Sensors and Actuators
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Lecture – 38
Photolithography - Part 2

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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 °C
  - Time – 60 s

Hi, welcome to this particular module. So, when we talk about wafer cleaning and pre-baking, silicon wafer cleaning methods are scrubbing, air bubble jet, high pressure rinse, sonication at 1.5 megahertz followed by dehydration or prebake and priming, high temperature baking to remove moisture. As we have discussed earlier, after the wafer cleaning process and then the we had to use a primer coating. This primer coating is to improve the adhesion of photoresist and this primer is hexamethyldisilazane which is HMDS, in short, and the temperature can be 125 and above, you, some people also use it 200 degree centigrade to 250 degree centigrade 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. So, photoresist is a polymer which is solid organic material and is used to transfer the designed pattern to wafer surface. The changes, its changes is photo solubility due to photochemical reaction exposed to the UV light. So, what should it have? It should have a high resistant and good adhesion; these are properties, ok.

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 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 kind of positive photoresist as well as negative photoresist which are listed here.

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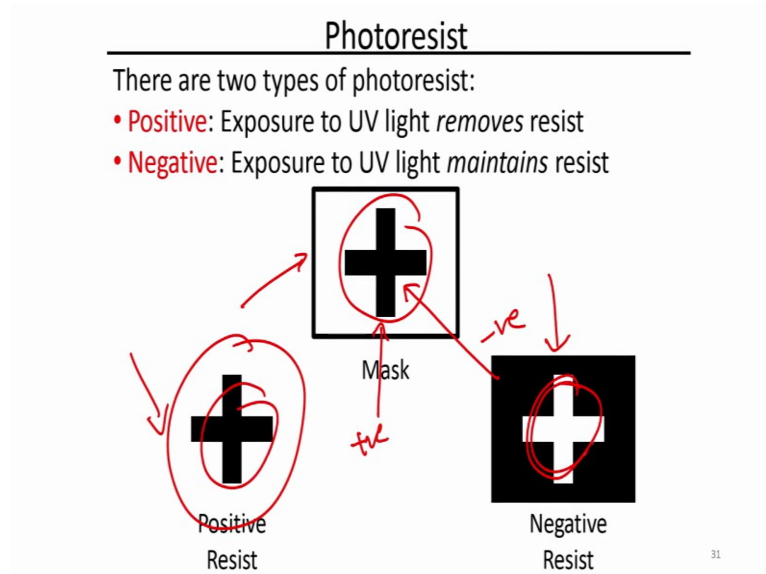

As we discussed earlier, the mask; mask are of two types, either it is bright field mask or a dark field mask, if I use a positive photoresist then I can replicate this pattern as you can see here. If I use a negative photoresist, the reverse of this pattern will come which you can see in this case. So, exposure to UV light remove 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 is stronger, weaker; easy.

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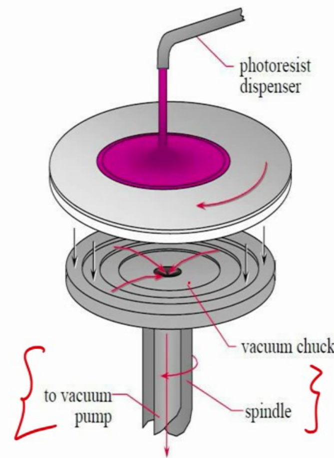

Now, this is the this is the schematic of the photoresist dispenser, where you can see there is it is connected to a vacuum pump, there is a spindle for spinning it, there is a vacuum chuck, so that wafer will not fly and then there is a photoresist dispenser. This wafer is hold to the vacuum chuck with the help of vacuum. We can dispense anywhere around 5 ml of photoresist, and to have uniform 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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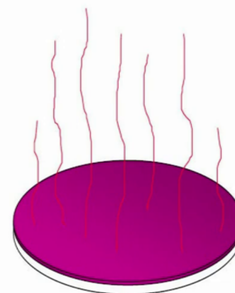

So, why to perform soft baking? Soft baking is generally done it 90 degree centigrade, right for 1 minute on hot plate but depends on what kind of photoresist you use. If you use SU8, this is the different thing compare to positive and negative photoresist. So, but the point of soft baking is, so that partially evaporation of photoresist solvents, it improves the adhesion, improves uniformity, improves etch wretching, etch resistance. What is etch resistance in this case?

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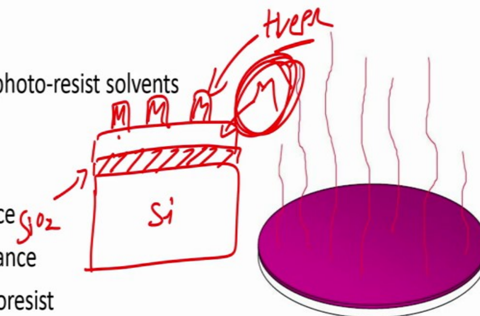
Soft Baking

Soft Baking

- Partial evaporation of photo-resist solvents
- Improves adhesion
- Improves uniformity
- Improves etch resistance
- Optimizes light absorbance
- Characteristics of photoresist



That if you, if you see this slide etch resistance is when, if I have a metal, right. If I have silicon that is the oxidized silicon, on this I have a metal, on this there is a photoresist which is patterned like this, ok. So, these are photoresist, this is my metal or material, this is silicon dioxide.

What is etch 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 greatly that the metal below it will get etched. So, it is resistant to the etching material, right, that is your etch resistance. Also, soft baking will improve the light absorbance or optimizes the light absorbance, and finally, this; the catalyst is the photoresist should be that it should be particle free and defect free.

Now, let me play two videos for you, so that you understand how to spin coat the photoresist. So, let me play the first video.

Hello, and welcome to this training on our lab spin 2 and 3, the manual spin coaters.

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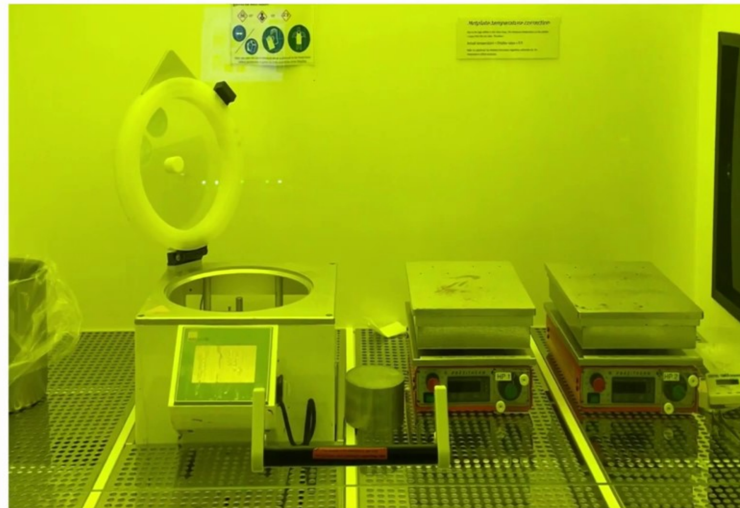

https://www.youtube.com/watch?v= neUkDsQhsM

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 afterwards.

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In the bowl sets, we have a bowl, we have a splash ring, then we have different sizes of chucks is 6 inch, 4 inch, 2 inch. Then we have small chuck for bits and 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 2 inch where the pins has 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.

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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 fume hood 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 inch gloves or pair barrier gloves.

We have different bowl sets that are depending on which chemical to using. If you, like today, use UV resists which is the solvent PTMEA and cleaning solvent as its own. Then you take this bowl set, it is important not to mix up bowl sets with different chemicals. Before we start the processing, it is a good idea to turn on the hot plates, on the green button here you will turn on.

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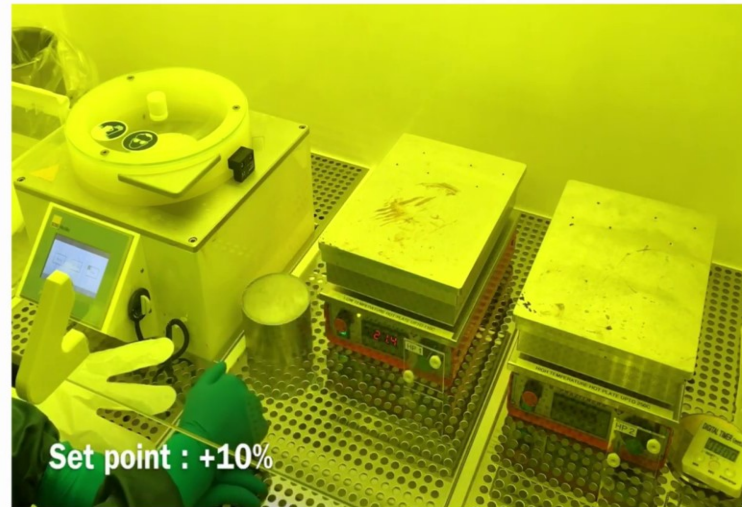

Then we have to put a set point. So, we have an aluminum cover plate that is changing the temperature by a 10 percent. So, hold then, set and then change the value that you need. So, for 90 degrees, I would go to 99 degrees.

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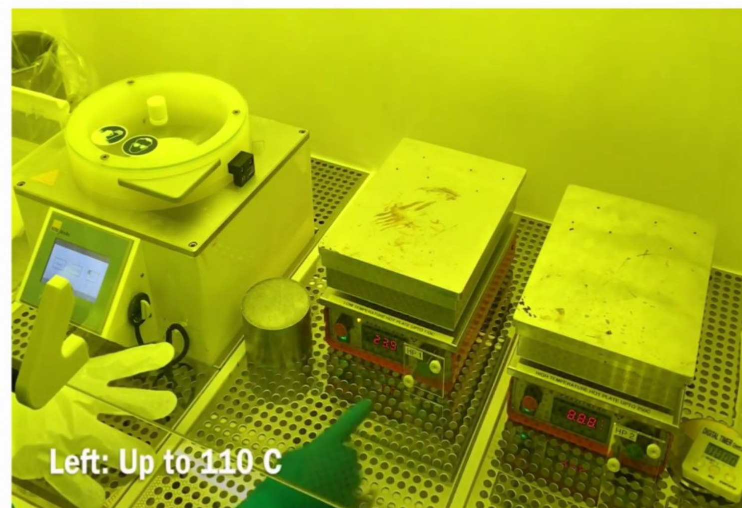

We have two different hot plates, we have one that goes to 110 degrees.

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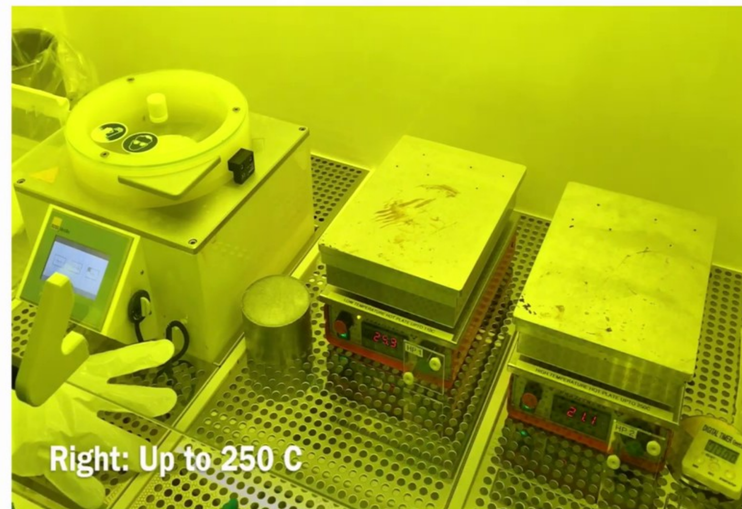

And another goes to 250 degrees.

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When handling the bowl set, we always use nitrile gloves on the outside. Take off the lid, always have the sash at chest height to a not make dangerous 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 splattering, the protruding side goes downwards. Make sure that its fits correctly and then a chuck here has a small recess and we also have a small pin down here. So, make sure that the pin is correctly you are adjusted and then place the

chuck underneath. And when you then push down, make sure that the chuck goes all the way down, so it is faster on the spindle.

Whenever, you have taking the chucks and the bowl set, please take the box and put it back into the drawer so that you have room. Every time you handle it, make sure that the lid is on and have the open the box inside the sash. Now, we are going to do processing, so 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 piece of paper, put on your resist and either disposable pipettes or this disposable plastic bottles.

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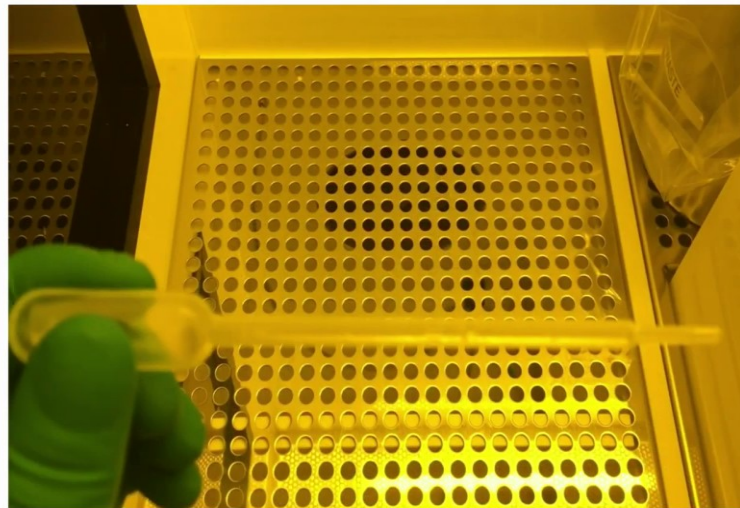

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Never use the glass bottles because then you contaminate them.

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We will open the spin coater, take a substrate and place on the chuck. Make sure to use the centering pins so that the chuck is leveled. Close the lid. Go to 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 ok. The touchscreen itself there is two things to be aware of, quick start which we just used.

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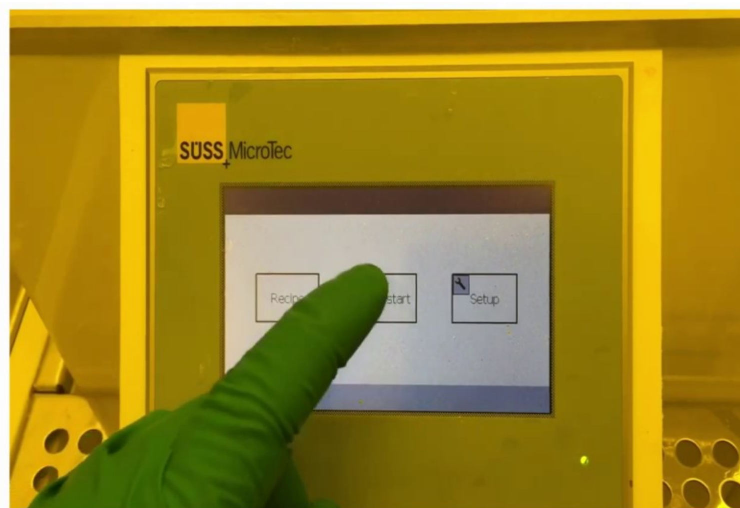

Here you can select the time that you need to spin code. So, 60 seconds for example.

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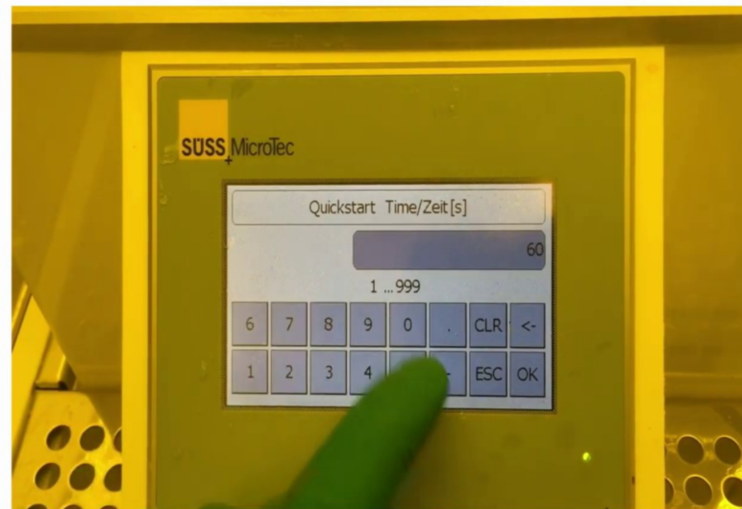

You can select the speed which give you the thickness. This case, 4000.

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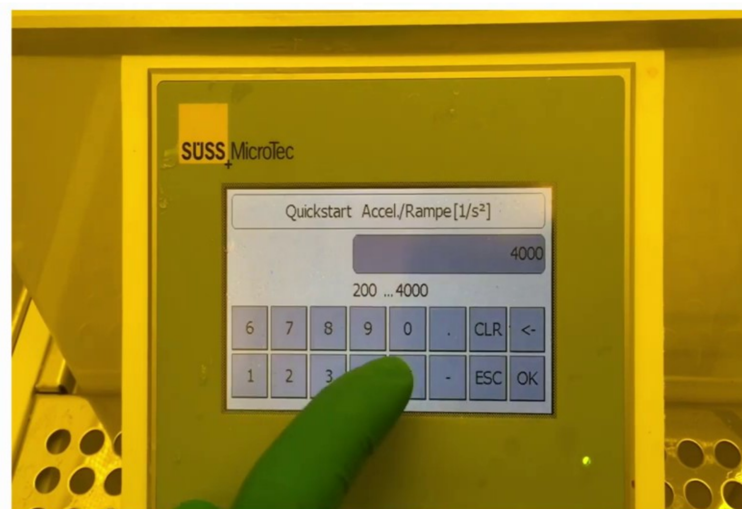

And the acceleration normally between 500 and 1000, but it's depending on your process. When you click start you can also do processing and of course, we need to spins first. We could also use a recipe if we need to make more than one step. We go to recipes, go to the bottom, find available slot. You could also use to pin.

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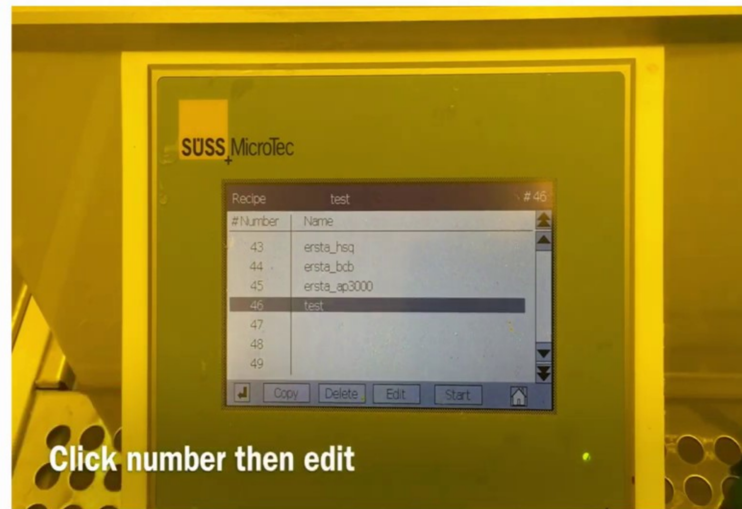

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When you click an available one, you can give it a name, let us call it test.

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And if you click the number out here and edit, then you can change the actual parameters. So, here we will start with a small spreading. So, let us say 30 seconds at a very small speed 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, the acceleration. If you start this process, it will go through step one to 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. So, you have the resist with the proper markings. Pour on a little bit in the center, try to make a uniform circle. Close the lid and press start on quick start. When we spin coating on a smaller substrate, we have chucks of different size. So, select the right chuck for the job. Again find the 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 so we check that the vacuum is ok. This is important because if the chip is misaligned, then we will have a resist so chip which is very hard to control.

When you are working with disposable pipettes, always clean them with nitrogen to remove excess particles. If it is a ebeam process I would recommend to use twenty seconds of nitrogen air, when taking resist from a bottle use to disposable pipette. Never touch the bottom, nor 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 to a fill the entire chip, make the first 2 or 3 drops go in the bowl set, no, the entire chip, as much as possible.

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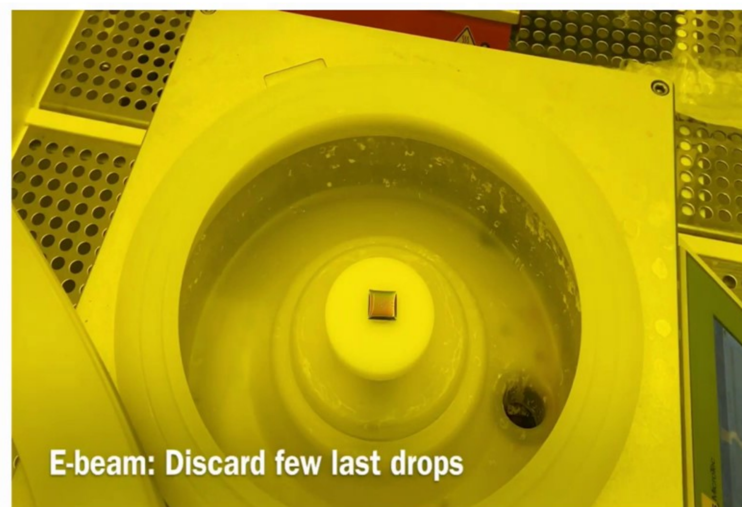

Sometimes you may need to take several times in the bottle. Make sure that you have a couple of drops or maybe even half a milliliter left. Close to lid and start the process.

When the spin coating is complete, we open the lid, take off our sample and put it on the hot plate and start the timer. When the process is done and the timer stops, you 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.

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Remember to open the fume hood, so that you can transfer your inlay set. Now, it is soaked with chemicals. So always wear to for etch gloves or parrot gloves. When disassembling the inlet set first take off the chuck, pull straight up. Here, make sure you have a tissue ready so you do not spill on the way when you transform your bowl set paths over to the other fume hood. If there is a lot of resists in the bowl set before removing that one, it is a good idea to take a tissue, wipe it off, just like this, just so we do not have as much liquid resist.

This discarded one in the solid c waste, remove the splash ring and the same way make sure that you do not trip on the way. And at the end, remove the bowl set. Here, it is important to have a piece of tissue underneath the nozzle so that we do not drip resist all over hot plates. Always remember to turn off the hot plate when you are done. When we are doing cleaning, we are working with dangerous chemicals. So, put on apron, facials and for etch gloves or parrot gloves. It is a good idea to take up the poles or the box that

you need for the bowl set in advance, open it with your natural gloves so 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 is acetone based, so 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 that plays, its placed on 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 resist 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 back side. So, there is no resist residues left. When you are done with one path just put it directly up into the bowl on the box and then continue with the next. Sometimes the resist is sticking very well on the surface, just make sure to apply plenty of solvent and give it a good mechanical scrub. When cleaning the chucks, make sure that you take the top, the sides, of the back side 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. So, you can use solvent in this fume hood and not in the wet bench. Put a piece of 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 ion side put both transparent path and the white paths. Dispose all tissues in solid c waste.

When you are done with the cleaning, you can take off your apron and your facial. The for etch gloves you should always be turned inside out like this. Remember to always empty the C-waste when you when it is a lot full or if you use dangerous chemicals. Always, inside the fume hood it is a proper nut, so no smells escape. Grab a new c waste back and prepare the bin for the next user. When you are done with the cleaning, remember to logout out of lab mentor and fill in the logbook.

So, you have seen the first video and let it me play the second video which is on Laurell 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 Coater. It has a maximum rotation of speed of 12000 rpm. The controller allows operator in action in real time during the process execution including buzzing time, stopping and continuing on from that point. The closed 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 vacuum to be at least 15 inches of mercury or more.

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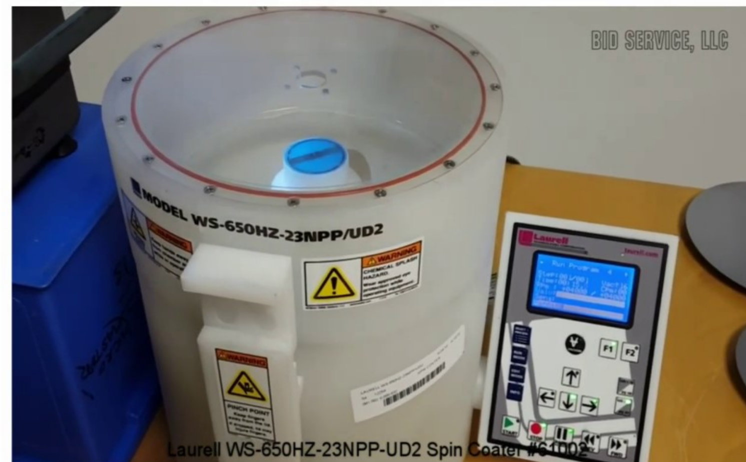

Laurell WS-650HZ-23NPP/UD2 Spin Coater #61002

https://www.youtube.com/watch?v=gjucsT37rCQ

First, I would like to give a demonstration of the speeds, so that I am going to use our little timing strip. First, this is the compact control panel, completely self-contained. I am going to call up a program here; program four, and what we 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. And then go, ok.

When it is done, in order to go on and run another program or any other process, you must open the lid. This thing is that it is ready for another one. But I am doing this one here is out double back to let us say 8000 rpm and you repeat. Open the lid, we are done. Always say done, and after lower the lid as long as we are vacuum is satisfied and your nitrogen purge it will tell you that is well. We will do one more spin and we will do this at the maximum rpm of 12000; so, on, on and done.

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

Next, we are going to spin a small wafer. It has this very nice little adapter here that you can fit right on top with the standard chuck. First, we will apply vacuum and we spin this little wafer at the maximum speed.

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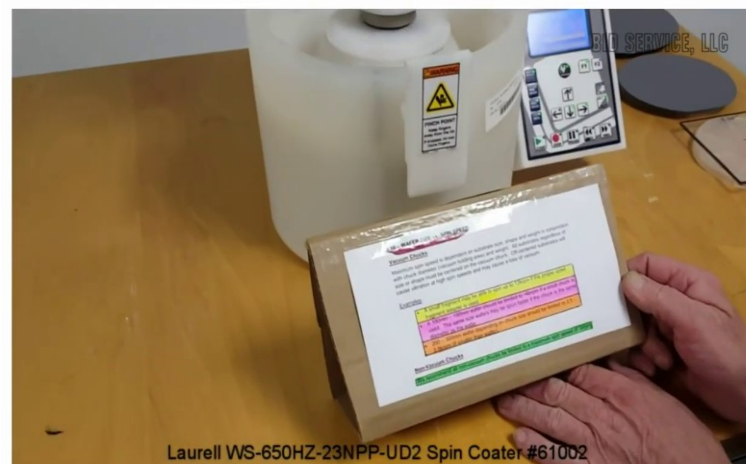

Laurell WS-650HZ-23NPP/UD2 Spin Coater #61002
https://www.youtube.com/watch?v=gjucsT37rCQ

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 they have given a 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. This is up to 150 over here, higher vacuum and we have also headed that speed down to 6000 rpm and here we go.

And we are done, turn off our vacuum, remove our wafer. Now, the spin coater has the capability for actually being able to spin a full 200 millimeter or 8 inch wafer. However, it is noted that in order to do so, you would have to remove the top and take off this plastic splash guard because that just is not enough room for it. It actually has the capability to spin 8 inch wafer.

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

However, what is important also in this particular unit is that it has the capability of spinning a full 5 inch by 5 inch square substrate. I have a piece of glass here that I can use to demonstrate the center that respectively. And, even though it is about approximately 7 half inches across here, if you look through the top, it still comfortably fits in between the splash shield. 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 3.5k rpm, I am going to spin this at 3500. And here we go. Oh, vacuum first, there we go; ready, lights on, starts says yes. And there we have it, very versatile, very compact lightweight, fits in anywhere and very easy to use.

Ok. So, now, we since you have seen the video which is of spin coating, the next step would be exposure.

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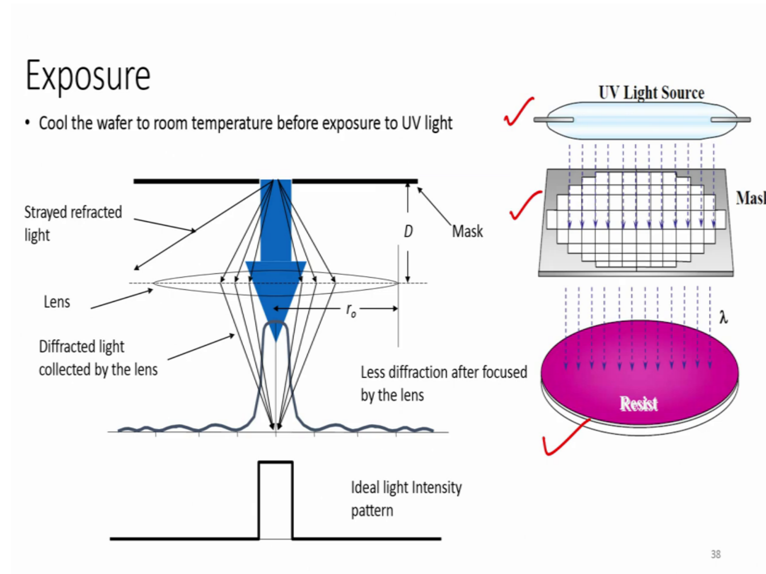

So, the exposure would be that you have the reflected light and then there is a lens, right. This distance is measured in terms of D. So, from the mask to the lens what should be the distance between two is calculated using optical physics. We are not going into detail about this particular technique; however, this is just like a lens is there, if it will light is connected 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, light source; you have light source, you have mask, bright field or dark field, and you have power positive or negative photoresist coated on the substrate.

So, the less deflection after focused by the lens, so lens will help to, you know, not allow the deflection to be you know larger area.

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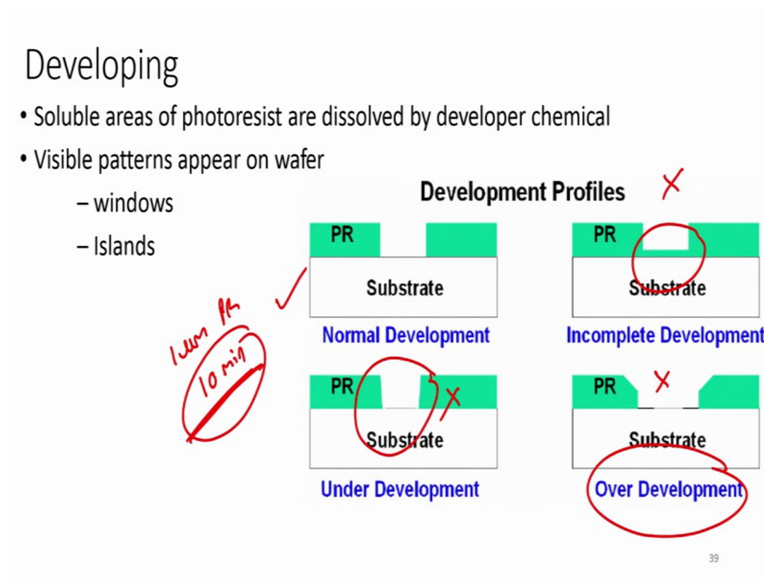

And if we want to talk about developing, then developing, you can see here; if you are concentrating on your time of the developer, right then you will get the normal development as you can see in this case. However, if there is a; if the time is less, that is a developer time for developing 1 micron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

So, these all 3 cases incomplete development, over development and underdevelopment is not accepted. The recipe should bake for 10 minutes and you should just take out the substrate in 10 minutes. So, the rest; along with the process flow, recipe is extremely important, right. So, this is one thing.

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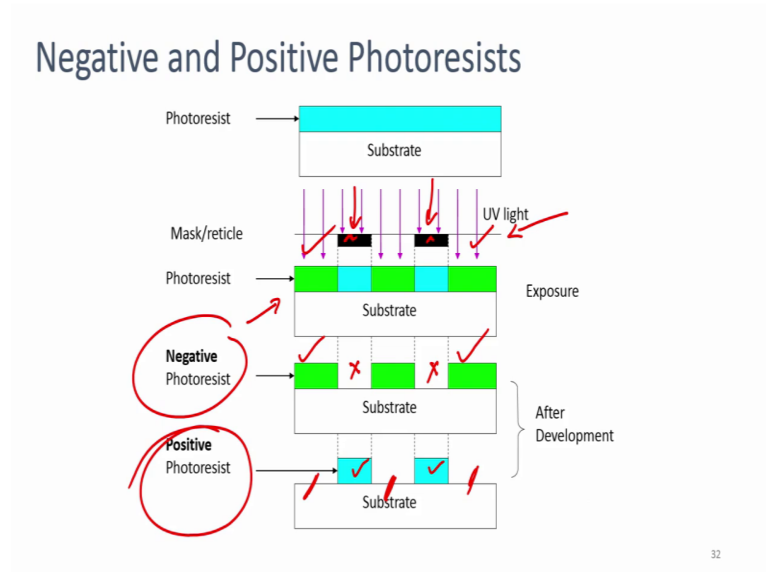

About negative and positive photoresist like I said the if you talk about this as a mask, and you see these are photoresist, then if we; in case of positive photoresist let us talk about first positive, the unexposed region is stronger, then unexposed region is this black region, this one and this one, you can see it is stronger in this case while the exposed region is weaker, we can see here in this case, correct.

While in 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 this two is become stronger. So, exposed region becomes stronger and unexposed region becomes weaker in case of negative photoresist. Exposed region becomes weaker and unexposed region becomes stronger in case of positive photoresist after photoresist development.

So, if you remember this formulas or this is, what you call, tricks then it becomes very easy. It is not really a formula, but it is a trick to remember.