Sensors and Actuators
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Lecture - 49
Process flow for Microcantilever for Mechanical Phenotyping of Breast Cancer tissues

Alright now we will look at one particular cancer which is Breast Cancer and the reason of talking about or discussing this particular cancer is that it is a second largest cause of cancer related death in women. Now, that is the why we had to design a sensor or a chip or any kind of actuator to diagnose this particular cancer tissue related cancer? The reason is that the gold standard which is the histology still results in lot of false positive and false negative results.

So, our goal is to come up with a sensor that can understand change in the tissue property and when we talk about change in the tissue property; what are those changes? If you know that when there is a tumour or when this tissue stiffness would be different. So, if stiffness is different elasticity would be different right. So, whether a tissue is more elastic or less elastic or less stiff or more stiff that is one parameter which we will say as mechanical properties of the tissue. Now, depending on the stiffness of the tissue maybe its composition may also have changed.

If the composition of the tissue is changed; that means, the tissue can be smooth tissue can be coarse right. So, if the tissue is smooth or tissue is coarse what will change resistance of the tissue will change, isn't it. So, the change in the resistance of the tissue we call as electrical parameters of the tissue. Now, since there is a change in resistance, if I apply if this is a tissue and if I apply heat on the bottom of the tissue. Anyway measure the change in the temperature the given temperature and the measured temperature this is t 1 this is t 2 this t 2 would be different than t 1 depending on the resistance of the tissue, from that I can calculate thermal conductivity of the tissue.

So now, we are talking about mechanical properties, electrical properties and thermal properties. So, we are adding three moralities electrical, mechanical and thermal over and above the existing morality which is biomarkers. So, can you fabricate such sensors that can measure these three properties alright. So, that is the idea we will talk about one

particular sensor which is a piezoresistor and we will see how can we fabricate piezo resistor using photolithography technique which I have already discussed with you in detail. But, if you have forgotten then I will just show you quick video about photo resist positive and negative type and how to coat the photo resist on a silicon wafer ok.

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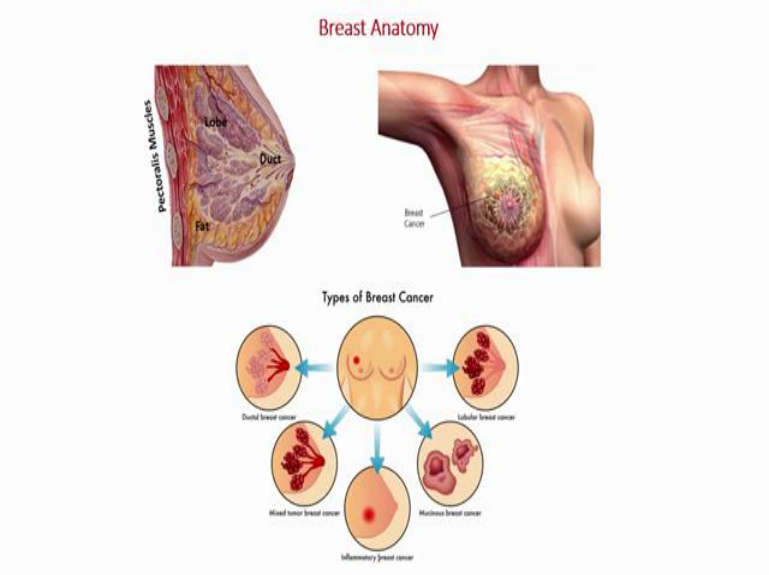

If you see the screen what you what you see here is the Breast Anatomy. Anyway look at the breast anatomy, if you see this particular image then what you will understand that the breast consist of a bigger picture consists of duct right, then consist of lobes and consist of fat and finally pectoral muscles right. This is a composition or anatomy of the breast.

Now depending on the type, like if there is a cancer and duct, then it is called Ductal cancer. If the cancer is in lobe then it is called Lobular cancer, if that cancer is in duct as well as lobe then it is called Mixed Tumour Cancer. If there is inflammation in the breast which we call inflammatory cancer and if there is a mucus in there then we say Mucinous breast cancer. So, you understand these are the type of breast cancer Ductal, Lobular, Mixed Tumour, Mucinous and Inflammatory alright.

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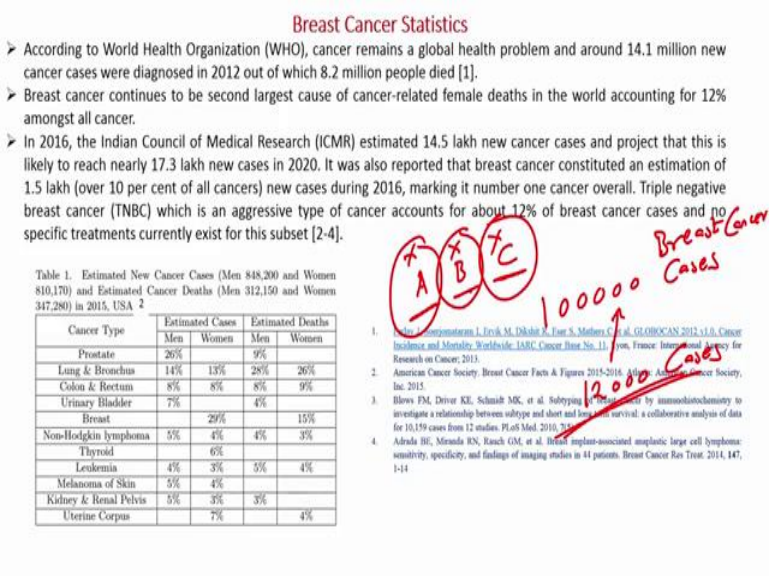

So, let us go to the statistics, what statistic says that according to WHO cancer remains a global health problem around 14.1 million, new cases were diagnosed in 2012, 8.2 million died in 2016. So, breast cancer continues to be the second largest cause of cancer related death in female in the world ok, accounting for about 12 percent of all the cancer. And, if you see Indian data, the last data from ICMR 2016 about 14.5 lakh new cancer cases as a project that is likely to reach about 17.3 lakh new cases in 2020. It was also this is just cancer, general cancer, but if you talk about breast cancer then breast cancer constituted an estimation of 1.5 lakh new cases in 16, marking it number 1 cancer overall from the 14.5 lakh cases.

Now, in particular when we talk about breast cancer there are different biomarkers, let us say biomarker A, biomarker B, and biomarker C alright. There are different name for that estrogen, prostrogen and then we say SMA green and then we also say HER2 plus HER2 minus that is let us not got to technical things because we are not interested right. Now, for this particular course what we are interested is that amongst breast cancer, when we see breast cancer there are three different biomarkers that are generally studied and if all three biomarkers are absent.

Then the patient is said that patient is normal a patient does not have any cancer, but 12 percent of the breast cancer say 1.5 lakh let us say 100000 ok, 100000 cases are there of breast cancer out of which 12000 cases. Out of 100000, 12000 cases right let me write

down 100000 in this format out of 100000 cases of breast cancer 12000 cases are triple negative breast cancer. What is triple negative? All three biomarkers are absent and if all three biomarkers are absent that means, the person is normal, but in reality person has cancer alright and that is the difficult part. That is why if we can design a sensor that can identify the change in the tissue property and we can correlate that with the existing gold standard. Then we will be able to diagnose cancer probably with much more accuracy alright that is the idea.

So, if you see the table here then we will understand that for women if it is breast cancer which is 29 percent of the women, then for the men it is 26 percent case when it comes to prostate cancer. So, as dangerous breast cancer is there for women, for men it is prostate cancer alright and then there are other cancers like lung, colon, urinary bladder, thyroid, leukaemia, melanoma which is skin cancer, kidney cancer, renal cancer it is a uterine corpus right, cervical cancer and many more ok.

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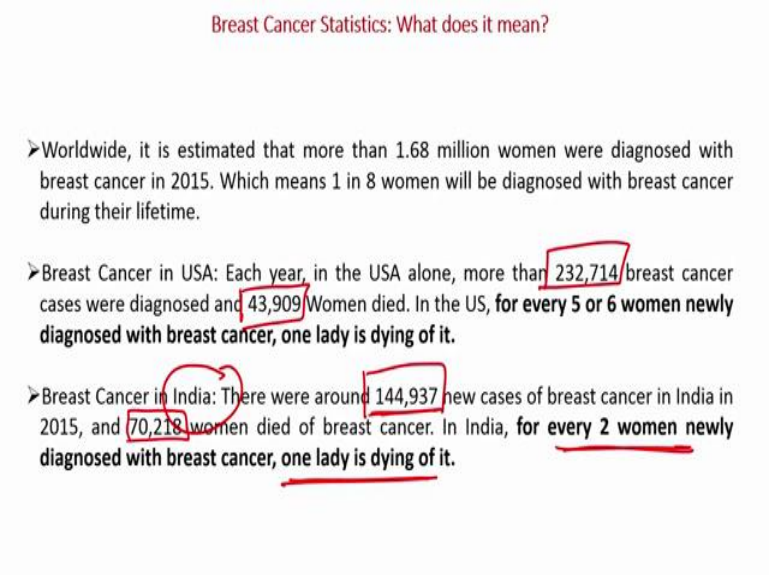

So, what exactly from this statistics what you understood? We understood that world wide it is estimated that 1.68 million women were diagnosed with cancer in 2015 which means 1 in 8 women will be diagnosed with breast cancer during their life time. In united states if we say more than 232714 breast cancer cases were diagnosed, out of which 43909 women died. Thus, for every 5 or 6 women newly diagnosed one is dying very sad to see these figures.

Now, let us think and look at the figures from our country which is India and here if you see that breast cancer in India around 144937 cases of cancer breast cancer in 2015 out of which 7218 died you can see this figure this is 232714, 43909 died it is 144937, 70218 died. That means, for every two women the near newly diagnosed one is dying when we talk about India and the reason probable reason is that the screening is not done as per the routine you know as routinely as it should be done that means, that women should go to a health centre to screen for any possible abnormalities in the breast alright.

So, if we are aware that there can be screening like mammography right and that mammography can probably help us to diagnose or at least screen the patient and patient can be diagnosed with the histology at early stages, then the cancer can be cured. And that is why if you see the figures from United States, it says that for every 5 or 6 women is diagnosed on is dying. Because if let us say 5 is diagnosed and 1 is dying, 4 of them are diagnosed at extremely early stage right.

In our country because of the not enough awareness about this particular cancer and in general about lot of cancer generally people do not go for routine check up and that is leads to the higher number of death. When it is diagnosed because already the cancer it has it is at the higher state or higher stage alright.

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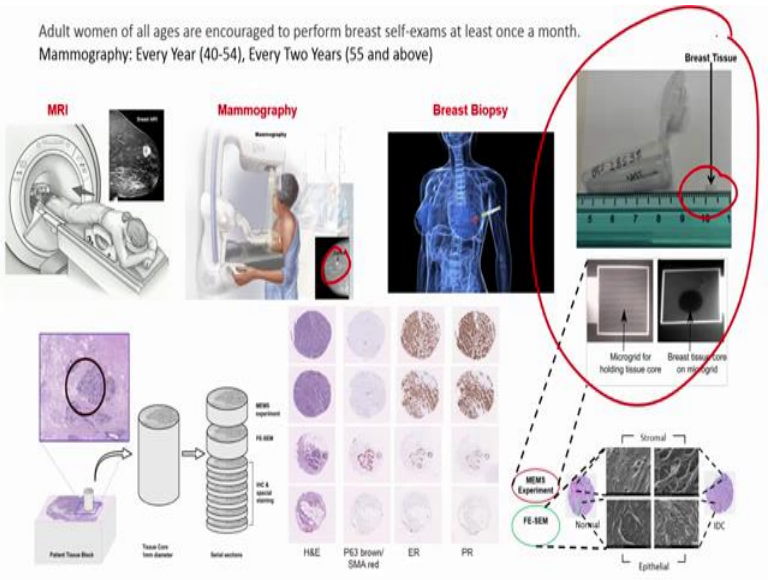


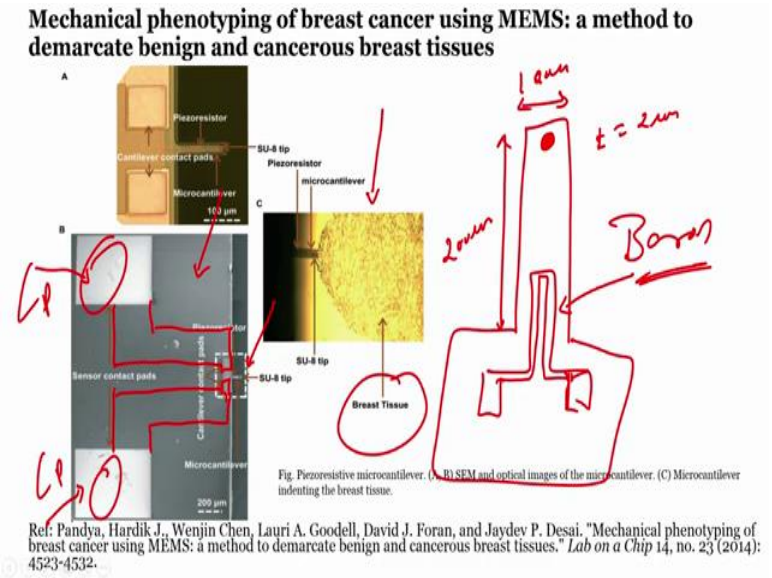
So, let us see if again screen that the current adult women of all ages are encouraged to perform breast self test at least once a month and for mammography which is a screening

tool every year if the woman is between 40 and 54 she should go and perform the check up, if it is every 2 years for 55 and above.

So, if you talk about MRI you can see that there is a lump here, if you go for Mammography again you can see a lump here when this kind of suspected region is identified a patient has to go for Breast Biopsy. So, biopsy needle is used to take out the tissue and that tissue is sliced with the help of microtome and this slice are used for immunohistochemistry and special staining.

There is P63 brown and SMA red I said SMA green earlier that just ignore that SMA red and P63 brown, while there is a ER is estrogen, PR is prostrogen and H & E. So, this are the staining methods to understand whether there is cancer or not and what we will do is that since the oncopathologist may not require the entire tissue, we will ask to get this particular tissue for our SEM images and another tissue for our experimental data or for our experiments alright.

So, we will see about this later, but if you see here what you see is there is a breast tissue here which is about 5 millimetre in length and you can also see from SEM images which is right over here. That the normal tissue which is this one and cancerous which is this particular one and this particular one these two images are cancer and this is normal right. Then the normal region looks much more smooth compared to the cancer region or in other words cancer region looks much more coarser compared to the normal region alright. We will talk about this microgrid sometime later.(Refer Slide Time: 14:09)



So, let us go to the next slide and next slide is a very important slide, because here what we are understanding is how to design a piezoresistive microcantilever. You see if I have a diving board right in a swimming pool this becomes a Cantilever. Now we are talking about cantilever which has a thickness of about just 2 microns and with a width of about few hundred microns and there is a piezoresistor in embedded or integrated on to it. So, that is using a diffusion technique and we use here boron for diffusing the piezoresistive material on to the silicon wafer right. And we also discussed this thing how can you create this particular piezoresistive material.

Then the width, like I say it is about few hundred micron thickn and also length is also few hundred microns, let us say length is 200 microns which is about hundred microns just do not do not worry about it, the diagram is not up to the scale and the thickness is about two microns alright and on this we are we are depositing an SU 8 tip is. So, if you see this particular figure this is the tissue and this is the cantilever, this one is cantilever and the SU 8 tip is in the bottom of the cantilever.

So, if you look at my hand if this is the tissue right, if this is a tissue and this is a cantilever, because see this is cantilever right, then this is SU 8 tip, if we fabricate it becomes like this. But you have to place like this and then you press it on this particular tissue, so this is the movement that we will do. Now depending on the thickness of the tissue, depending on the stiffness of the tissue not thickness, stiffness of the tissue my cantilever will bend right, because there is a SU 8 tip that will indent. When it is indented depending on the tissue my cantilever will bend, this bending will cause strain in the piezoresistor and that will change the resistance of the piezoresistor. That means, that depending on the stiffness of tissue the cantilever will bend and correspondingly the resistance of the piezoresistor which is integrated on to this particular cantilever will change. What is piezoresistor?

When you apply force there is a change in resistance is not it. So, if you now see the figure you will understand that when I am talking about this particular image. There is a cancerous tissue breast tissue, normal (Refer Time: 16:50) cancer, I do not know let us say breast tissue and the SU 8 tip is at bottom of this cantilever, right bottom of this cantilever. And if you see this particular chip then you, here what you see is what the piezoresistor can deliver.

The context all the way, it goes to here this is the sensor contact, I do not know whether you can see very clearly or not. But this is how it goes it goes all the way here to here and this is how it is it goes here and all the way here and for here this is how it is and the cantilever is here right at the tip of it, right, this is the silicon chip. So, the contacts from the piezoresistor all the way here this is contact pads, right.

So, you take the contact from these two regions, when there is a change in the piezoresistor the resistance value of the piezoresistor and that change will be there depending on the elasticity of the tissue. So, when you indent the tissue there will be change in the resistance of the tissue, here you can see is a microcantilever about the length, is close to 120 microns there is a piezoresistor embedded on to the silicon wafer.

It is a p type material which is Boron, we have used diffusion technique to integrate sensor if you want you can also read our paper which is mechanical phenotyping of breast cancer using MEMS, a method to demarcate benign and cancerous breast tissues this is in general lab on a chip it was published in 2014 ok.

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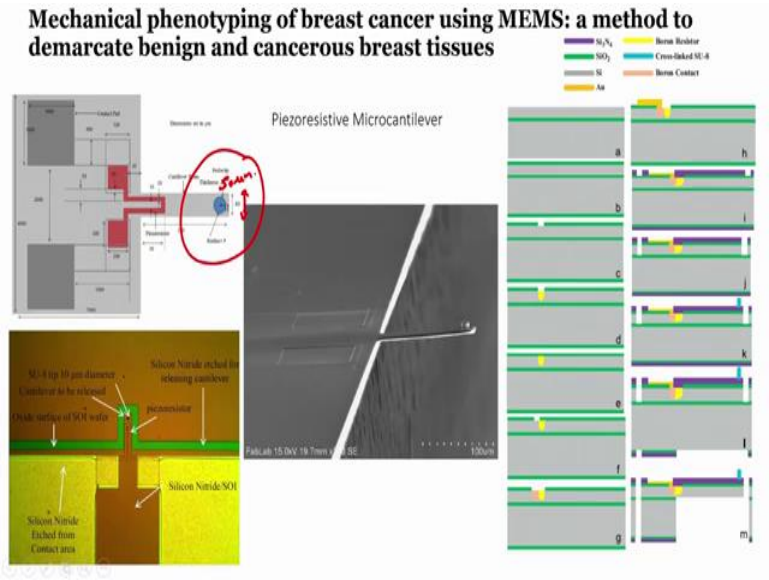

So, further to understand that is what I have drawn earlier, you see this contact pair is all the way here alright, it is continuous line. The detailed dimensions are given in this particular image, you can see that 40 microns yes is the width, about 130 microns is the length this particular cantilever.

As the piezoresistor, when we talk about the width is 10 microns, spacing between two piezo resistor line is 10 micron, the spacing between two contact pair is about 2000 microns, the overall chip size is about 4000 microns which is 4 millimetre. The piezoresistor length from the contact pair to the end of the piezoresistor would be 60, but from the silicon wafer edge to here is 30.

You see here is 30 and then another 30 is 60 anything else, yes. So, that is what it is here and then you have a SU 8 tip which is a probe tip the thickness is about radius is about 5. So, diameter is about 10 and I am sorry the thickness is close to 50 microns, 50 micron is the thickness of the tip.

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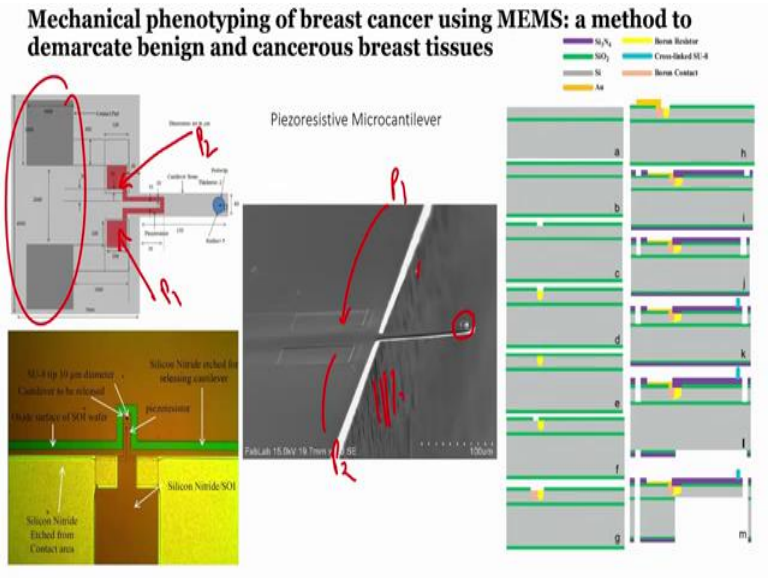

So, you can see here now, you see this tip right this is a SU 8 tip and this two pairs that you see are this pairs, let us say P1 P2 this is P1 P2. This thing you are not even looking in SEM you cannot see the complete chip at least, in this image alright and here you can see this lines right, this is all etched using deep reactive ion etching technique. So, here what we have used is DRIe to etch the wafer and fabricate the piezoresistor cantilever.

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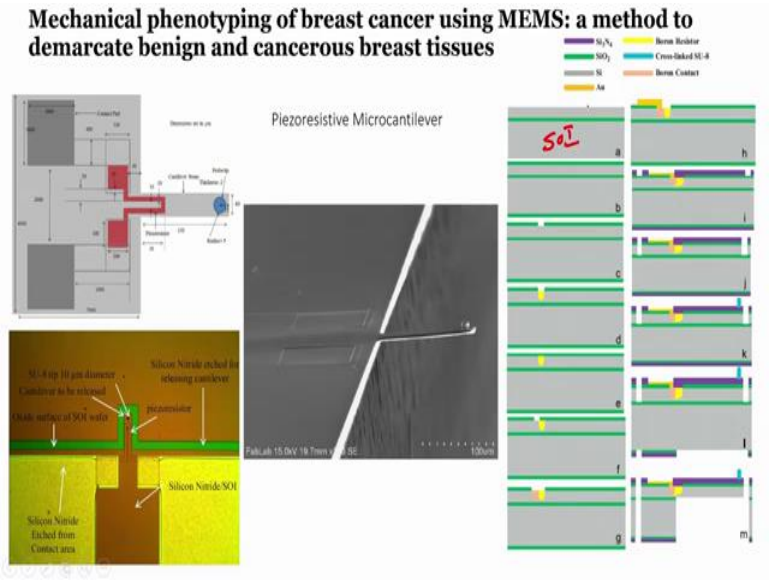

Now, if you see this particular image again you can see SU 8 tip cantilever is released, this is silicon nitride, green one is silicon nitride we will etch it later on. I will show you in the process flow which is right over here and yeah that is nothing else to see on this particular image. So, let us come to the process flow alright. So, if you see this process flow we start with SOI wafer, SOI means silicon on insulator alright.

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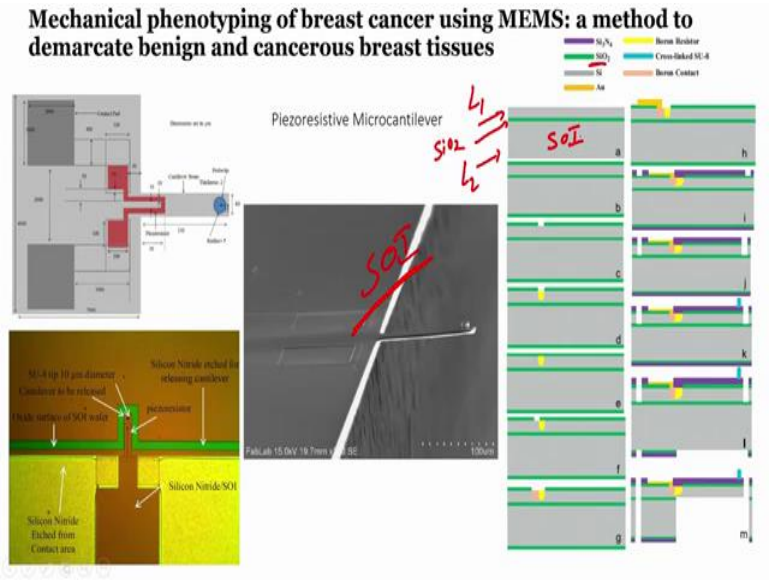

So, where is silicon on insulator here, you see the grey colour is silicon, this one is silicon, this one silicon, green colour is SiO_2. So, this silicon which is layer one right,

this is layer two, what is the substrate, layer one is on silicon dioxide, silicon dioxide is what, silicon dioxide is an insulator, so silicon on insulator which is SOI right. So, our first wafer that we will select for fabricating piezoresistor micro cantilever will be silicon on insulator or SOI wafer alright.

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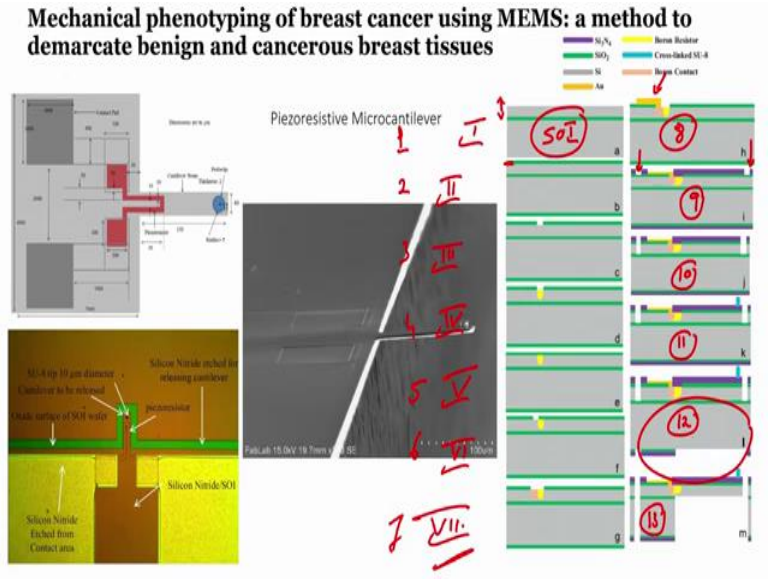

Second step is to grow silicon dioxide right. So, you be with me, let me, let me write down here this is step 1 step 2 step 3 step 4 step 5 6 seven alright. Let us see 7 steps first one is your SOI, second one is you are growing silicon dioxide correct, third one is you are creating a window by using photolithography and in photolithography you will protect all the area except this particular area where the window is created, did refer in BHF silicon dioxide will be etched. Next step is you diffuse boron resistor which is yellow colour in picture here alright.

So, the resistor value will be different than the boron contact value. So, let us see the colours here, if I am, I am sure that you can see the same colours. So here is purple, purple is for silicon nitride, green colour is for silicon dioxide, grey colour is silicon, golden colour is gold orange colour is for boron contact blue colour is for SU 8 material and yellow colour is for boron resistor alright.

So, now if you understand these colours then you what you understand is first is our SOI, second is we have grown silicon dioxide on SOI wafer, third one third step is where we have created a window by performing photolithography, fourth one is we have diffused

boron resistor again by photolithography, because here if you spin code boron everywhere then the boron can only.

Let us say this red colour thing is boron everywhere, when you diffuse it boron cannot pass through silicon dioxide layer. We will select silicon dioxide layer such that the boron cannot diffuse through silicon dioxide layer, but boron can diffuse through silicon and that is why you can see a boron resistor alright this is the cross section of course. The next step would be, we grow again silicon dioxide and then the next step, so this fifth step, number fifth we grow silicon dioxide.

Step number six is we created we create a window, so as to diffuse boron contact and in a next step which is step number 7 we have diffused the boron contact. The reason of diffusing boron contact along with boron resistor is that boron contact will give a ohmic contact when you deposit chrome gold. If you directly take contact from boron resistors you are not guaranteed to have the ohmic contact.

After this particular step the next step is you deposit chrome gold everywhere. So, we assume that this chrome gold is everywhere alright, any perform photolithography such that you will only have the contact pads alright. So, this number this one would be our mass number 8 right, I will just write down in this letter. So, I am not using roman anymore if you want you see this one is 1 2 3 4 5 6 7 and this one is 8.

So, after then after this boron diffusion, boron resistor diffusion, boron contact diffusion, gold diffusion for creating contact pads the next step would be to deposit silicon nitride and pattern it as shown in step number 9 alright here. So, you would, you deposit silicon nitride everywhere and then create window.

Next step would be which is step number 10 would be, that you etch silicon dioxide and silicon through this window right using your RI and DRI. And the 11 step would be use pin code everywhere SU 8 and then do lithography such that you can only have SU 8 tip which is protected. Here is the step number eleven, step number twelve what you do is in step number 12.

You create a window from the backside of the wafer and in step number 13 you etch the silicon completely, completely still you reach the silicon dioxide. Silicon dioxide is a mask will act as a mask when you etch, in silicon agent and thus what will happen that

here the etching will stop when etching stops, then you can you can put this wafer in the RI to remove silicon dioxide

Or you can use BHR to remove silicon dioxide, need to be very careful and that is how you have your piezoresistive micro cantilever. Let us again quickly repeat so that you can understand step number one would be silicon on insulator. The silicon cantilever thickness depends on the thickness of this particular silicon wafer alright. Second step would be you grow silicon dioxide on the SOI wafer, third step is you create a window, forth step is to create diffuse boron resistor.

And fifth step would be grow silicon dioxide, sixth step would be to create window, seventh step would be to diffuse boron contact, eight step would be to spin deposit chrome gold and pattern it using lithography to form the piezo resistive contact pads, ninth step would be to create windows, tenth step ninth step would be to deposit or grow silicon nitride and then create windows.

Tenth step would be to etch silicon dioxide and silicon nitride silicon dioxide and silicon from the windows and step number eleven would be you spin code SU 8 and create a tip step number twelve would be you do front to back lithography. You see in this particular case there is a front to back lithography right, it should not see if you do not properly perform lithography what will happen that you cannot release this cantilever alright. Only cantilever region should be protected other region should not be protected.

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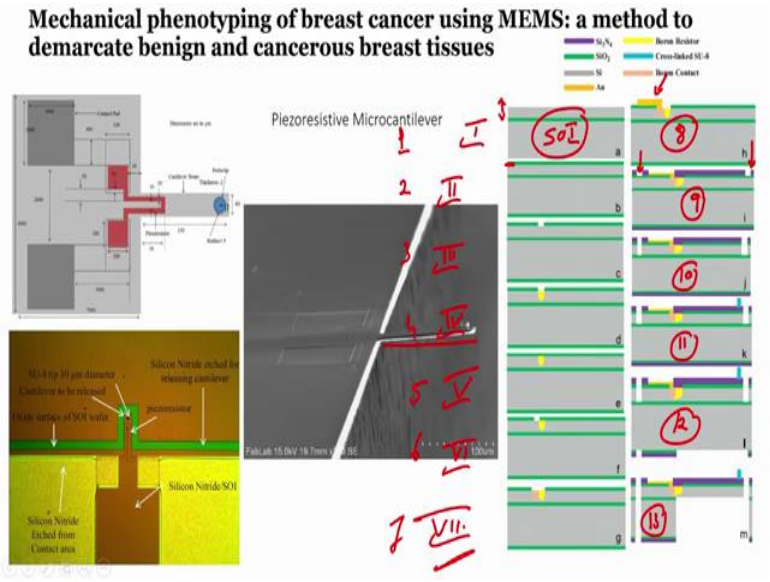

So, now, or in a way that only cantilever region this everything should be etched right except cantilever. So, that for that you have to perform the front to back lithography, which is your step number twelve and finally you etch it in DRI which is step number 13 to get your piezoresistive or to realise your piezoresistive micro cantilever. And then the application as you have seen we can use it for indenting the tissues, when you indent the tissues depending on the elasticity of the tissue the resistance would change.

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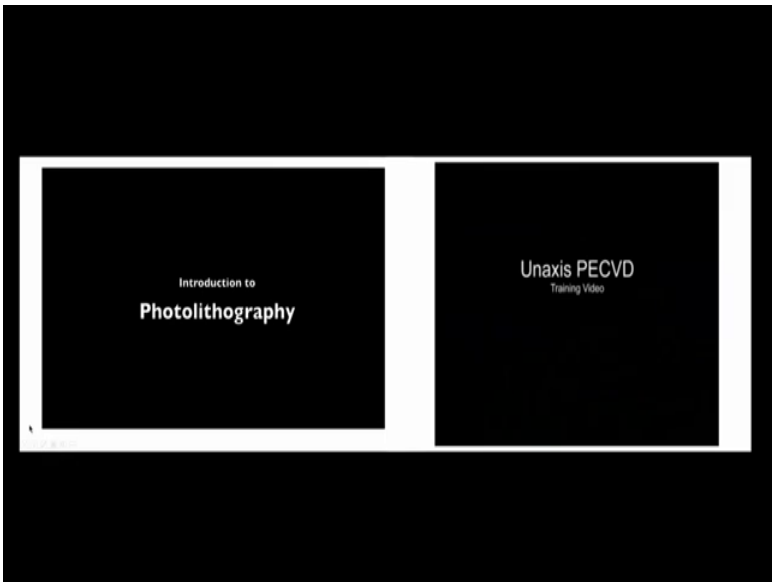

So, let me play two videos one is a on the photoresist coating or lithography and the second video is on the silicon dioxide. The silicon dioxide in particular we are using PECVD, the reason of using PECVD in silicon dioxide is that we can use the system at a lower temperature. But if you do not use PECVD if you go for the thermal oxidation then you have to grow silicon dioxide at extremely high temperature.

You do not want that, you want to grow silicon dioxide at a lower temperature and PECVD which is plasma m n chemical (Refer Time: 29:56) deposition technique will help you to grow silicon dioxide and silicon nitride at lower temperature from hundred degree centigrade to 400 degree centigrade. So, let us play the video and then second video would be about the spin coating of the photoresis,t again two photoresistive. we will see positive photo resistant and negative photo resistant let me play the videos.

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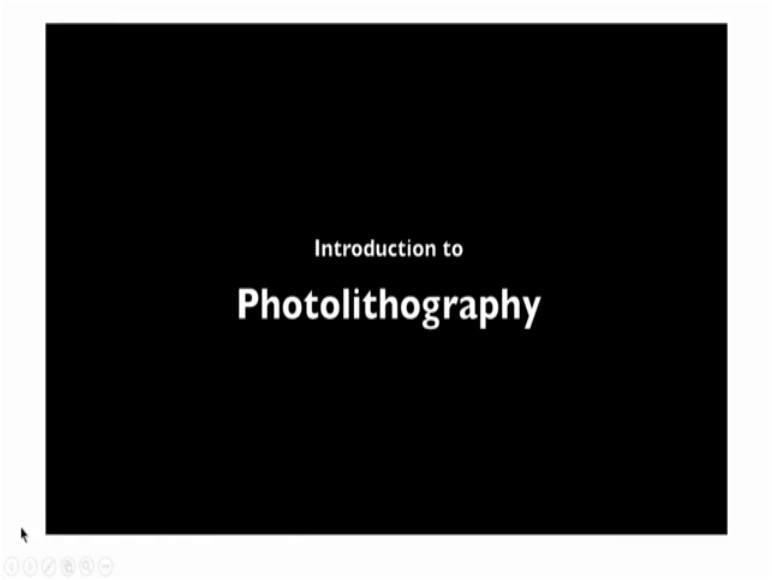

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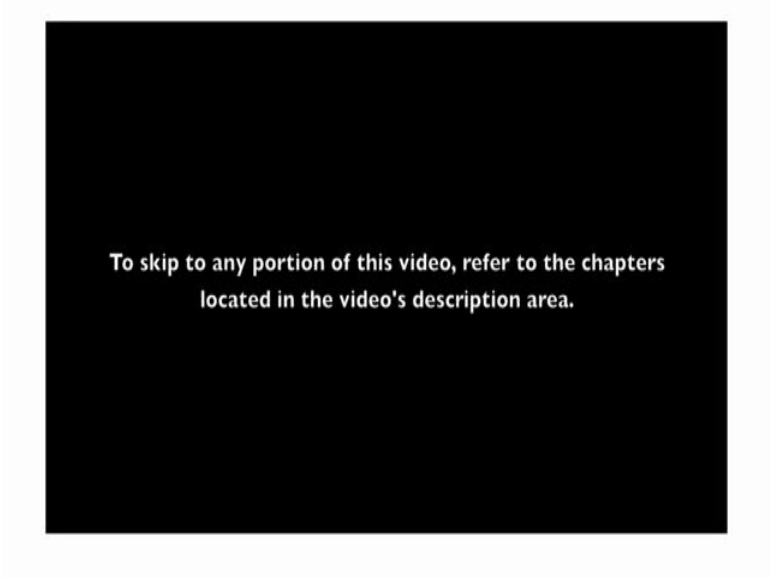

Hello today in this video we let us talk about Photolithography. Now photolithography is a process where you take photo resists or the solvent that is sensitive to lights, now this lights spectrum is usually in the UV. So, whenever you do photolithography you are going to be working in this yellow room. So, as you can see the room around is yellow and the hood is little bit orange, but the both serve the same function and that is to filter u v light.

So, photoresist comes in two general categories we have positive photoresist and negative photoresist, positive photoresist works by being exposed to UV light and becoming weaker.

So, you can use a mask to reveal areas you want to get rid of while negative photoresist is just the opposite whenever you gets exposed to UV light it gets stronger. So, areas that are exposed are kept and areas that are not exposed are removed. Now in our facility we have two separate rooms for each kind of photoresist in this room the hot embossing room we only do negative photoresist we have another room down the hall that is dedicated to positive photoresist.

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Now, the same tool is used in each case we have a Laurell spinner right here the Laurell spinner is designed to take your photoresist put on a substrate and evenly distribute it. So, you have a nice uniformed layer. So, before we start using this tool we have to log in to remove the interlock without the interlock removed the tool will not light up on the screen and will not let you use it.

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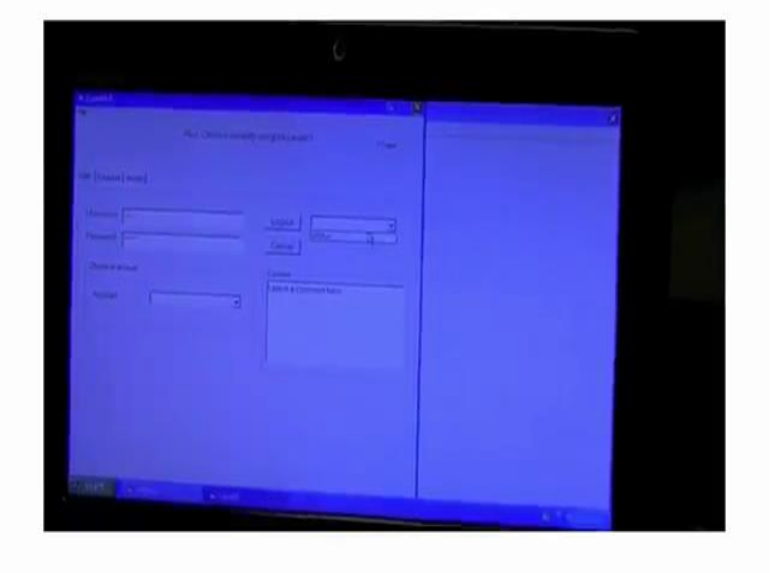

So, to log into the tool our laptop is over here and this location has two tools. So, make sure you are logging into the Laurell 3 spinner, as you can see I am already logged in however if you come here and you see something like this.

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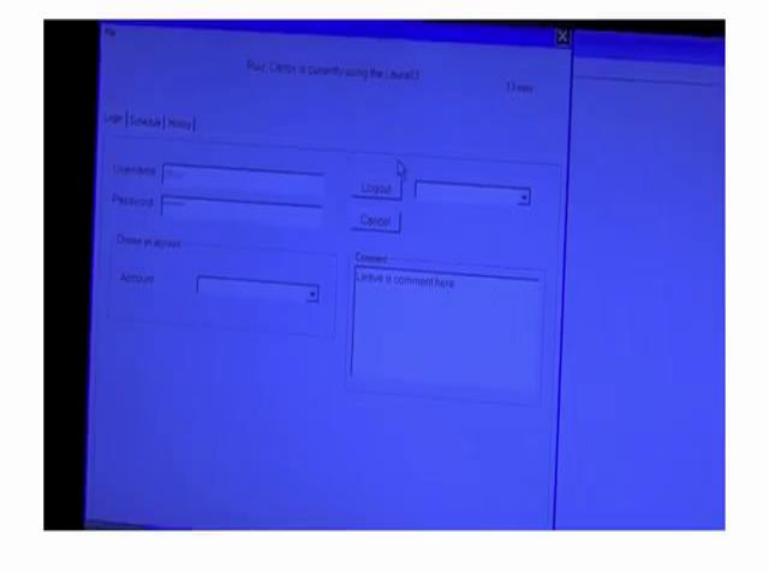

Now, right now it is setup for the AMBUV which is another tool we use in photolithography. If you see this screen you can simply switch to Laurell 3 by clicking this side here the dropdown menu comes out and just click Laurell three and it will switch over see how I am back in Laurell 3 and then you can log in as normal. So, once you have logged in you are now ready to approach the tool, when you first approach the tool there is a certain condition the tool needs to be in before you start using it.

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First you want to make sure these two valves right here are perpendicular to the line, that means they are closed you see how it is perpendicular. So, open them you turn them, so they are parallel you should hear a small hiss coming from the back that means, they are open and it is good. So, the reason why we have to both of these lines open when we use the tool is, because it provides functionality to our spinner this line here is a nitrogen line.

It provides nitrogen gas to the chamber of the spinner this is important because, it keeps the environment inert inside the spinner and prevents any kind of gas leaking into the motor and possibly causing a reaction. The line here the vacuum line here is important because it sucks in and holds your sample on the chuck, without this vacuum line your sample will not stick to the chuck as a spins. So, fly out. So, it is important to have them both functional working.

This is also why we keep them closed by keeping them closed when the tool is not in use, will prevent any kind of built up from getting into the lines you should make the lines even harder to open and close or not functional at all. Now the vacuum lines provided by the building if you ever hear a loud noise open in this line, as soon as you see there is no loud noise it would be pretty obvious. That means, there is a problem with vacuum line you should report it to staff as soon as possible, because this is provided by the building and we have to know notify them to make sure there is no problem upstairs.

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This hood on top of the Laurell spinner should be closed we want to maintain an inert environment. So, you want to make sure all the gas is going to sit there and this is not going to get exposed to anything else.

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We also want to make sure this is clean as you can see right. Now, it is pretty clean you do not see any kind of epoxy like material or photoresist anywhere. The surface should not be sticky see how it is really smooth, inside in particular it should be pretty clean. If it was not clean you would see a an drip down of photoresist coming down here and

dripping to the bottom. But you do not see it here the photoresist is pretty viscous. So, it drips on slowly you may not see it immediately, so it is always good to inspect the inside as well.

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You also want to make sure that you are logged in has enabled the screen, this screen will be blank if you are not logged in. So, that just says the interlock is working and the tool appears functional. If the tool is not clean or any of these conditions are not met when you first arrive please inform staff, we want to make sure these are followed rigorously. Now, the reason why it is important is for two things the Laurell spinner itself uses a electric motor which can be the source of ignition for fires. So, if these are on the vacuum is on and if the vacuum is on and you do not clean this adequately it is going to suck in photoresist.

Most photoresist is flammable. So, if the wrong condition happens maybe a spark maybe something like that happens the whole thing can ignite and that is not good. Another thing we do not want photoresist to go inside and clog the valves on this chuck here is a small hole. Now, when you do not clean the photoresist around the tool, it can actually crawl and get stuck into here which goes into this hole as you can see it is a little dirty in there. You see how the photoresist is in there someone go to re follow these directions and as you can see it is dirty that will eventually get clogged inside and if it gets clogged the vacuum line won't work. And if it does not work you cannot spin the photoresist, so

this is all important to follow. So, we can keep the tool up and running and prevent from getting damage alright.

So now, that we have done all the preliminary checks of the tool and it is surroundings we are ready to start using it. So, whenever you do any kind of spinning and photoresist you want to pre process your sample or wafer.

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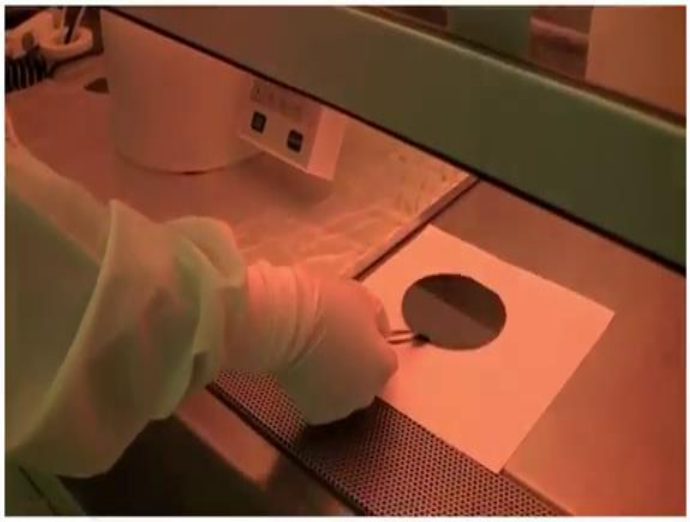

And this can involve RCA cleaning piranha cleaning or any kind of other process such as HMDS. Once your device or your wafer in this case have a simple ordinary silicon wafer is ready, you can start using the tool.

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So, this chuck here has a vacuum in the middle this vacuum is going to hold the wafer down. So, when it spins the wafer will fly out, it is very important that your sample is bigger than this chuck. Now, if your smaller sample than this chuck that means some air will be sucked in around these edges.

If that is the case you must mount your device on a bigger chuck size or a substrate like this. So, if I have a small glass piece I put on top of the wafer like this and put this on top of here. When you mount it on top you want to have it cantered. So, when it spins it is not lop sided that is going to give you a more uniformed coat.

Assuming you open your valves earlier pressing vacuum here will initiates the lock mechanism here, you see the V equal to 25 that is the vacuum pressure in millimetres of mercury you want at least 16 for good hold you have 25 which is more than enough. So now, that is holding personally I like to spin it a little bit as you can see it is kind of wobbly it is not cantered.

So, I like to make adjustments it is better now it is never going to be perfect, but you do not want to have it obviously lop sided, so once you have done that your sample is ready you want to blow with this nitrogen gun to get rid of any loose particles that may have landed while doing this landing process. Typically we will store our photoresist in flammable cabinets because photoresist as you know is flammable.

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So, for SU 8 we keep in underneath here in the SU 8 resist storage.

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Inside you will find a couple of secondary containers please store your photoresist in these containers these are important. Because, if the bottle ever leaks or breaks it is not going to drip all over the floor it will stay isolated in here.

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Now, bottles should be clearly labelled you have to know what it is in this case SU 8 you need a PI it should not be expired either this has not expired. So, this is good usually we throw away unlabelled or outdated bottles. So, make sure you are on top of that. So, ordinarily you could pour from the bottle directly to your sample, but if you have a very low viscosity SU 8 I recommend using a drop it. So, with that out of the way let us talk about how we are going to dispense it.

So, I am not going to do that in the video, but if you have a viscous solution you can just pour it in carefully and do it slowly, if you have a dropper you can just drop it in you want to apply it in the middle and you only need a little bit you do not need to use much. I am not going to say how much you need because that really depends on your photoresist, there is always a manufacture recommendation and I would recommend using that volume. It tells you per square centimetre how much volume you need. So, once you have that settles you can close it.

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Here is where you program it so as you can see there is a couple of buttons here.

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If you hit F1 you will see PGM on the top, that means it is in Programming Mode then you can use the curser to adjust the rpm right. Now it is 500 rpm and the acceleration is 224 rpm per second. Now this varies according to your process. So, I am not going to say what is right or wrong you have to check your processes and see what is your what is your steps are required to the programming.

So, if you need multiple steps you can always add or delete steps. So, right now we have two steps available here most SU 8 requires two steps. But if you want to do a more

complicated routine you can definitely add more steps. To program the other steps you hit the step button under here you see two out of two earlier was one out of one I will press it again so you can see it. Now it is one out of two so this step is programming the second step as you can see is 3250 rpm the execration is a little higher and the time is difference the time is over here.

Right now this is 35 seconds over here it is minutes always double check what you are going to spin you want to make sure you hit step and read everything. So, it is the right the right formula. Now the reason why we use these formulas because higher rpm give you thinner layers of sub when you spin it is and also depends on the viscosity. So, this is a very important step in your fabrication when you are done here you can hit F1 again and the program will go away and it will say off.

Now, assuming your vacuum is above 16 and you have no errors you should be good to go. Now, to run it you hit run and stop you run it you see the timer starts going and you see that the wafer visibly spinning.

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It is going to spin for the exact recipe you put it for. Now some complications can occur you will see on the screen right here, see how it is met the top is what it wants to spin and the bottom is what it is spinning now. If there is a problem with the rotor you will see that it is not going to spin the right speed it might be lower or above. So, always keep note on what is happening here.

Also if you see ACDA error that means the nitrogen feed is not working it could be because, you did not open it is it could be because something wrong with the line. So, just keep awareness on this source screen it will give you errors. If there are any now assuming there is no errors you get this ends and nothing who will pop up and your sample will be ready. What you want to do is open this and take your sample out, there is a lot of ways of doing this personally I like to grab it underneath because you have photoresists all over the top at this point right, now there is none.

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Then you can pull it out and carefully move it to see an oven.

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Ordinarily I would wear a particle mask because, that is going to prevent you from breathing on your sample. But since we are not actually spinning SU 8 in this video I am not wearing one and also I want to be more audibly clear. So, SU 8 generally has two baking steps we have a 65 degree and a 95 degree step. The manufacturer actually recommends that you use a hot plates and you can use a hot plate on any metal bench which well show a bit later.

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But we also provide these ovens for a use these ovens are usually presets, but you still want to check the temperature let us form a appear.

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Right now it is a little bit above 65 which is fine it is the right setting. Now something very important about these ovens is you want to make sure the doors are properly latched.

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You see how I am pulling on it is not coming out it is because it is latched. If you do not latch it see how it opens up it should not be open able, to close it you want to pull it make sure this is over the clip and that it clips down. Now if you leave it open the oven is

going to try to burn itself out, basically what it is going to happen is it is going to try to reach the temperature that it cannot reach.

So, it is going to keep going and going and going and it is going to burn a fuse and it is not going to work. So, then we have to replace it and it is going to have downtime. So, we want to avoid any downtime. The other oven is over here.

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This oven is set at 95 degrees and again I would check with the temperature to make sure it is a right setting.

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As you can see we have several trays you want to make sure these are aligned some of them are little bent. So, you do not want your sample to creep you want to make sure it is on a flat surface, when you close this you want to make sure it latches too. Many times people will just leave it like this and see how it is open you do not want to do that it has to click and then when you pull the door it should not open that is how you know it is properly closed.

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So, once your sample is baking this is a good opportunity to start cleaning the spinner. Now you only want to clean when you are done spinning everything. So, I recommend if you are doing three or four wafers to spin them all first. So, all you have to do is clean once. So, the clean is spinner you want to use acetone.

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It is usually located on this side of the hood and you will notice the red bottle that clearly says acetone. If this bottle is running low we usually have spare bottles over here.

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So, this yellow cabinet is meant to store flammable chemicals acetone is flammable. So, we want to make sure we always store it here.

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Inside you will see a nice inventory you have acetone right, here we usually have isopropanol which isopropanol alcohol and methanol. You want to make sure this is properly closed, see how I kind of pushed it. But it is not really closed you see it is still open when a open the latch push it and close the latch. You want to make sure you do all the pouring in the hood; I did not bring them because we have plenty of acetone here. But if you were empty for instance you would bring the bottle over here pour it while in here and make sure you do not breathe any of the fumes and also put it back in storage.

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I know some users like to do this and I want to address this, some people like to put a chuck like this on it turn on the vacuum and spin it while spraying into this little hole.

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Now that is not good for two reasons, first you are getting acetone everywhere and some of the pieces like the motor I mentioned earlier might get stuck to that area with the electric motor and might be a source of ignition so that is dangerous. Second your splattering SU 8 and acetone kind of everywhere it will leak out here and out here and it is going to make the whole area dirtier, the better way to do it is not to use this chuck.

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But instead to wet a clean wipe like this give it a nice amount and scrub it out.

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So, you want to reach in and just wipe the walls, it is clean now but when you wipe it you will see a lot of gunk building up. So, try it as much as you can and when you think you have enough you can dispose of it over here, this yellow can is meant for SU 8 and solvent wastes which includes acetone methanol and isopropanol put it right in and keep going. It takes a few wipes you cannot do it in one unless it is a very small mess, you know when you when it is its very smooth to the touch and not sticky that is when you know you are done that is when you know it is clean everything should be smooth.

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Here, here, here and inside.

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Now, another area you should clean is underneath this piece. So, how do you remove this piece? Well if you see underneath here this little thing right, here you want to grab on to it and spin the top it will unscrew itself and this comes out.

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Then you can get this over here and you can spray acetone then wipe it here safely, because here it will not get stuck to the motor and will not get stuck to the tubing you do not want to spray it directly on here, because it will get sucked in. So, here it is safe you just drench it you clean it take off the chuck clean it here too.

And when it is clean and smooth you can also clean the walls here that are hard to reach and underneath. So, you are just going to wipe and wipe it, when it is done you put it on the same way you hold this little stick here and you see this screw just screw it back in. It is in good condition you should be able to spin it freely see how I give it a little push and it spins.

Right now it is not so great it is little dirty you want to see it do two revolutions at least right. Now it is doing may be one. So, it is almost due for a good cleaning, but if we all take these steps to clean the inside and clean the surroundings we can prevent this from happening and keep the tool up longer.

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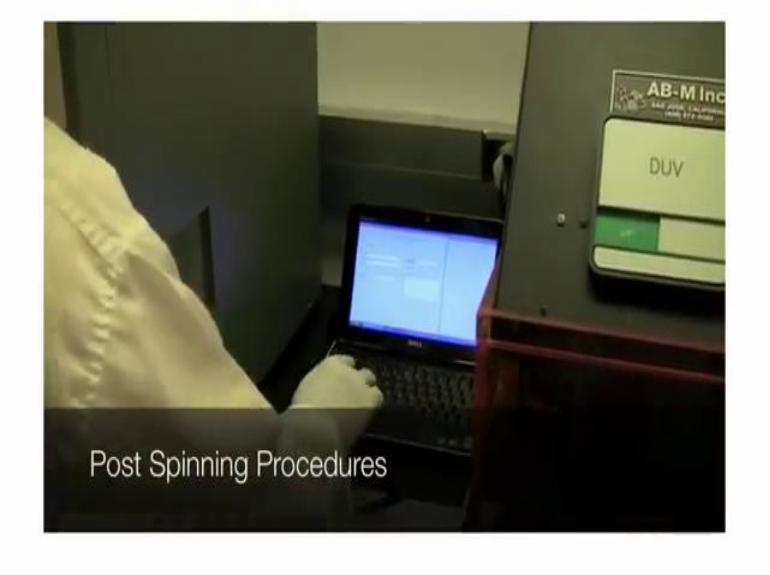

Alright, so once the spinner has been cleaned thoroughly you want to make sure you close these two valves over here. Remember the rule if it is perpendicular it is closed if it is parallel it is open. Keep it like a flow and see how they are kind of crossing the flow, now to remember you also want to close this and put this back on the on the right side, you want to make sure these cabinets are closed if you took out photoresist and then lastly you want to log out. Now the next step that we usually have in SU 8 processing is the exposure.

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For most of situations a single mass is enough and for that we use the AMBUV which is right here. The login is right next to right next to the Laurell spinner and as I said earlier you can use the drop down menu to switch to this tool, this tool is more covered more in depth in another video. If you have more than one layer and you need alignment we have tool another tool called the MA56 it is in another room in the lithography room and that is also covered in another video. So, assuming you have done all of the processing including the baking and the UV exposure and you are ready to develop then we come over here.

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This is our development bench.

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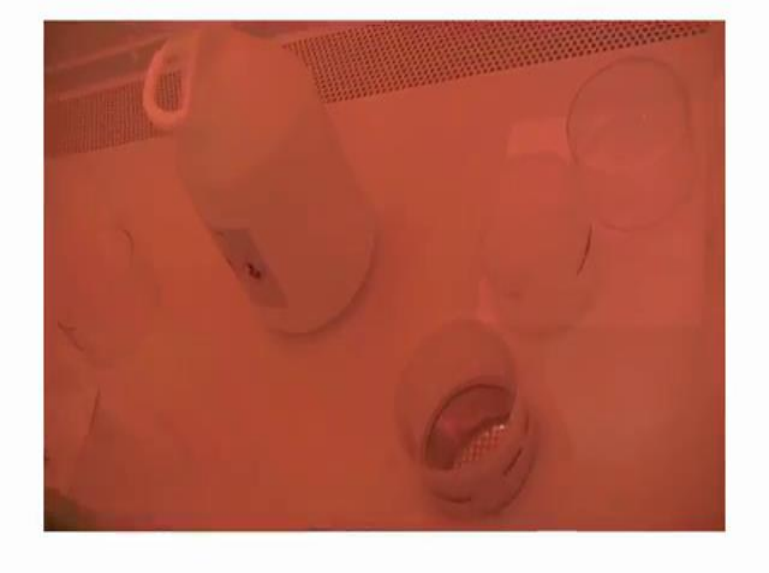

The lights over here, notice I have already set up here, but usually you do not want leave things laying around.

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So, to develop you want to use SU 8 developer which is usually stored down here, where you see SU 8 developer.

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S U 8 developer is pretty universal. So, this will develop almost every SU 8 that I can think of in this facility, but I would check just to be sure. You want to put it in here and you want to open it carefully. Typically you only need enough SU 8 developer to cover the sample. So, I am going to bring over a sample very quickly and just pop it in, next I am going to pour very carefully just a little bit you do not need a lot; that is all you need SU 8 develops faster if you agitate it or if you use an ultrasound machine, the INRF provides an ultrasound machine that you can borrow.

Typically, this can take anywhere from 1 minute to 20 minutes it really depends on how thick your SU 8 layer is for thicker layers more development time is needed.

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But the most importantly, I want to stress you do not that need much developer anymore in this is wasteful as you can see it only covers. The last step in SU 8 development is to check whether or not it actually developed.

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So, when you think the time has gone by, you can take out the sample with your tongs, make sure it does not drip out then use isopropanol which is the yellow one here labelled isopropanol and you spray your wafer you do it; very slowly and gently you do not have to splatter it just take your time.

Slowly on both sides to make sure it is thorough and take your time notice I am using a separate container to catch this you do not want to mix the developer, I will explain why in a second.

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So, then you can dry it off here, I like to use a clean wipe and this nitrogen gsun here, just blow it slowly; this gun speeds up really fast. So, you want to slowly ramp it up unless you might blow your sample out of your tong. So, if this had SU 8 on it you might see some white streaks; that means, it is not done yet. And, if it was not done just stick it back to the developer and give it more time.

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Now, once you are done, I am going to show you how to dispose of everything. First of all you want to make sure this bottle is closed and put it back where you found it which is down here in the SU 8 developer. Next we have two different kind of wastes; we have SU 8 developer and we have isopropanol now. Isopropanol methanol and acetone are all

considered mild solvents and we have a different waste container for that ordinarily we can just take it out.

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Here is our solvent waste you can open this, we have couple of lid funnels you can use and pour it in. You want to make sure this is closed tightly because all of these will evaporate out and fill the room with solvents and that is not good for your health. So, you want to make sure it is contained in that container.

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Next you usually rinse these. So, what you can do is put this in the sink and run some d I water in it you see it is a little soapy that is normal, you keep rinsing it until the soapiness goes away I am going to speed it up a little.

As all things done in the cleanroom, you need to take your time. So, you do not want to rush this just let it run go put away samples things like that. So, you see some bubbles, but it does not look soapy anymore which means it is pretty much rinsed off I am going to close the line not all the way just enough like this to lower the pressure, reach in and give it one more rinse carefully. A lot of users like to leave their samples to dry and that is fine, but you want to remember to pick it up.

Because if you do not pick this up in a few days, we are going to put it somewhere and it might get lost. So, you want to make sure you keep track of your beakers. Now the SU 8 developer is not thrown in there, but in a different place here you see waste developer.

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You see a bottle designated SU 8 waste developer.

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So, you want to put it in here bring out a funnel, carefully pour this in there. For this I like to rinse the funnel a little bit with the D I water before I put it back down there just as a courtesy, just some low pressure water is enough. Secure the cap and then take it out put it right underneath. If there is no more bottles to use for waste we have a separate room where we contain waste bottles you can ask staff for help if you do not know where it is.

So, right now I am going to rinse the last container, but that pretty much concludes photolithography for our facility and thank you for watching.

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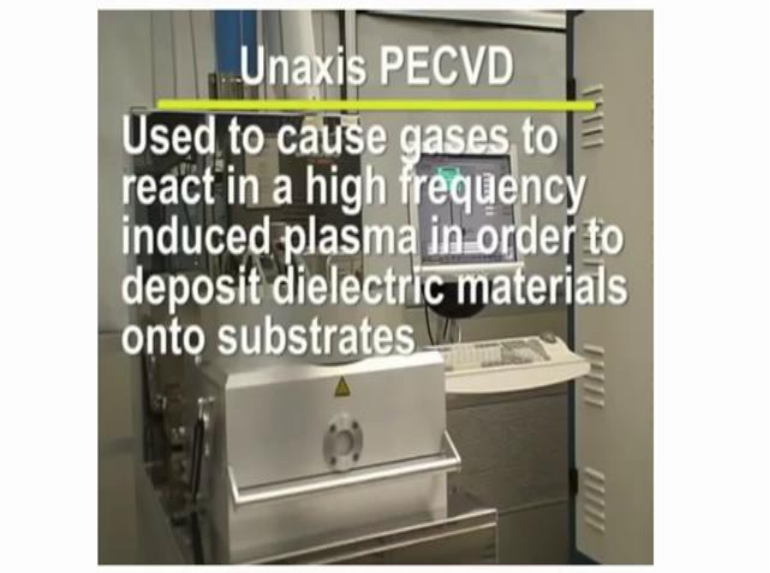

The unaxis PECVD or plasma enhanced chemical vapour deposition system is used to cause gases to react in a high frequency induced plasma in order to deposit dielectric materials onto substrates.

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The unaxis PECVD is a single chamber system capable of depositing silicon dioxide silicon nitride, silicon oxynitride, silicon carbide, polysilicon, P-doped polysilicon.

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All users should contact the trainer for the system prior to depositing any type of Polysilicon Lake.

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The unaxis PECVD can process a wide range of sample sizes the number of samples depends on the size of the samples a typical run can process up to 44 inch wafers typical deposition rates range from 60to 600 angstroms per minute. Let us now go over the various parts of unaxis PECVD.

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The process chamber is where all the processing takes place on the system. The two main parts of the process chamber of the showerhead and the plate on.

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The showerhead is used to evenly distribute the gases in use during the processing.

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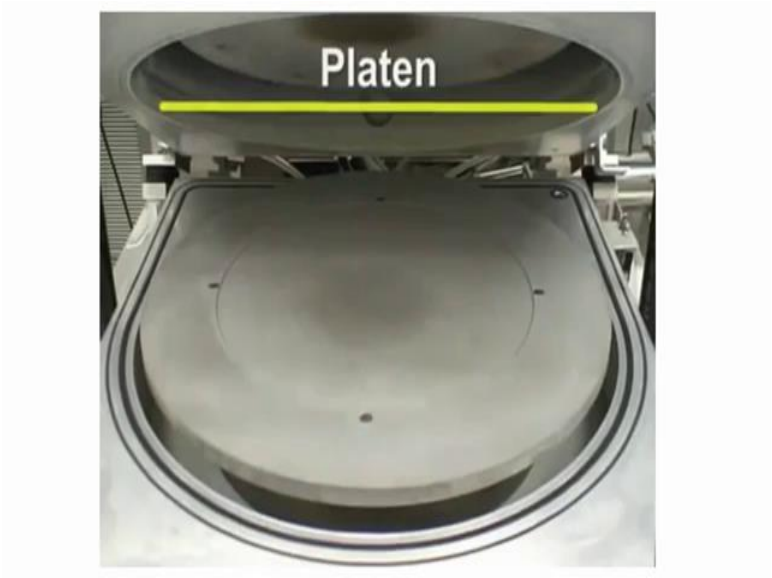

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The platen heats the samples to improve the deposition quality and increase the deposition rate. The systems computer monitor and keyboard allow you to control the software of the system.

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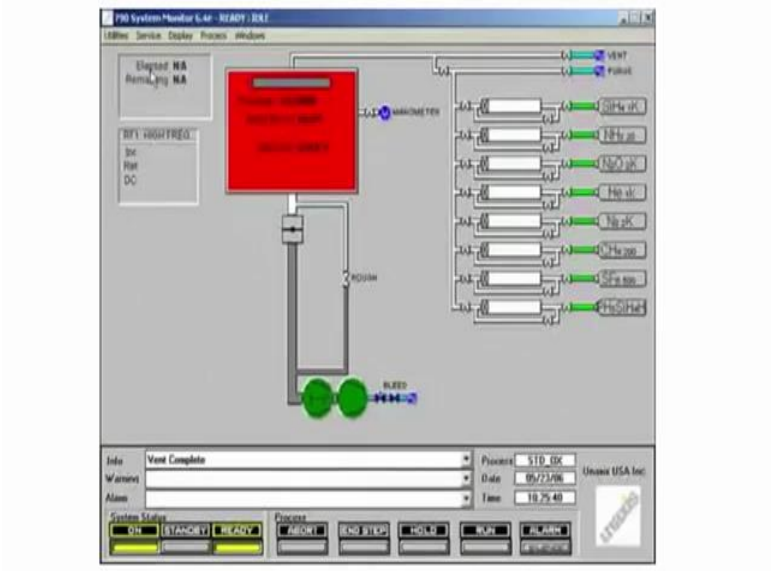

The software enables you to vent and pump down the process chamber.

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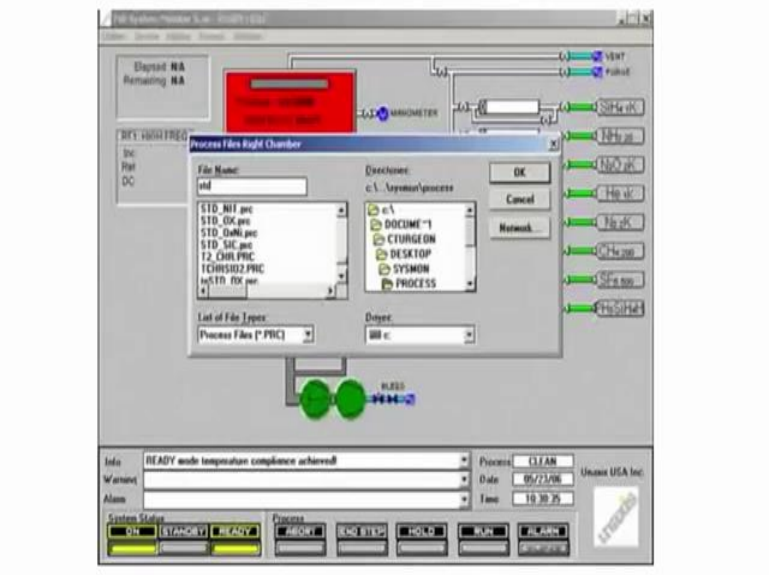

Select or create the proper process for your process run.

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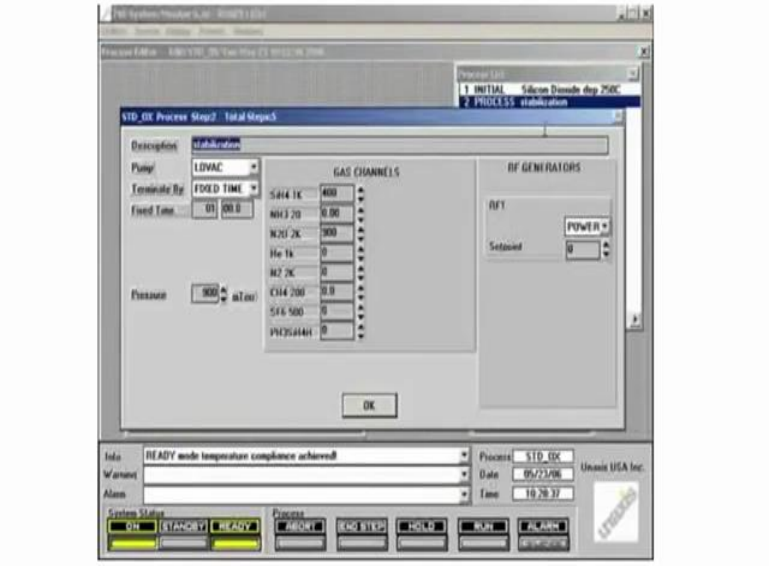

Adjust the parameter of your recipe.

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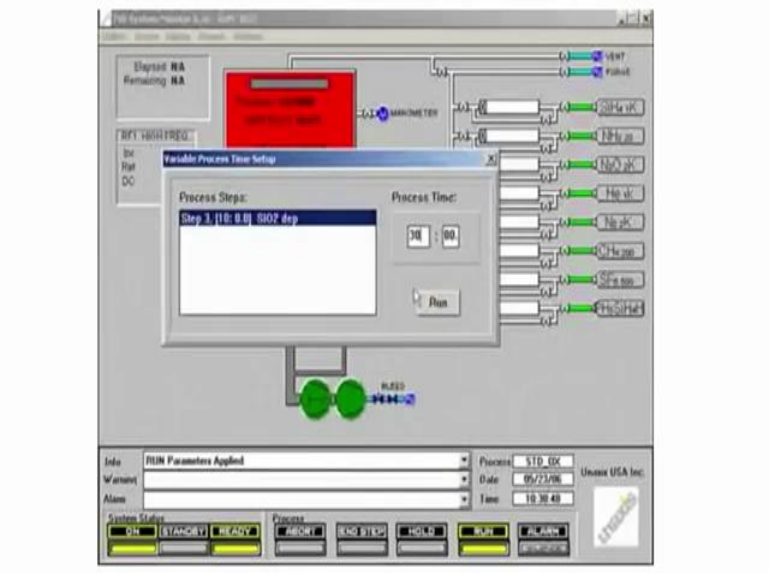

And initiate the process run.

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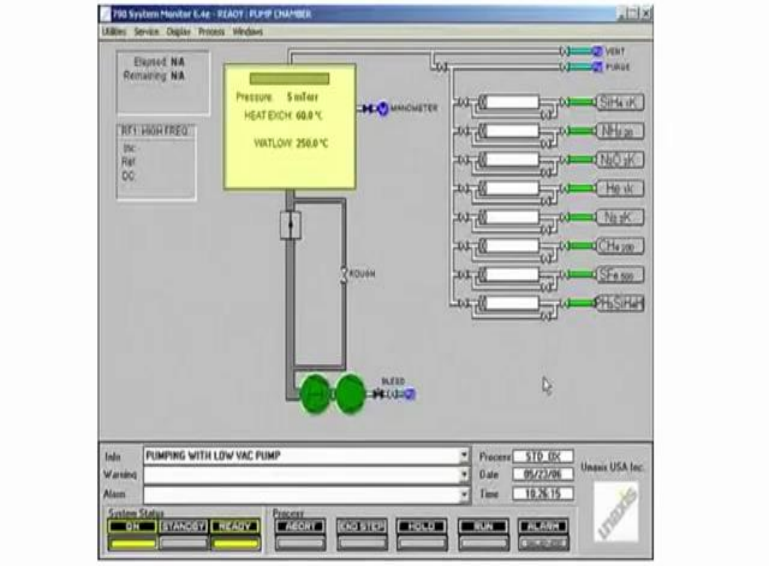

The status window within the software displays the chamber pressure, the heat exchanger temperature and the watt low or plate and temperature. All the available gases are listed on the right side of the screen.

The info warning and the alarm message windows are intended to make users aware of any action being taken by the system or any problems that may be encountered during a process run. All user should be mindful the buttons located the bottom screens and their functions. Unbuttoned should always be highlighted during a process run. If this is not

the case you should notify an MRC staff member immediately, but standby button may be used if you are editing the parameters of a recipe, but it is not essential to a process run.

The ready button should always be highlighted unless the machine is in standby mode, the process will not run unless the system is in ready mode the abort button should not be used in any circumstances the end step button can be used to terminate a step before it is finished; the hold run and alarm buttons will be discussed later in the video.

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The system is also equipped with the emergency shut off button, which should be used only in the event of an emergency. Now, let us introduce to our lab users.

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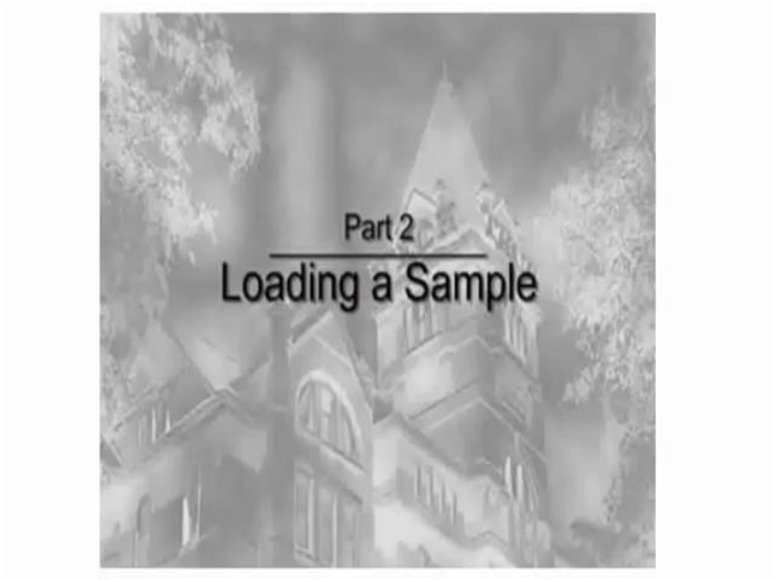

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Before you make using the unaxis PECVD he must first log into the system at the access controller.

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Once you are logged in you should be inventing the process chamber.

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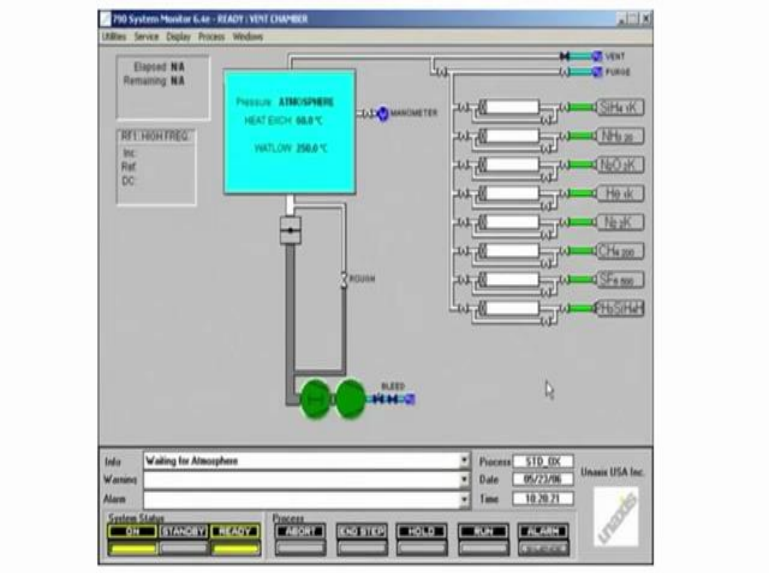

To do this you must first open the utilities drop down menu located at the top left hand corner of the screen and then select the vent from the list of available options, should be able to hear the chamber venting during the bending process. Once the chamber is vented the system will initiate a 60 second over vent step. The gates will close automatically once the over vent step is completed. Even though the chamber may open prior to the completion of the over vent step.

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It is recommended that you keep the chamber closed until the entire step has been completed. Once the chamber is vented you should begin cleaning the chamber.

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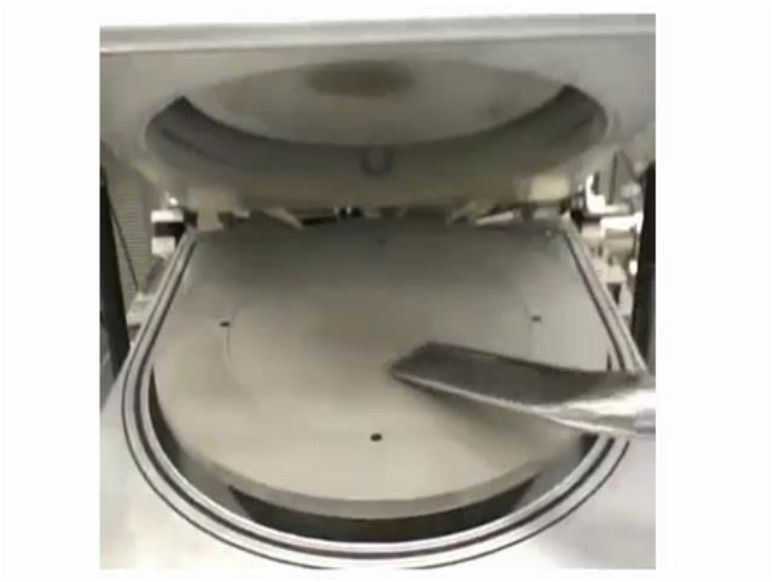

To do so, you must first locate the vacuum which should be located next to the system, there should be a flattened middle attachment connected to the nozzle, which was specifically designed for vacuum in this system; that tightly across the plate as well as under the plate.

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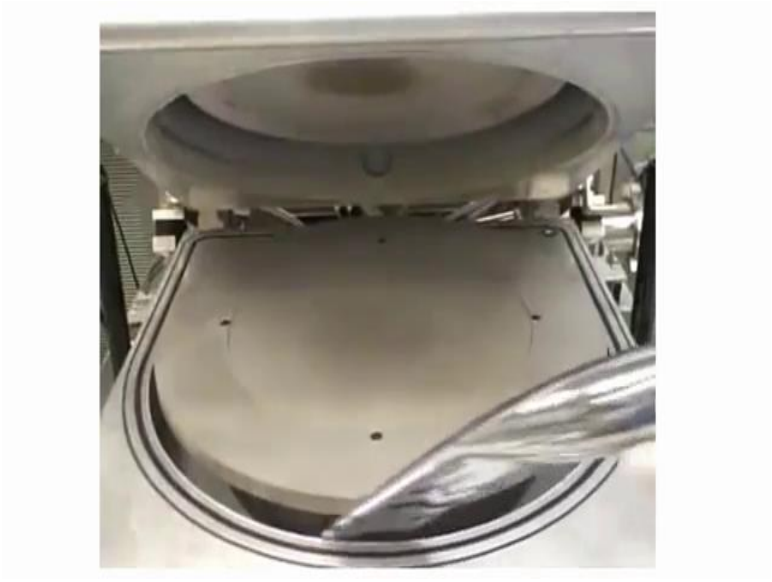

Not vacuum the rubber seal because this could cause it to become damaged.

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Instead wipe the area around the seal with techs way.

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Under no circumstances should you ever touch the shower head. If you happen to notice material flaking on to the plating from the shower head you should notify an emergency staff member. So, can we clean manually?

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Do not leave any text mites or any other item low material that could possibly melt inside the chamber; one heated materials such as plastic are prone to melt and leave behind residue, which could in turn lead to contamination issues inside the chamber therefore, it is imperative that any tools you may wish to use such as tweezers not be made of anything other than metal. You should never use any kind of chemical inside the chamber as well it is possible for them to ignite and or produce dangerous fumes if they are heated.

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Once you have finished cleaning, you may load your sample into the centre of the chamber. Once your sample has been properly positioned, you may close the chamber lid and prepared upon the chamber down.

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Before running the recipe, you must first pump down the chamber.

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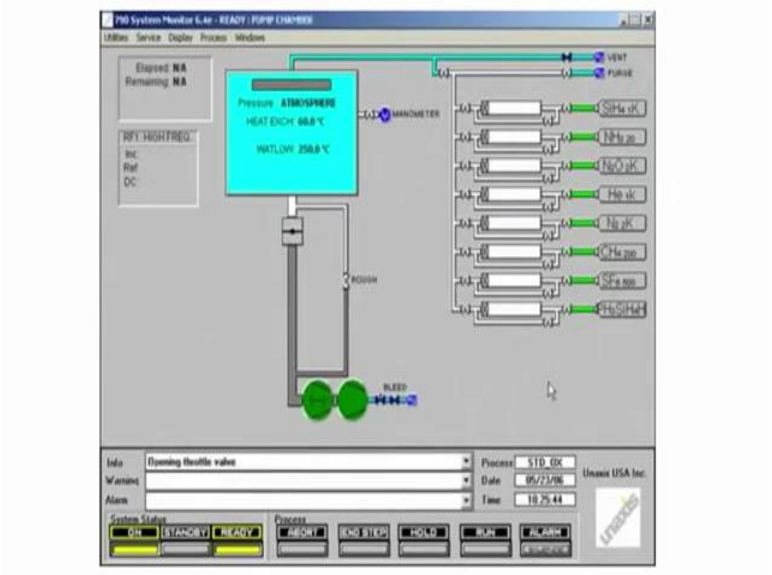

In order to do this you must open the utilities drop down menu and then select pump chamber. Hold the chamber cover down until the rough pumping is complete.

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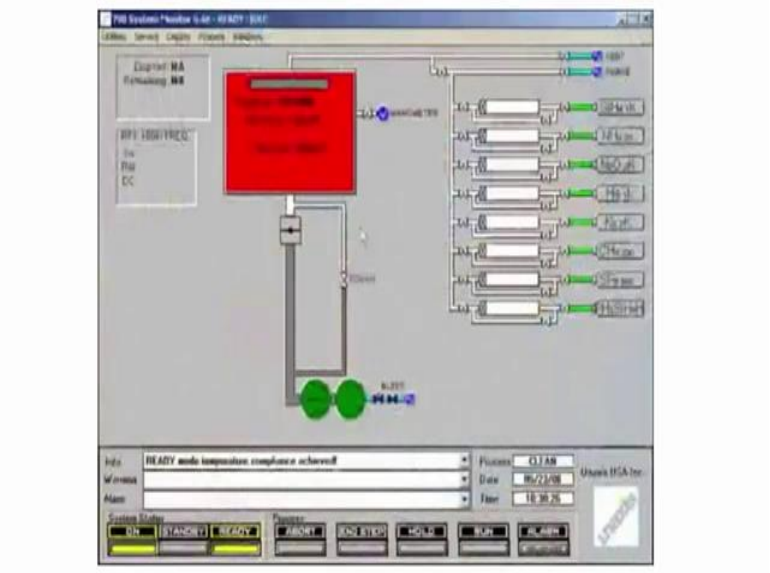

To select and run an existing recipe, you must open the process drop down menu and then select the load recipe.

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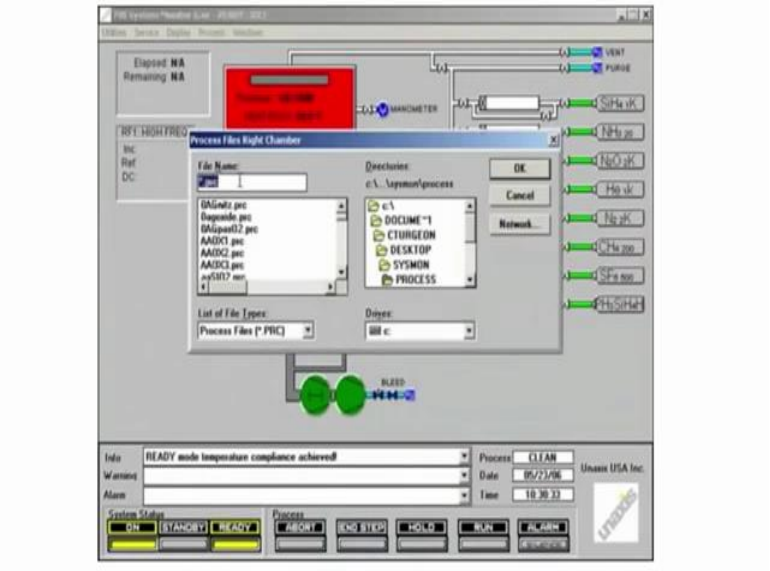

The name of your recipe should appear in the process window. If necessary select the ready button and then select run.

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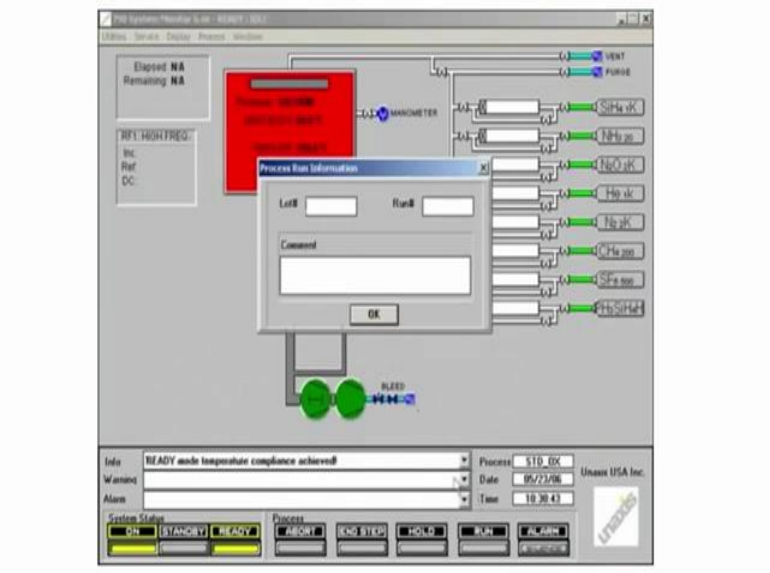

The process will begin once you have selected the run button. Do not try to open the chamber door when a process in running. The chamber is pressurized and will not open attempting to open the chamber could result in the handle being damaged.

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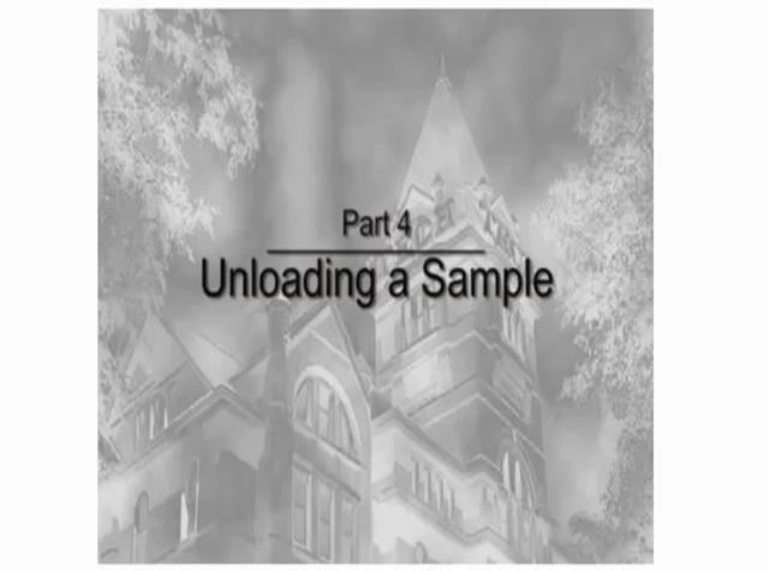

When the process run is completed, open the utilities dropdown menu and then select event.

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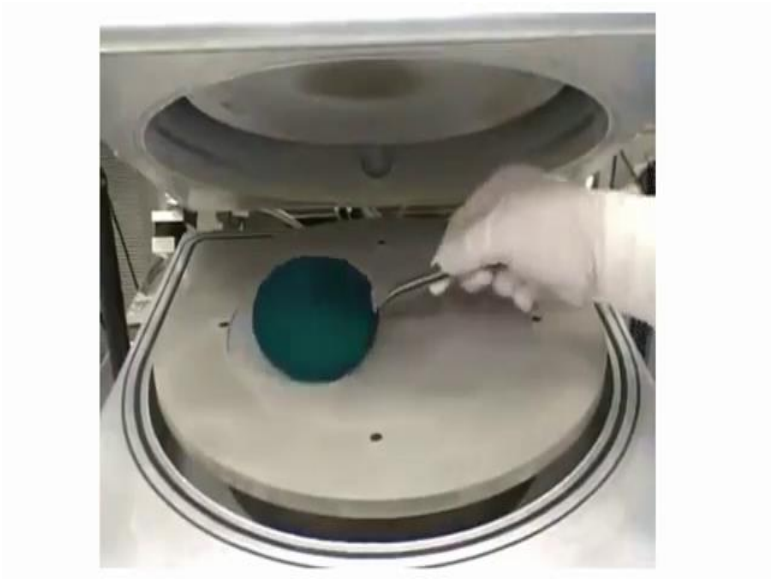

Once the system is vented you may open the chamber and remove your sample. When you have finished using the system, you should perform the same cleaning procedure used earlier in the video in order to keep the chamber clean for future users.

Do not restart the system computer, it can only be restarted by a staff member and will be unavailable for use when it is down.

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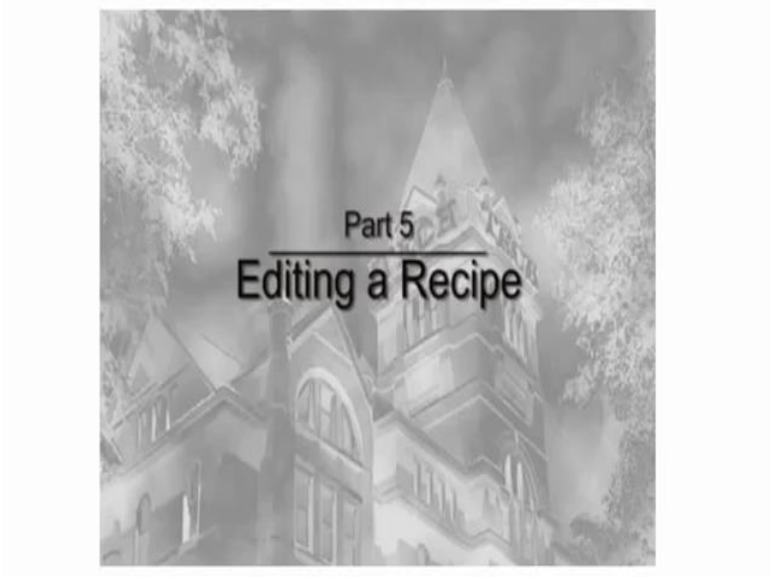

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We will now create a new recipe by editing an existing recipe. In general a recipe should have five basic steps. The initial step the gas stabilization process step, the deposition process step, the nitrogen purge step and the end step. For the purposes of this training video we will be editing the standard oxide recipe.

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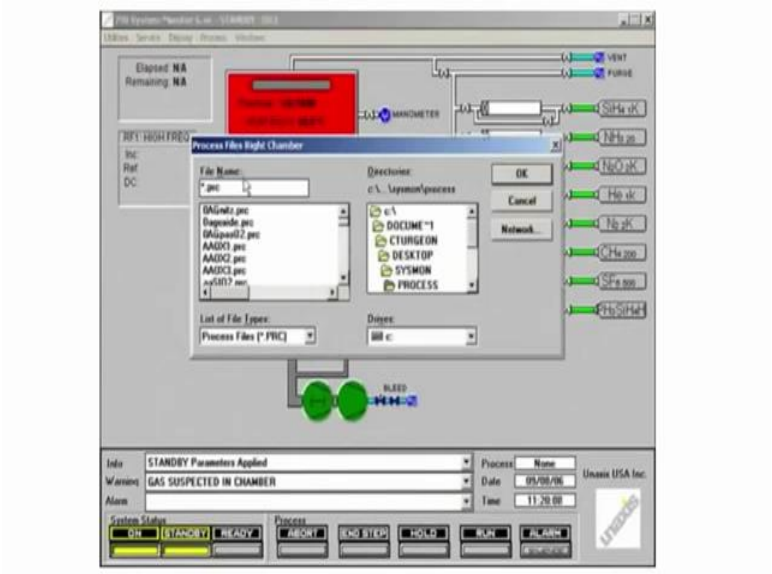

From the process menu you should choose to edit an existing recipe. All of the standard recipe starts with std in the process menu.

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To edit a step double click on it all the recipes start with an initial step this step will cause the chamber to evacuate and bring the plate into the desired operating temperature. So, the pressure to 10 Millipore and the time to 30 milli seconds this will cause the system to evacuate as much air as possible before starting the process. You should not attempt to use pressure set below 10 Millipore. The chamber will still evacuate as much air as possible regardless of the set point at this point you should set the temperature to your desired process temperature.

Note that the temperature is measured in degree Celsius you should set the temperature below hundred and 50 degree Celsius or above 300 degree Celsius without first consulting the trainer. The heat exchanger temperature should also not be adjusted. You may describe your recipe in the description box. The first few words will be displayed by the filename when you are loading your recipe once you have done this click ok.

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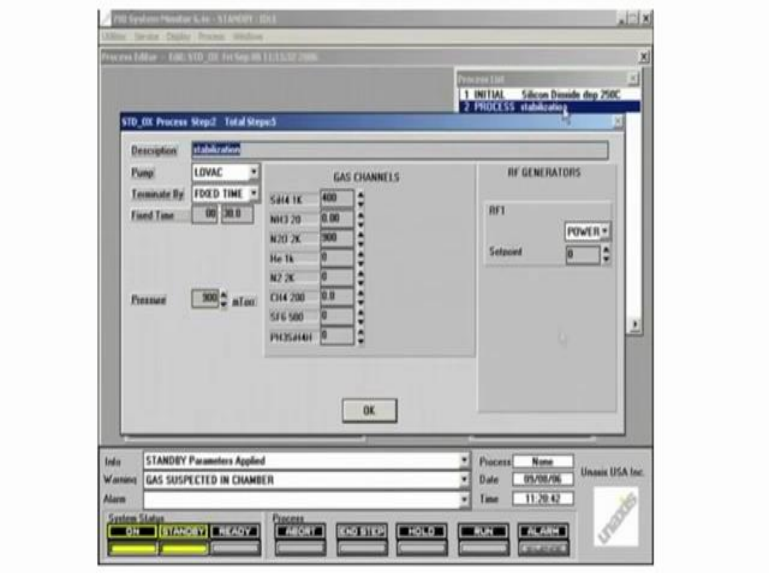

Double click on the first process step, this step stabilizes gas flow rate and sets the process pressure; because the RF power is off no processing will actually take place during this step.

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The process step dialog box has four major areas; time, pressure, gas flow and power. The first process steps terminated by time should be set to fixed time the time is not critical for 30 seconds should be sufficient.

Leave the power set to 0 in the first process step should also set the gas flow rate for each gas here flow rates are given in SCCM. So, that the pressure you want for the process

and the unites for Millipore the system is optimized to run between 900 and 1100 Millipore.

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The second process step is deposition of the material takes place. If you said it is terminated by time to variable time, you will not be prompted to enter the process time each time you run your recipe. This is more convenient than editing your SP each time.

However, you can set the process time to fix time and set the time here if you prefer the pressure and gas flow rates should be the same for both process steps, you should now set the power for the second process step make sure not to exceed 400 watts click once you have done this.

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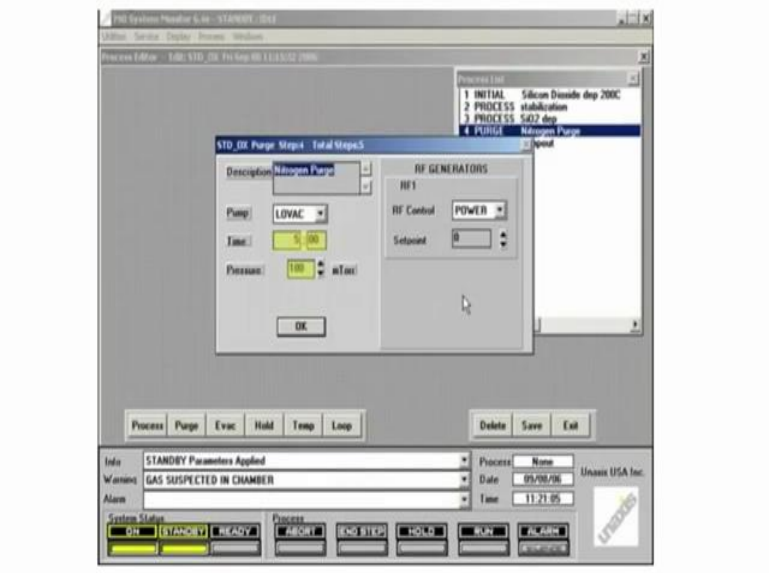

The fourth step is a 5 minute nitrogen purge step at 100 Millipore. This step is necessary to remove any trace amounts of gas which are very toxic even is small quantities; you should not under any circumstances skip the step end it early by clicking the end step button. This is for your own safety and for the safety of other cleanroom users.

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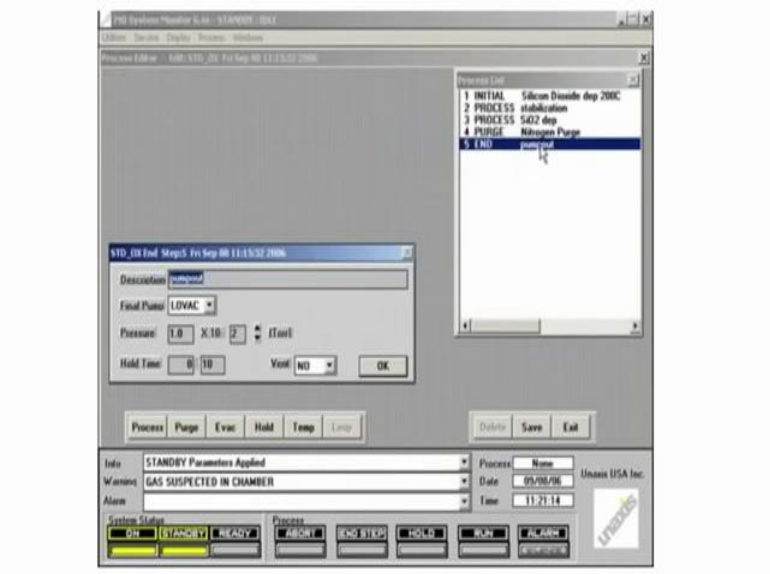

The final end step is one evacuation of the chamber takes place, set the pressure to 10 Millipore like you did in the initial step. So, that all the nitrogen is removed. The automatic vent feature gives you the option of venting automatically after the process is complete or leaving the chamber pumped down until it is manually vented. You may set this to your preference, but the standard recipes should always remain manually vented.

After you are done editing recipe you must save the file when you modify a process you only change the copy on the disk.

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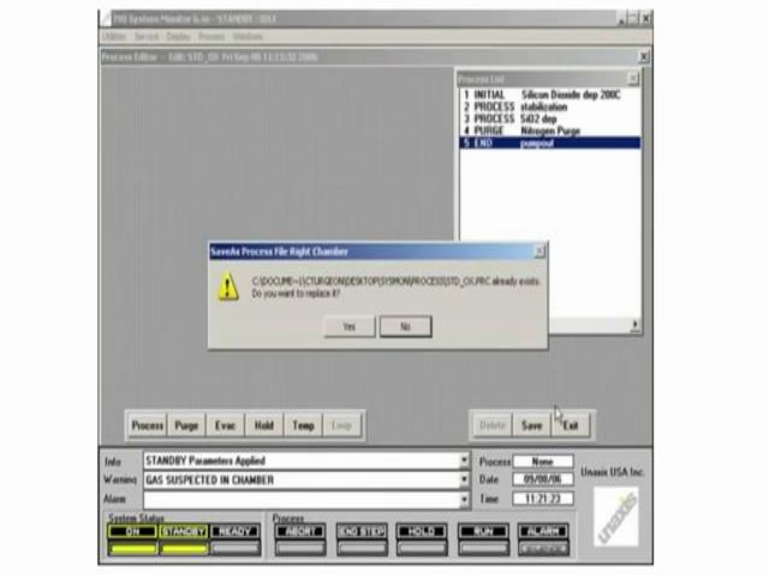

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If the process is already loaded, you will need to reload it for your changes to be reflected. You should name your recipe by the first letter of your first name followed by the first two letters of your last name, followed by an underscore and then abbreviate the name of the material that is being deposited. Now save the recipe.

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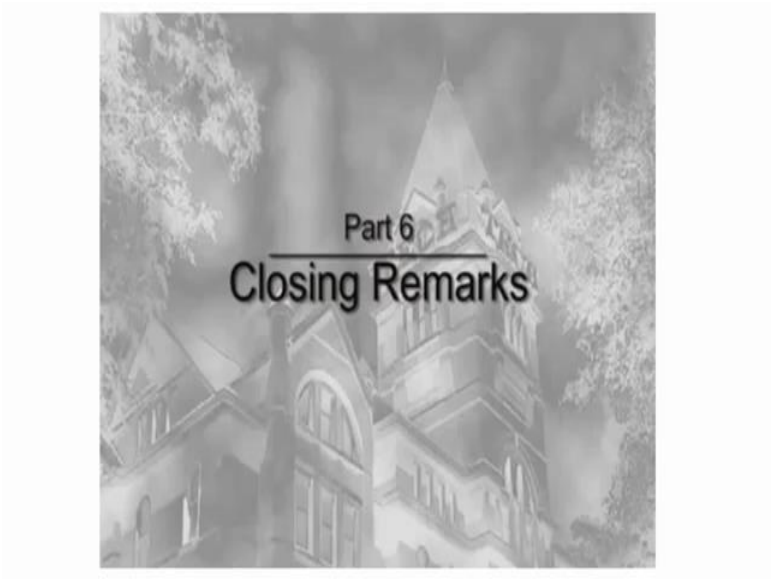

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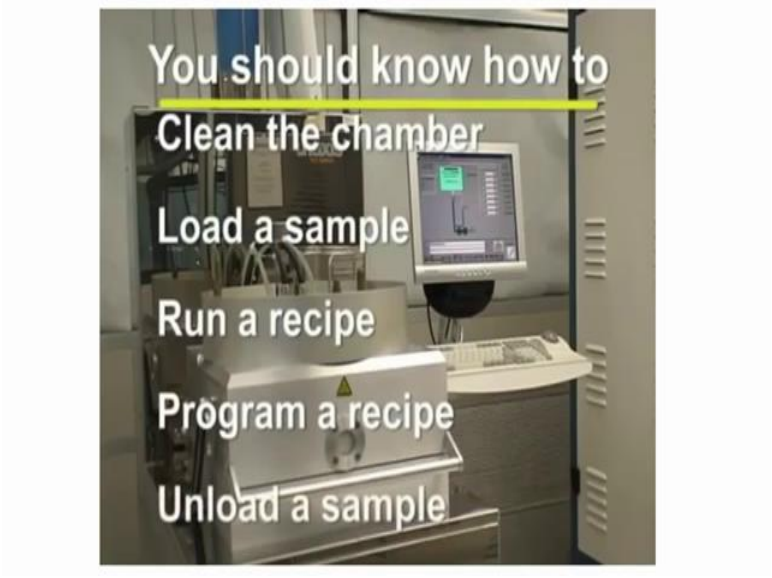

After watching this training video, you should have a pretty good understanding of how to clean the chamber, load a sample run a recipe program, a recipe and unload a sample. If you have any questions please direct them to the trainer of this equipment please do not ask Charlie.

What you see? You have seen in both the videos the first video was on lithography which is more on the spin coating of the photoresist and the second video was focusing on the the PCVD technique right. So, now, let us see each step in detail and what I would prefer is that you you see the screen so, that you have some idea about what we are talking about.

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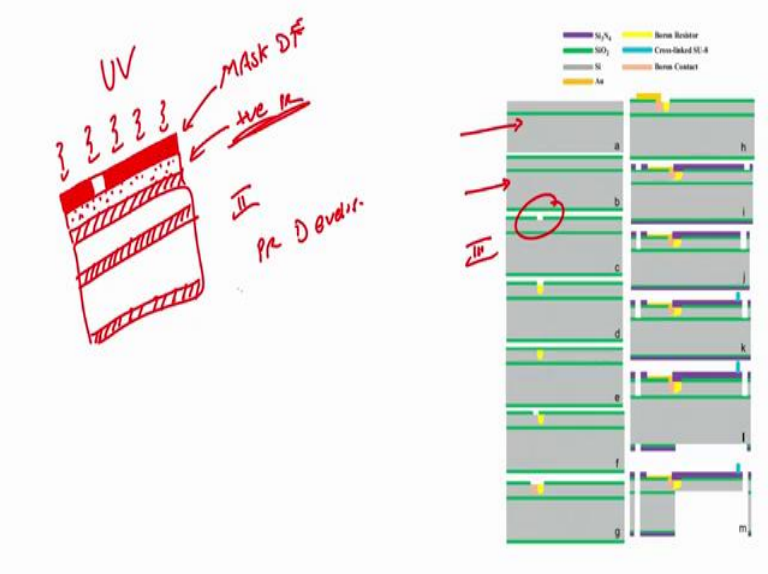

If you see the screen what you see is first step would be your silicon on insulator material next step would be to grow silicon dioxide. So, we do not bother after that if we want to quickly see how lithography can be done, I will just show it to you, here one step so, that you understand other steps by yourself. This is silicon dioxide; silicon dioxide here alright and silicon dioxide on the back side.

So, this is our step number 2 what I am showing is how to reach to step number 3 and how to create this window. So, creating window you spin coat photoresist alright. So, I am spin coating my positive photoresist, next step is you soft bake it at 90 degree centigrade for one minute on hot plate, next step would be you will load the mask; mask such that this will be dark film mask.

You know two types of mask, bright film mask and a dark film mask this will be dark film mask because we have used positive photoresist and the properties of positive photoresist is that, which the area which is not exposed under UV light will be stronger the area which is exposed will be weaker. So, now, this is your positive photoresist, this is a bossy photoresist this is your mask and your mask is dark field mask. After this you will expose your wafer using UV lithography or UV light right and next step would be photoresist developer.

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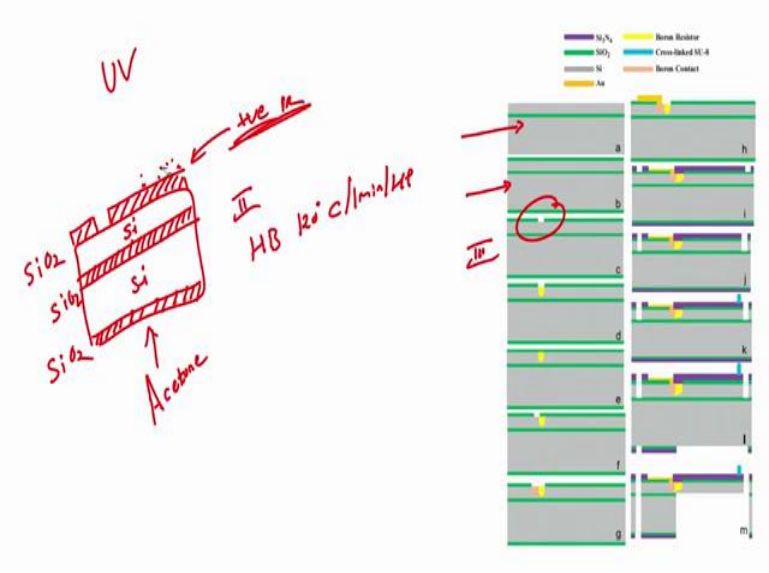

When you develop the wafer in photoresist developer what will happen that, the area which was not exposed would be protected and the area which was exposed in UV will get developed. Next step would be you perform hard bake. Hard bake is done at 120 degree centigrade for 1 minute on hot plate. If you perform hard bake the next step would be it is what is this? Silicon dioxide, then you have silicon, then you have silicon dioxide, then you have a silicon, here again you have silicon dioxide. So, if I did this effort in BHF what will happen? I will leave this wafer in BHF then what will happen?.

We we can etch silicon dioxide from this particular region. So, what I will have is right if I dip this wafer, if I have dipped earlier refer in BHF b h f will add silicon dioxide and other other silicon dioxide will be protected with using the or with the positive photoresist. The next step would be I will dip this wafer in acetone. If I dip this wafer in acetone what will happen? Let photoresist will get stripped.

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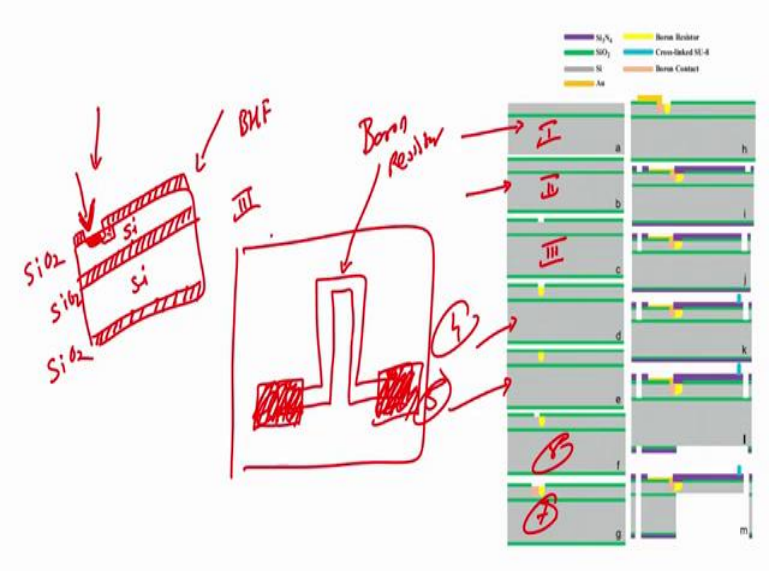

If my photoresist get stripped then what will I have? I will have my step number III you know from step II to step III this is the lithography process you got it easy right? Now step IV same way what is next step step IV is we have to diffuse the boron here step IV right. So, boron is diffused next step is you again grow silicon dioxide. So, silicon dioxide everywhere right. When you diffuse boron what will happen you know when you diffuse boron there will be borosilicate glass. So, some borosilicate glass would be there.

So, you have to dip this wafer in again a BHF . So, when you dip this wafer in BHF what will happen? So, this silicon dioxide and everything will get etched. So, you have to regrow silicon dioxide like this and that is why you can see this particular step this is 4, this is 5. So, this fourth fifth step you can see is silicon dioxide is again grown is not it after diffusing and then you are getting create a window and this time, what you will, where you will create the window? You create a window such that this window would be overlapping a part of the boron diffusion and this is for what? This is this is silicon dioxide.

So, you are creating window for diffusing boron with a higher concentration or so, that the conductivity is high and that is used for the boron contact and this is what you have done in step number 7 right in step 6 you have open the windows and step 7 is you are now created the contact right and this is the contact of the piezo resistor and you create a contact of piezo resistor.

If I see, want to see the top view top view is like this, the silicon is there everywhere silicon is there and earlier what I did is I just created or I just diffused the piezo resistive piezo resistor material like this and this is my boron boron resistor. Then everywhere there was silicon dioxide, I just open window here and window here and again diffuse the boron contact. So, I have boron contact all the way here sorry which will overlap my my piezo resistor.

So, this is what is overlapping this contact that you see on this particular image right this one is this particular part. This is boron contact on the boron resistor see this is the top view. So, you have to just keep on imaging imagining that where are we which step or what will be front view, what will be side view these are all the cross section view that you can look at when we are talking about the process flow; this is called process flow for fabricating the piezoresistive microcantilever.

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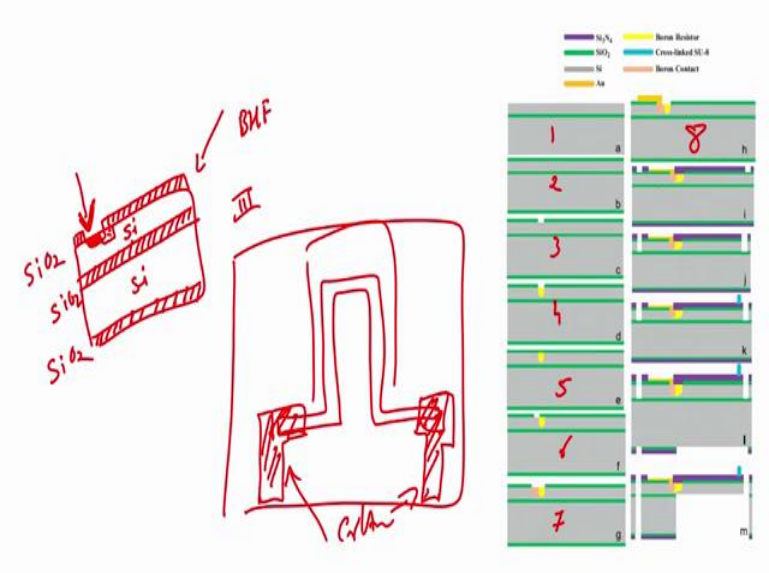

So, first second third step is over, fourth step over, fifth step over, sixth and seventh step is also done after this like I said whenever you have. So, after you diffuse boron contact the next step would be you you deposit chrome gold everywhere right like this and then pattern it such that you can only have contact so, there was the piezo resistor right like this like this.

And this was the contact right. Next step would be you create a further big contact like this right. This will be chrome gold this would be chrome gold alright this is what we are

talking about in step number 8. After that you grow silicon nitride everywhere right and then open window such that you are now starting fabricating your cantilever alright. So, next step step number 9 would be you you deposit silicon nitride and open windows.

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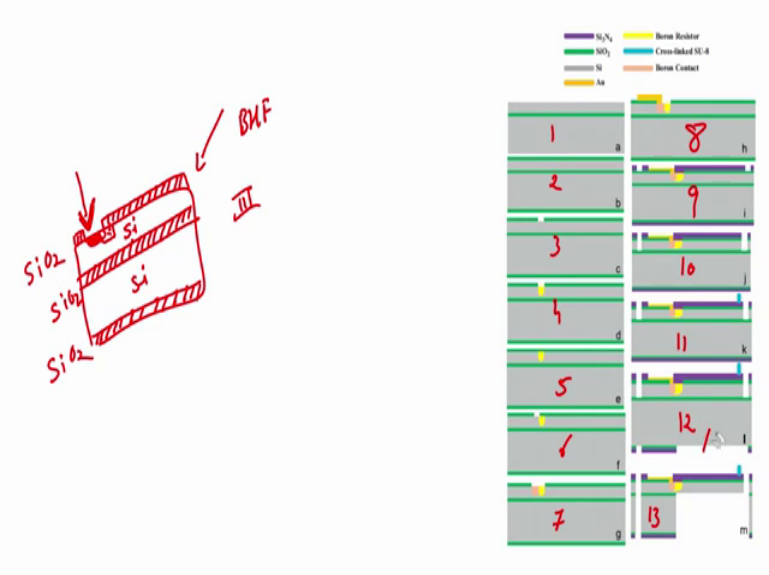

Step number 10 would be that you dip this wafer in silicon first is silicon dioxide HN which is BHF. So, this silicon dioxide will get etch followed by DRI which will etch your silicon and it will not etch silicon dioxide because DRI etch silicon DRI will not affect silicon dioxide as silicon dioxide will act as a mask after that eleventh step would be.

So, after this the eleventh step would be you spin coat SU 8 and then you again do photolithography, such that only this region is protected this is your eleventh step. Step number12 is you create the front to back alignment and etch silicon dioxide from the backside followed by silicon. So, silicon nitride from the backside followed by silicon dioxide. So, first is you can use RI to remove silicon nitride then you can use BHF to to remove silicon dioxide or you can only use the DRI technique.

To remove the silicon dioxide and nitride both after this you can see the silicon is visible and this silicon you can etch with DRI to form your piezo resistor piezo resistor microcantilever with integrated piezo resistor into it ok.

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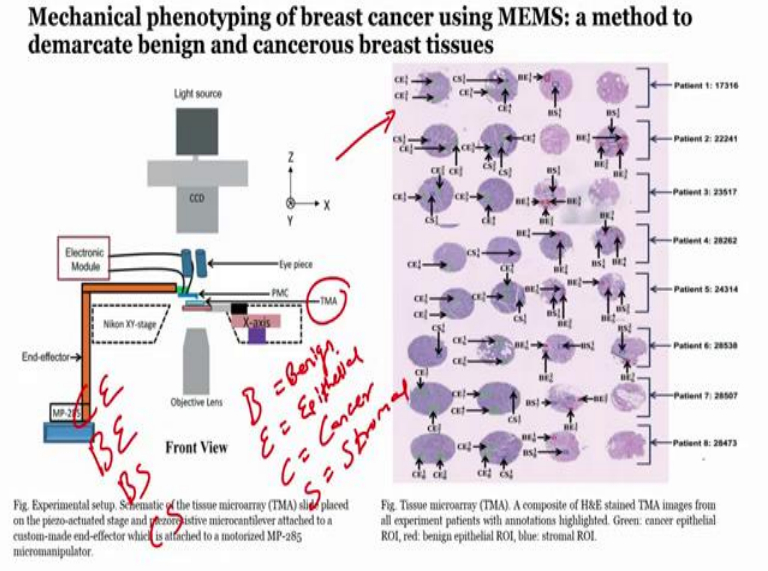

Fig. Experimental setup. Schematic of the tissue microarray (TMA) slide placed on the piezo-actuated stage and piezoresistive microcantilever attached to a custom-made end-effector which is attached to a motorized MP-285 micromanipulator.

Fig. Tissue microarray (TMA). A composite of H&E stained TMA images from all experiment patients with annotations highlighted. Green: cancer epithelial ROI, red: benign epithelial ROI, blue: stromal ROI.

So, once you have that this is inverted microscope and we have loaded the the tissue micro array on to a glass slide and this is the indenter or a piezo resistor micro cantilever which is indenting this particular micro array and these are the corresponding tissue micro array biomarkers, which will help us the green green box is that you can see in each one of this particular tissue are the region of interest BE stands for benign B stands for benign, C stands for cancer, E stands for epithelial region. So, let us say B is benign E is epithelial Epithelial C is cancer S is stromal.

So, now, if I say BE; that means, benign epithelial, CE cancer epithelial, BS benign stromal, CS cancer stromal alright. So, you can see here different nomenclature and this has tissue samples from patients patient 1 to patient 8.

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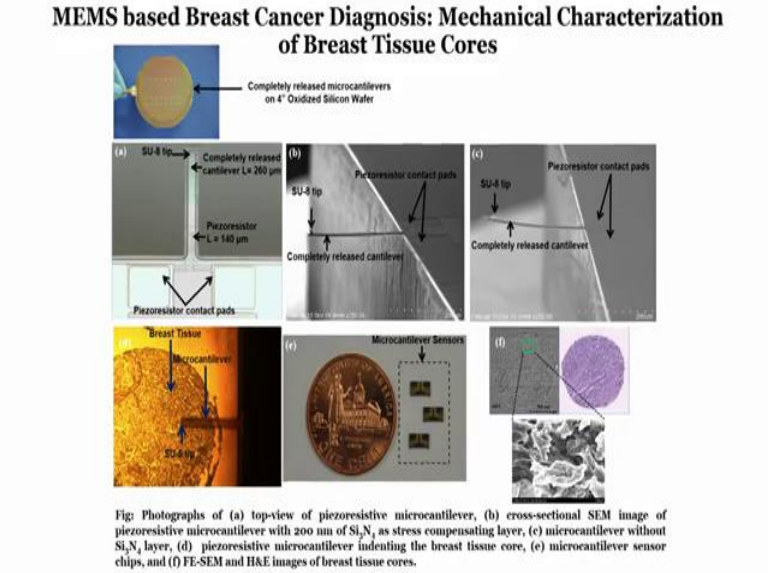

Fig: Photographs of (a) top-view of piezoresistive microcantilever, (b) cross-sectional SEM image of piezoresistive microcantilever with 200 nm of Si_3N_4 as stress compensating layer, (c) microcantilever without Si_3N_4 layer, (d) piezoresistive microcantilever indenting the breast tissue core, (e) microcantilever sensor chips, and (f) FE-SEM and H&E images of breast tissue cores.

And when you indent you can get the different different readings we will see this particular what kind of readings you get in the next class. Till now what you have learnt you have learnt how to how to work in a clean room, then you have learnt what are the clean room protocols, then you have learnt what can be how can be fabricate piezo resistor micro cantilever for understanding the tissue property we took example of a breast cancer, then we have seen the process flow of how to fabricate cantilever.

While working on the process flow I have just shown you two more videos, which were on the PECVD because we will be coating silicon dioxide at lower temperature and another video was for the photoresist, followed by we have seen how can you take the indentation, I can use piezo resistor for indenting the tissues in the next class we will see how can you what kind of data you get when you indent this, as well as we will continue with the electrical sensors for understanding the resistance of the tissue alright.

So, till then you take care, I will see in the next class if you are any question feel free to us in NPTEL forum bye.