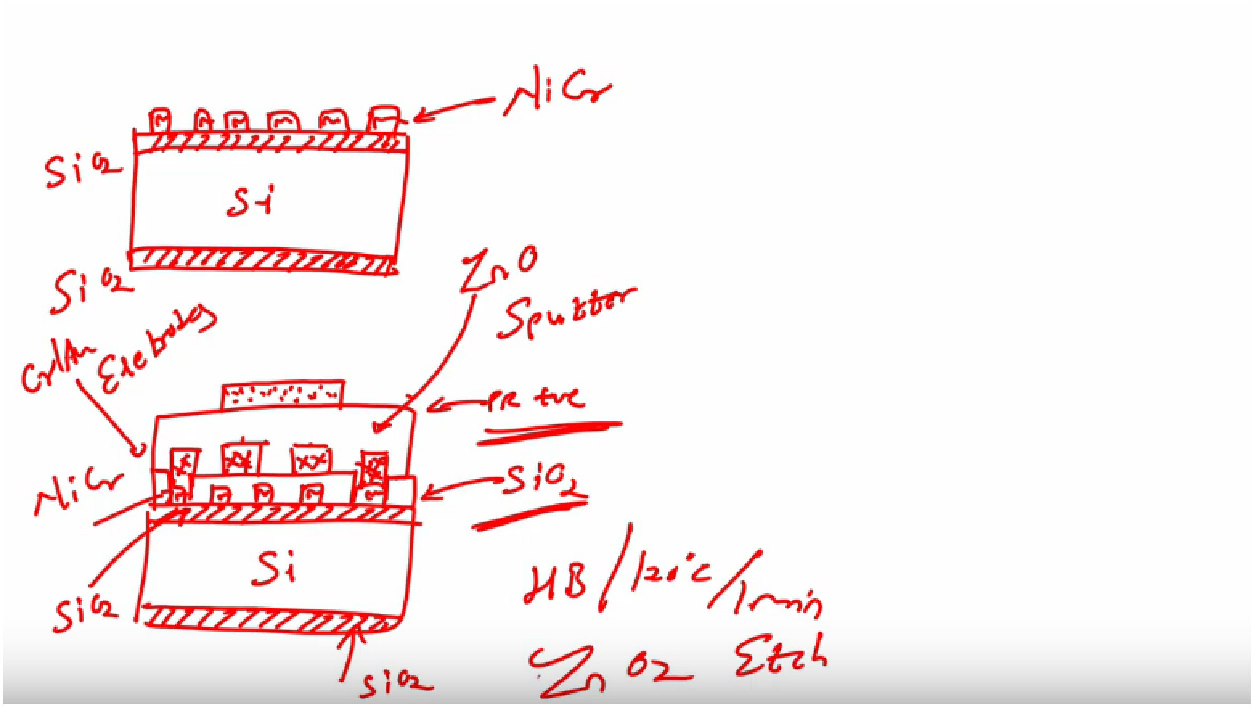

my Photoresist only in this area because, I used a bright filed mask with a positive Photoresist and that's why the unexposed region became stronger. After this algo fought hard bake 120 one minute and then I will dip this wafer in zinc oxide, etched a deep discipline zinc oxide etching if I dip this effort in zinc of zno, zno etch zno2 zno etched if I did if I dip this referencing zinc oxide etchant what will happen? I'll have zinc oxide only on this area. Right? Only on this area, why because this area, is protected by the, Photoresist correct? The last step is, last step is I'll dip this wafer,

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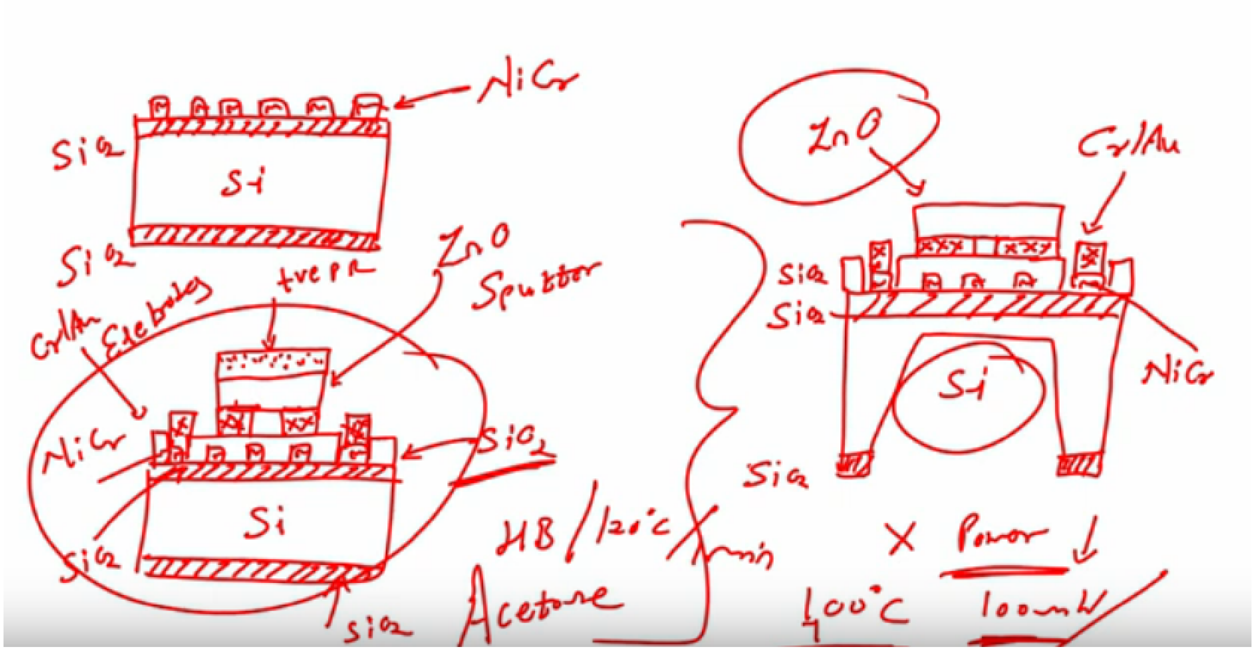

in acetone if I dip the wafer in acetone, what will I have ?I will have, my silicon oxide that is oxidized silicon wafer, on which I will have, my heater, then I have insulating material. Right? On which I'll have, my electrodes. Right? And my hater. Right? So, this is my sio2, this is sio2, this is sio2, this is my chrome, this is chrome gold and this one is my zinc oxide. Right? If I dip this particular wafer, in acetone my Photoresist will be stripped off and I will have my zinc oxide, material on chrome gold, which are the electrodes. So, how many contacts are there I have for context to for the electrodes and to for the heater. Alright Guys? So, this is the process flow, for fabricating a sensor, now if you see, if I want to heat this particular silicon substrate, then I will require, some X amount of power. Right? X amount of power, if I want to reduce the power consumption, for hitting the silicon substrate, I can make a diaphragm, what I can do? I can make a diaphragm, what does it mean? If I edge the silicon substrate, with bulk micromachining. Right? Then now I have to heat, sorry for the design like, this is the kind of little bit better than earlier one. Okay? Now I had to heat, thin a thin layer, of silicon and that's why I'm a power to heat the semiconducting oxide, will reduce. So, to obtain one hundred degree centigrade or as a 400 degree centigrade, earlier was let's say 100 milli what of power we required. Now for the same temperature, if you want to reach 40 centigrade, I will require less amount of power, because of my micromachining. So, this is a separate topic, we don't get into this band just giving an example that you can design a sensor and you can do this micro machining, to fabricate the entire gas sensor. Alright guys? So, what we have learned? We have learned this last slide. So, what we have learned, we have learned, how we can design a gas sensor, we have learn.

How you can fabricate a gas sensor, process flow and how can we design the signal conditioning circuit: that can be attached, to gas sensor. So, as to control the heating, of the gas sensor. Again this is a part of where we are understanding the heating of the gas sensor, but, what about, further, changing the resistance, to a readable format. So that we, will be looking at or we have looked in the earlier slides or if not, we will be looking in the next slides, our next lecture, in fact right? So, I hope that you, understood the importance of sensors, in particular you understand how can design signal conditioning circuit, for a particular sensor which is a guest sensor and how you can fabricate, a gas sensor, using the process flow that I have shown you, in this particular module, again to understand the process flow, a lot of things that you need to understand for example, what kind of silicon subsidry to use? What is the thickness of silicon dioxide you use? What kind of material you use and what is the thickness of the sensing material? What is the thickness of electrodes? What is the thickness of heater? Which material to be used for heater? Why only nichrome? Why not platinum? Why only chrome gold? Why not other material like aluminium? Right? Then why zinc oxide, if I change the zinc oxide, with thin oxide or indium oxide or indium tin oxide, what will happen? If I use tungsten oxide, what will happen? These are all 2d materials, if I go for like, so just a thin film. Right? Yeah! If I instead of thin film use nano structures or nano wires, will my sensitivity improve, lot of questions. Right? To give you answer quickly, aluminum cannot be used because get oxidized. Right? Nichrome is easy to fabricate, platinum is costly, chrome world can be used because you know, the conductivity of gold is very good, compared to platinum, platinum is costlier, chrome gold is cheaper.

Now, if you want about the different materials, each material has its own characteristics for sensing particular voc. Right? When we talked about zinc oxide or indium oxide, or thin oxide, oxide the extremely sensitive, indium oxide is selective, indium, in thin oxide we can use both the, you know, parameters of indium oxide ,in thin oxide. So, these are the some of the equations that you need to understand, what is the thickness? So, this is everything, about the thickness, changing that heater, temperature everything, you can do, if you know, how to perform, a simulation, using a software called, ‘Comsol Multiphysics’. Alright? So, we will see, how a comsol multiphysics can be utilized, to understand and to simulate your sensors, in a next module, right till then, you take care, of any question, you ask me, right are asked in a forum, we will be very happy, to you know help you out, again you understand this thing, this is all thin film technology, where you require, sophisticated equipment like cleanroom, inside the cleanroom for example, thermally operator, ebimo operator, sputtering, photolithography, wet etching, dry etching. Right? But, if I want to use screen printing, then I can do it, anywhere in the with us, with us with a little bit of facility, because in screen bending, what I want I? Just want; let's say you have this particular screen. Right? You have a screen, now what I am doing is? What I am doing is? I am, I am just cutting a sample, from that particular screen. Alright? One second, just to give you an example. Okay? Let’s to give you an example. So, you guys understand, how what is the advantage of screen printing and how you can utilize it, for in your lab. Now, this is a let's say a pattern, what will happen? If I load this screen, on to a substrate, let's say now, I had loaded the screen, onto a substrate. Right? If I depose, if I have a material, which is my sensing material and if I use a squeezy, if I use a squeezy. Right? Squeezed I understand that, that there is I'm sensing material here, if I squeeze it like this, on this particular substrate, what will happen? That the material will pass, through this particular hole, the remaining area, will not be affected. So, when I remove this mask, I will only have the central region, where it will have sensing layer. Right? Now, if I heat this one, at a particular temperature, I have my sensing layer ready. So, screen printing is very easy, to up work on compared to thin film. Right? But, there are advantages, advantages like, in thin film you can have an extremely vinyl sensor and thin film, it's a kind of difficult. Again, once your sensor, you need to have a signal conditioning circuit. Alright? Now till then, you take care, I'll see you in the next, class bye.