Dr. Hardik J. Pandya
Department of Electronic Systems Engineering
Indian Institute of Science, Bengaluru

Lecture – 25
Surface Profilometry and Physical Vapour Deposition Techniques

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Wafer Cleaning and Pre-bake

- Si Wafer Cleaning Methods (Scrubbing)
  - Bubble Jet ($N_2 + H_2O$)
  - High Pressure Rinse
  - Sonication (1.5 MHz)

- Dehydration bake (Prebake) and priming
  - High Temperature baking – to remove moisture after wafer cleaning process
- Priming – to improve photoresist adhesion
  - Hexamethyldisilazane (HMDS)
  - 200 to 250 ^{o}C
  - Time – 60 s

Hi, welcome to this particular module. when we talk about wafer cleaning and pre-baking, silicon wafer cleaning methods or scrubbing are a bubble jet high-pressure range sonication at 1.5 mega Hertz followed by dehydration or pre-bake and primering high-temperature baking to remove moisture as we have discussed earlier after the wafer cleaning process. And then we had to use a primer coating, this primer coating is to improve the adhesion of photoresist and its primer is hexamethyldisilazane which is HMDS in short and the temperature can be 125 and above you some people also use it 200 C to 250^0 C for 1 minute on hot plate this is to improve the adhesion right.

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Photoresist

Polymer

- Solid organic material
- Transfers designed pattern to wafer surface
- Changes photo solubility due to photochemical reaction exposed to UV light.
- Should have,
  - High etch resistance and good adhesion
- Wafer held onto vacuum chuck
- Dispense ~3-5 ml of photoresist
- Slow spin ~ 500 rpm
- Ramp up to ~ 1100 - 5000 rpm
- Photoresist spread by centrifugal force
- Quality measures:
  - Time, thickness, speed, uniformity,
  - particles & defects
- Negative photoresist – SU-8,AR-N 4200, 4300, 4400
- Positive photoresist – AZ-3312, Shipley 1.2L

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Now, photoresist when you come to photoresist, the photoresist is a polymer that is solid organic material and is used to transfer the designed pattern to wafer surface. The change is photo solubility due to the photochemical reaction exposed to the UV light. What should it have? It should have a high resistant and good adhesion these are properties and for this first is that we had to hold wafer onto a vacuum chuck and then dispense 3 to 5 ml of photoresist, then slow spin at 500 rpm followed by a higher rpm or ramp up to from 1100 to 5000 rpm photoresist is spread by centrifugal force we will see as photoresist spin coating schematic in the following slides.

And the quality measures are the thickness, the time, speed, uniformity while particles and defects are something that we need to also understand because the particles and defects will destroy your overall pattern. There are several kinds of positive photoresists as well as negative photoresists which are listed here.

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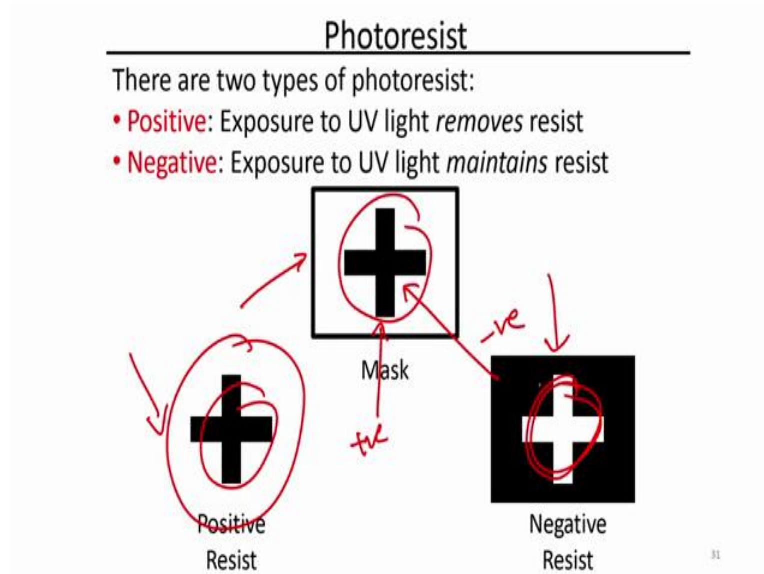

As we discussed earlier the mask. Mask is of two types either is a bright field mask or a dark field mask. If I use a positive photoresist then I can replicate this pattern as you can see here. If I use a negative photoresist, the reverse of this pattern will come which you can see in this case ah.

So, exposure to UV light removes resist, exposure to UV light maintains resist right. You can see very clearly that the photoresist is intact in this case because it is not exposed to UV light this is your positive photoresist when the photoresist is exposed to UV light in case of negative, it will become stronger the unexposed region become weaker. Again I am repeating the unexposed region in the mask in case of positive photoresist will become stronger, while the unexposed region in the mask for negative photoresist will become weaker it's stronger weaker easy.

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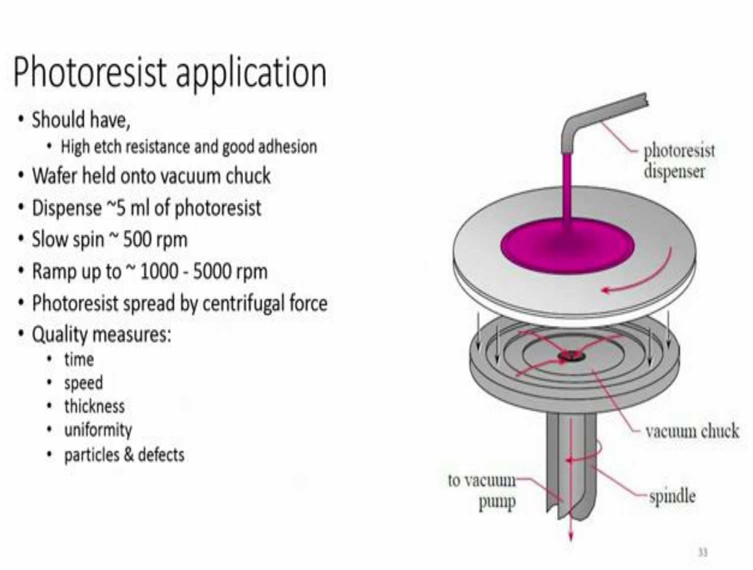

Now, this is the vector this is the schematic of the photoresist dispenser, where you can see that is it is connected to a vacuum pump, there is a spindle for spinning it there is a vacuum chuck. That wafer will not fly and then there is a photoresist dispenser. This wafer is held to the vacuum chuck with the help of vacuum, we can dispense anywhere around 5 ml of photoresist and have uniform spin-spin coating, we can start with 500 rpm which is slow spin followed by 1000 to 5000 rpm which is ramping up and as you understand the centrifugal force will help the photoresist to spread again the quality measures are same which we had discussed earlier.

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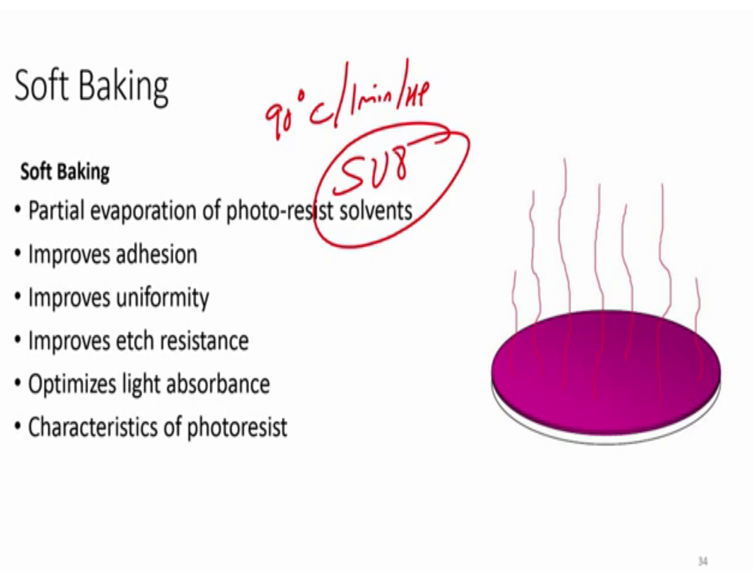

So, why to perform soft baking? Soft baking is already done it 90^0 C right for 1 minute on the hot plate. But depends on what kind of photoresist you use. If you use SU8 this is different and compared to the positive and negative photoresist.

So, by the point of soft baking is. That partial evaporation of photoresist solvents it improves the adhesion, improves uniformity, great etching etch resistance. What is etching resistance in this case? That, if you see this slide.

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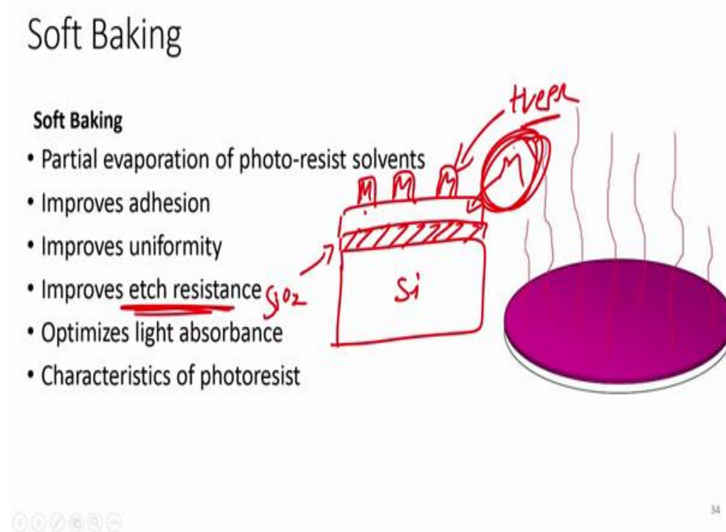

Etch resistance is when if I have a metal right if I have silicon let us say oxidized silicon on this I have a metal on this there is a photoresist that is patterned like this. These are photoresist, this is my metal or material this is silicon dioxide. What is etching resistance? Etch resistance is that, if I dip this wafer in a metal etchant then it will affect photoresist, but it should not affect that great that the metal below it will get etched.

So, it is resistant to the etching material right there is your etch resistance. Also, soft baking will improve the light absorbance or optimizes the light absorbance and finally, the characteristic of photoresist should be that it should be particle-free and defect-free.

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Now let me play two videos for you that you understand how to spin coater photoresist. Let me play the first video.

Hello and welcome to this training on our lab spin, 2 and 3 the manual spin coaters. Today we will be talking about the spin coater itself the hot plates different types of bowl sets, how to do the spin coating and the cleaning afterward.

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In the bowl sets we have a bowl, we have a splash ring, and then we have different sizes of chucks 6 inch 4 inch 3 inch, then we have small chucks for bits in pieces normally we

have a 20 millimeter and 12 millimeters. In a special holder in the chemical cupboard, we have a box looking like this it contains normally 2 or 3 chucks.

We have an etch handling chuck that is only handling on the etch of the wafer, this one can maximum be spun at 3000 rounds per minute, then we have a two-inch where the pins have been removed just to give a large area for large substrates. And there should be a second chuck which is even smaller that is only like 5 by 5 millimeters into the bowl sets and these different drawers down here, we have the bowl set itself. When we take it out, we need to use nitrile gloves clean nitrile gloves we open the sash and put it inside the few more before we open it.

When we handle things on the outside it is nitrile gloves, the same on the sash and on the panel pot and on the spinners, but as soon as we handle the bubble set itself we need to have 4 etch gloves or pair (Refer Time: 07:26) gloves.

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https://www.youtube.com/watch?v= neUkDsQhsM

We have different bowl sets that are depending on which chemical to using. If you like today use UV resists which is the solvent PGMEA and cleaning solvent as its own then you take this bowl set it is important not to mix up bowl sets with different chemicals.

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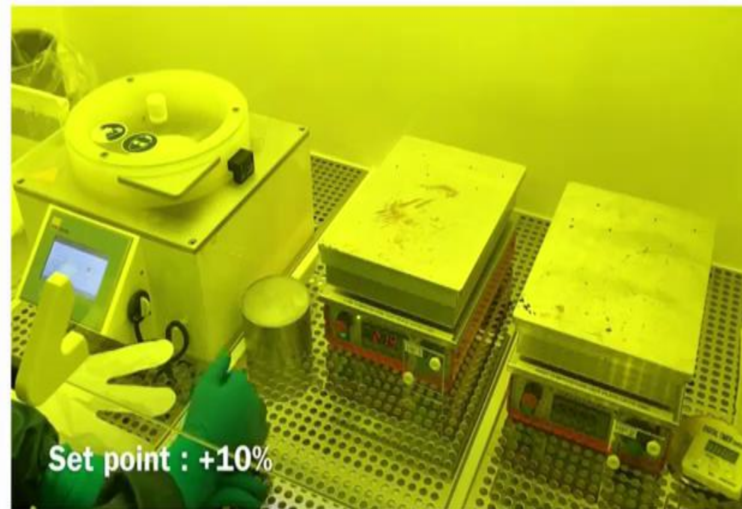

Before we start the processing it's a good idea to turn on the hot plates on the green button here, you will turn on then we have to put a set point. We have an aluminum cover plate that is changing the temperature by 10 percent. Hold them set and then change the value that you need.

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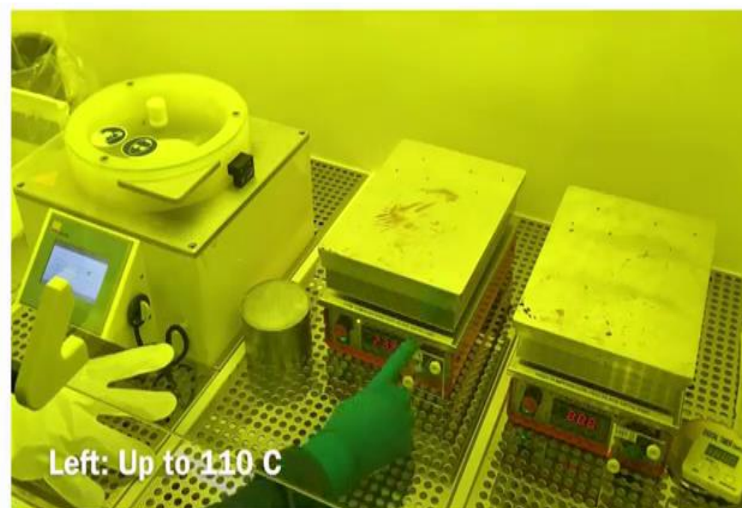

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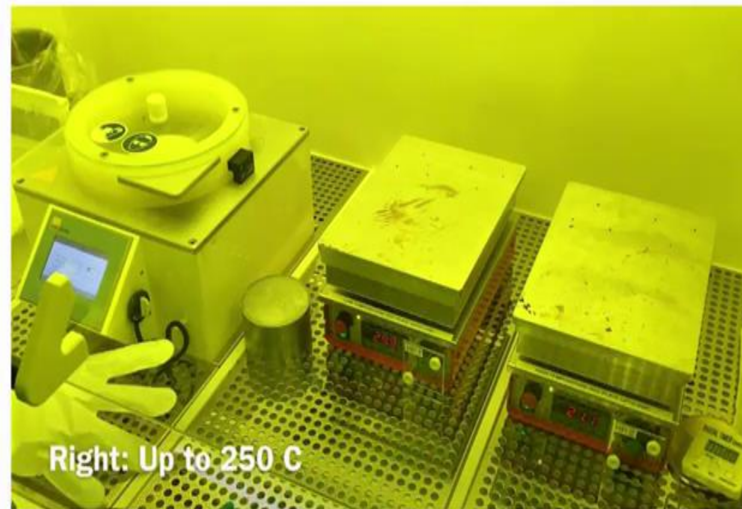

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So, for 90^0, I would go to 99^0. We have two different hot plates we have one that goes to 110^0 and one that goes to 250^0, when handling the bowl set we always use nitrile gloves on the outside, take off the lid always have the sash at chest height.

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So, not make things fumes come out into everybody. Then we take the inlay set the bowl here the nozzle goes into the hole down here in front, the splash ring the protruding side goes downwards make sure that it fits correctly.

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And then a chuck here has a small recess and we also have a small pin down here. Make sure that the pin is correctly adjusted and then place the chuck underneath and when you then push down make sure that the chuck goes all the way down.

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So, it is faster on the spindle. Whenever you have to take the chucks and the bowl set please take the box and put it back into the drawer. That you have (Refer Time: 09:15) every time you handle it to make sure that the lid is on and have the component open the box inside sash. Now, we are going to do the processing. I will talk about the spin coater

and how to set up recipes and quick start when we need to do processing I would always make a small workspace two pieces of paper put on your resist.

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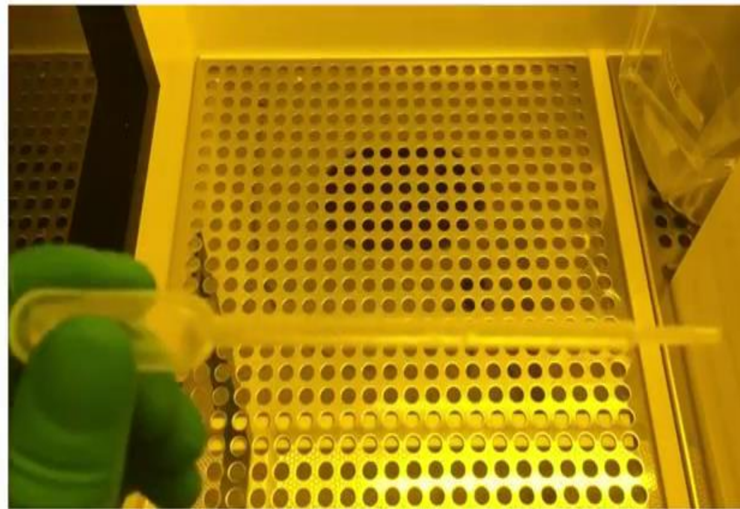

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And other disposable pipettes or this disposable plastic bottle never use the glass bottles because then you can terminate them. We will open the spin coater, take a substrate and place on the chuck make sure to use the cantering pins.

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So, that the chucks levelled close the lid.

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Go to a quick start and start a random process, this will show us that the vacuum is on and the time starting, the wafer is rotating and we are just checking that the vacuum level is.

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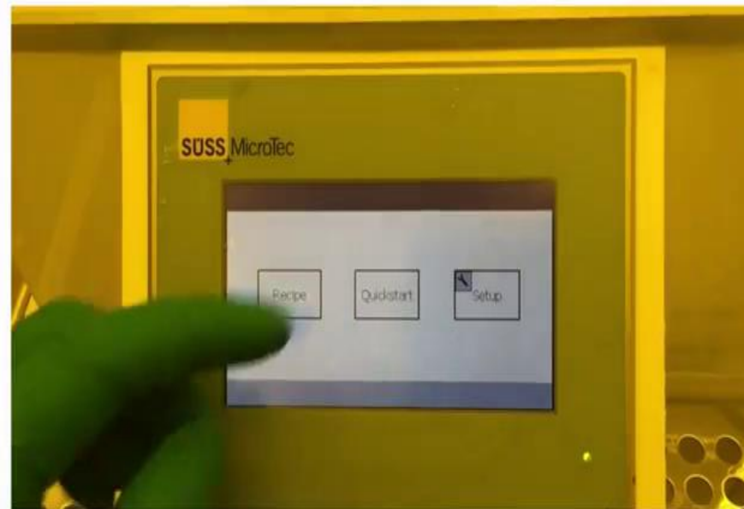

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https://www.youtube.com/watch?v= neUkDsQhsM

The touchscreen itself, there are two things to be aware of the quick start which we just used, here you can select the time that you need to spin code. 60 seconds for example,

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You can select the speed which gives you the thickness this case 4000 and the acceleration normally between 500 and 1000, but it's depending on your process. When you click start you can also do processing and of course, we need to dispense first. We could also use a recipe if we need to make more than one step, we go to recipes go to the bottom find an available slot, you could also use to pin when you click an available one you can give it a name let us call it a test.

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https://www.youtube.com/watch?v= neUkDsQhsM

And if you click the number out here and edit then you can change the actual parameters. Here we will start with a small spreading. Let us say 30 seconds at various small speeds, just to disperse the resists and a standard acceleration. Then the next step would be the actual thinning of the resist, the spin-off and of course, to acceleration. If you start this process it will go through step one through and how many steps you have made, it is up to you if you do a recipe or a quick start it gives you the same results.

When we are starting a process, open the lid, first I will show you how to pour from a plastic bottle. You have to resist the proper markings pour on a little bit in the centre try to make a uniform circle, close the lids and press start on quick start. When we are a spin coating on a smaller substrate, we have chucks of different sizes.

So, select the right chuck for the job, again find recess and the spindle. When working with a chip we take a chuck of the right size place the chip in the center, close the lid and start the quick process quick start just. We check that the vacuum is this is important because if the chip is misaligned, then we will have a resist. A chip that is very hard to control.

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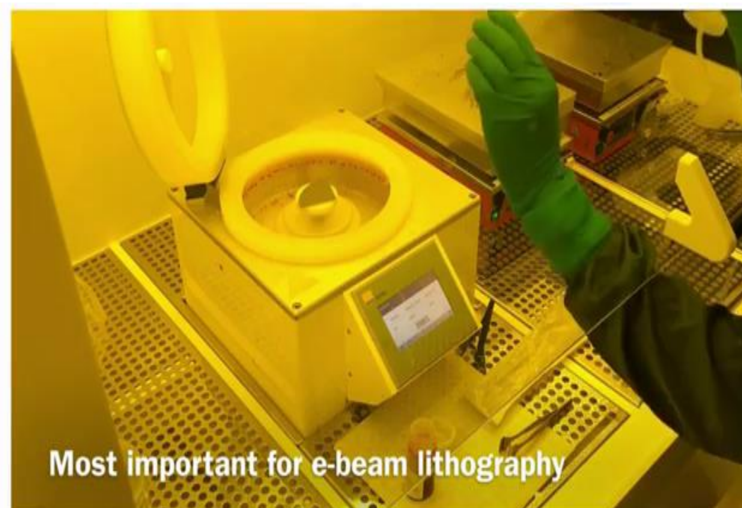

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When you are working with disposable pipettes always clean them with nitrogen to remove excess particles. If it’s an EPM process I would recommend using 20 seconds of nitrogen air, when taking resist from a bottle using the disposable pipette.

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Never touch the bottom of the sides, the pipette goes in the middle just below the surface and you start up the amount that you need. On a chip, I would always recommend filling the entire chip to make the first 2 or 3 drops go in the bowl set fill the entire chip as much as possible.

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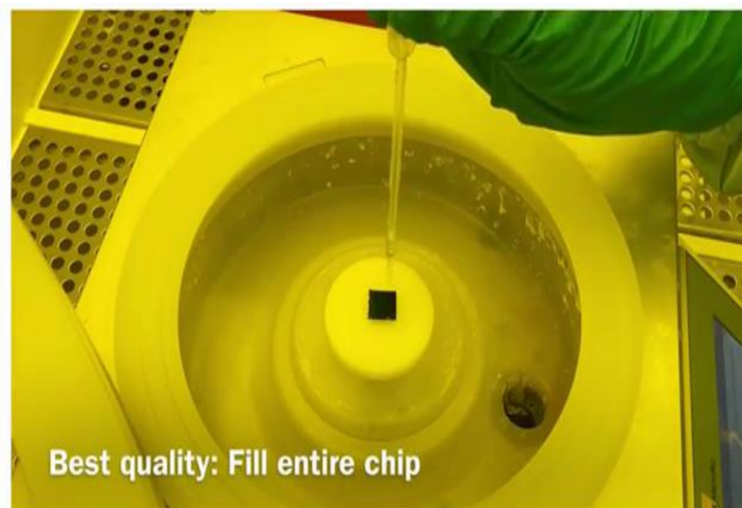

Sometimes you may need to take several times in the bottom, make sure that you have a couple of drops or maybe even half a millilitre left, close the lid and start the process. When the spin coating is complete, we open the lid to take off our sample and put it on

the hot plate and start the timer. When the process is done and the timer stops, we take the sample to the etch and pull it off onto this cooling block. Just a few seconds until its cold when the process is complete and we need to clean, open the sash into the clean fume hood. Remember to open the fume hood that you can transfer your inlay set. Now it is soaked with chemicals. Always wear two (Refer Time: 14:59) gloves or barrier gloves.

When disassembling the inlay sets, first take off the chuck pull straight up here makes sure you have a tissue ready here. It will not spill on the way when you transform your bowl set paths over to the other few (Refer Time: 15:22). If there is a lot of resists in the bowl set before removing that one it's a good idea to take a tissue, wipe it off just like this just. We do not have as much liquid resist discard. This one in the solid C waste removes the splash wing and the same way make sure that you do not drip on the way and at the end remove the bowl set here it's important to have a piece of tissue underneath the nozzle. That we do not represent all over hot plates.

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Always remember to turn off the hot plate when you are done. When we are again cleaning we are working with dangerous chemicals. Put on apron facials and (Refer Time: 16:14) gloves or barrier gloves. It's a good idea to take up the poles or the box that you need for the bowl set in advance, open it with your nitrile gloves. Then you could displace your stuff immediately.

Take, for example, the bowl set or the chuck does matter and clean it probably with the cleaning agent. In this case, it's an acetone paste. read on the bowl set which cleaning agent you are using and take the solvent put it on a napkin like this make sure if there are some drops place the napkins make a workspace for yourself in advance with clean napkins and then wipe everything the bowl, the inlay the splash ring all the chucks inside-outside nozzles everywhere. The longer you wait before, you clean the more fixated the cist will come and therefore, you may need to use a little bit of time on the cleaning.

Remember to also clean the inside of the nozzle from the front and the backside. There is no cist residue is left. When you are done with one path just put it directly up into the bowl on the box and then continues with the next. Sometimes the resist is sticking very well on the surface, just make sure to apply plenty of solvents and give it a good mechanical scrub. When cleaning the chucks make sure that you take the top the sides or the backside and also the recess because if any resist gets in here, it acts as glue and then we cannot get the chuck off.

When we have cleaned the chucks, we need to clean the actual spin coater. Remember to open the sash before you start also have the door open here. You can use a solvent in this fume hood and not on the wet bench. Put a piece or the amount of solvent on the tissue that you want to use. Here wipe the entire spindle also the small pin and the inside of the lid never the I outside put (Refer Time: 18:42) transparent part and the white parts.

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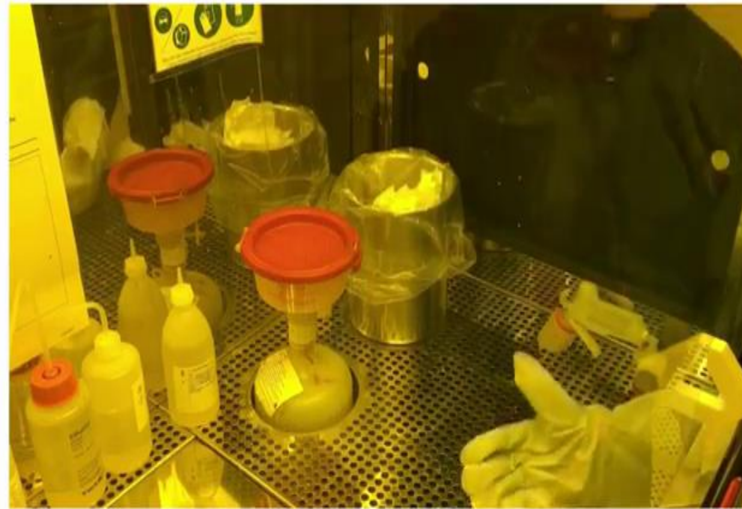

https://www.youtube.com/watch?v= neUkDsQhsM

Dispose of all tissues in solid C waste. When you are done with the cleaning you can take off your apron and your facial, you the forged gloves should always be turned inside out like this. Remember to always empty the c waste when you have when it’s a lot full or if you use dangerous chemicals.

Always inside the fume hood a proper knot. No smells escape grab a new C waste pack and prepare the bin for the next user. When you are done with the cleaning remember to logout out of Laplander and fill in the logbo So you have seen the first video and I let me play the second video which is on Laurel WS 650 HZ spin coater the number is 61002 let us see that video and then we will continue.

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This is the Laurell WS 650 HZ spin coat it has a maximum rotational speed of 12000 rpm. The control allows the operator in an action in real-time during the process execution including (Refer Time: 20:02) time staffing and continuing on from that point. The close bowl design allows most coating materials to dry in a quiescent state increasing uniformity and minimizing particle contamination.

This convenient tabletop unit is powered by 120 volts ac single phase it also requires a vacuum to be at least 15 inches mercury or more. First I like to give a demonstration of the speeds for that, I am going to use it as a low timing strip. First, this is the compact control panel completely self-contained I am going to call up a program here program for and what will first do is we will change the spin speed to let us say 4000 rpm, there we go and then we will first we will apply vacuum, tells us that we were ready.

When it's done in order to go on and run another program or any other process, we must open the way. This singles it that it’s ready for another one, but I am doing this one here is out (Refer Time: 22:48) that to let us say 8000 rpm and you repeat. Open it pull down it always sits down and after you lower the lid as long as we are vacuum is satisfied and your nitrogen purge you know tell you that is well could you one more spin and we will do this at the maximum rpm of 12000 and on on and done.

Next, we are going to spin a small vapour for it has this very nice little adapter here that you can fit right on top with the standard chuck. Once we apply a vacuum and one spin wants to go for maximum speed.

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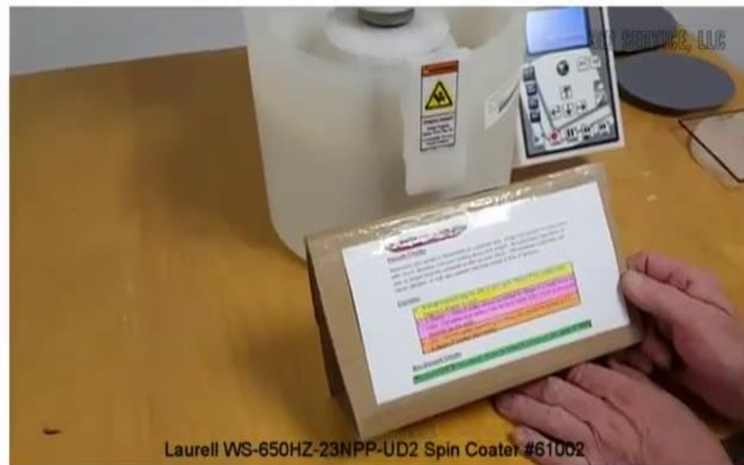

Laurell WS-650HZ-23NPP/UD2 Spin Coater #61002
https://www.youtube.com/watch?v=gjucsT37rCQ

Now, next I have this chart here and this is wafer size versus spin speed. Obviously, the smaller the work piece the faster you can spin and then given little guideline here, first we ran this little guy up to 12000. Now, we are going to run a 100-millimeter wafer as suggested up to 6000 distracting on 50 we use some here my vacuum and we have also added them speed down to 6000 rpm and from the and then the run turn off the vacuum removes a wafer.

Now, the spin coater has the capability for actually being a spin a full 200 millimetre or 8-inch wafer; however, it is noted that in order to do you would have to remove the chuck and take off this plastic splash guard if that just is not enough from the hole. But actually has the capability to spin an 8-inch wafer.

However, what is important also in check over the unit is there has the capability of spinning a full 5 inch by the 5-inch square substrate. I have a piece of glass here, but I can use to demonstrate the center at respectively and even though it's about approximately 7 and a half inches across here if you look through the top it still comfortably fits in between the splash here.

Now, I am going to spin this one since this is closer to the very larger size which they recommend between 2 and a half and 3.5 k rpm. I am going to spin this at 3500 and here we go vacuum first there we go ready lights on start (Refer Time: 29:49). Now, you have it very versatile very compact lightweight fits in anywhere and very easily.

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Now, since you have seen the video which is of spin coating the next step would be exposed.

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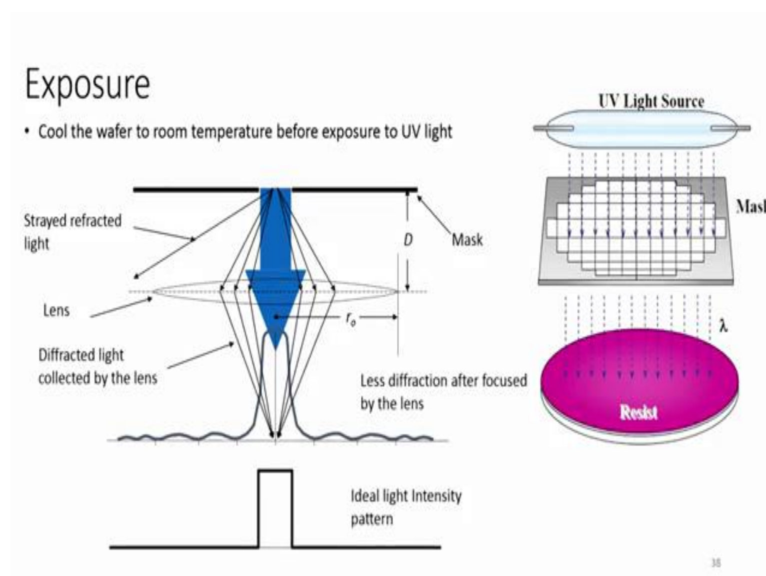

So, the exposure would be that you have the reflected light and then there is a lens right this distance is measured in terms of D. from the mask to the lens what should be the distance between two is calculated using optical physics. We are not going into detail about this particular technique. However, this is just like a lens is there if it will light is corrected by the lens and the ideal light pattern should be as shown here, but the actual pattern is what we get is as shown here right.

So, you have a light source you have mask bright field or dark field and you have power positive or negative photoresist coated on the substrate. The less deflection after focused by the lens. The lens will help to ah you know not to allow the deflection to be you know the larger area.

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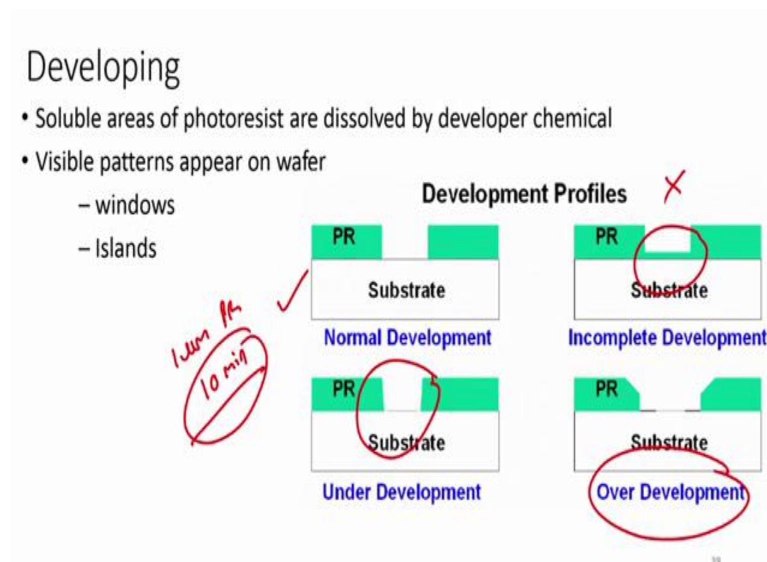

And now if we want to talk about developing, then developing you can see here if you are concentrating on your time of the developer right then you will get the normal development as you can see in this case. However, if the time is less there is a developer time for developing 1 micron of photoresist is 10 minutes right and if you take out the wafer before 10 minutes, then there can be incomplete development. However, if you also it can also result in an under development, while if you keep it for greater than 10 minutes what will happen that there will be over development.

So, all three cases in complete development, over development and underdevelopment are not accepted, the recipe should bake for 10 minutes and you should just take out the

substrate in 10 minutes. The rest along the process flow recipe is extremely important right.

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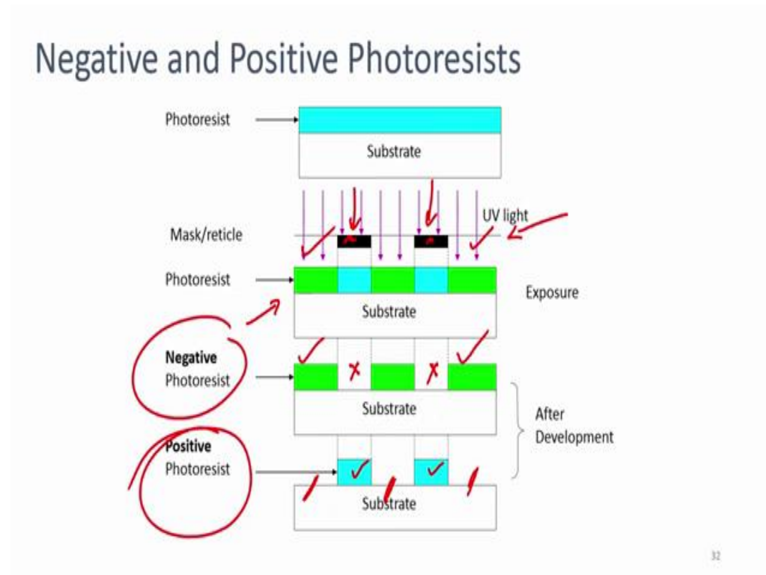

So, this is one thing about negative and positive photoresist like I said, the if you talk about this as a mask and you see this is photoresist, then if we in case of positive photoresist let us talk about first positive the unexposed region is stronger than unexposed region is black region this one and this one you can see it is stronger in this case while the exposed region is weaker we can see here in this case correct. When the case of negative photoresist the unexposed region which is this one and this one will be weaker which is here and the exposed region which is these two becomes stronger.

So, the exposure region will become stronger and unexposed region becomes weaker in the case of negative photoresist, the exposure region becomes weaker and the unexposed region becomes stronger in the case of positive photoresist after photoresist development. If you remember these formulas or this what you call tricks, then it becomes very easy it is not really a formula, but it's a trick to remember.