Micro system Fabrication with Advanced Manufacturing Techniques
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Lab Session – 7
Photolithography

Hello and welcome to the Micro system Fabrication Laboratory. I am Shantanu Bhattacharya. And I will be teaching today, I will be demonstrating some experiment from photolithography, which is the very essential component of memes, for meme's a fabrication essentially. So, let us go to step by step in this. The first thing, I would like to enhance and like to emphasis in such a laboratory, is that you have to really maintaining the cleanliness. And there is certain entire, which is useful for processing. And basically one needs to cover and almost entire portion of the body; and take the proper safety measures. So that the particular operator in question who is doing the experiment is not affected, and also the experiment is done in a dust free environment.

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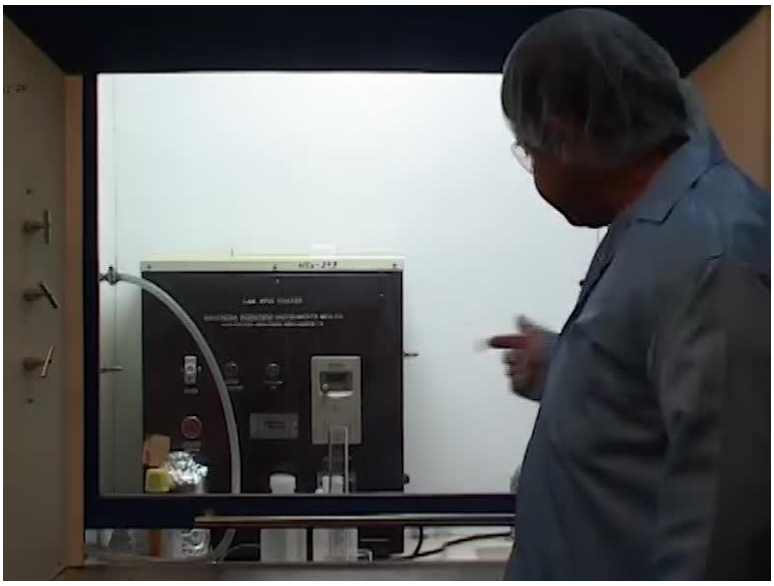

So, let us look at the components one by one. This right here is one of the fundamental component used in such a laboratory. It is known as the fume hood, essentially it provide the class 1000 clean space or clean area, which is just underneath of behind the particular panel. There is essentially blower unit, which circulates and causes a laminar flow of here inside this particular hood. So that, typically all the task which is around, goes passes through set up HEPA filters. And air is the re-circulated back, and there is absolutely no entry of dust particle from outside, into the clean space.

Most of the dust particles exist, because of this continues laminar flow operation. So, other components, important components of the few mode is basically air track, a compress track, which is the kept for the purpose of cleaning wafers. Once we process these wafers, there essentially a water connection; which is used for again washing samples, as we do the processing.

And the very important components, which is useful, which is the primary components where all the processing in done, is actually silicon wafer. So, silicon wafer is commercially a manufacture by on the of few manufactures all around the world. One of them being memcy, which is located at central west. And essentially the wafer manufactures have standardized processes, where in the produced different diameter wafers. Including a 3 inches wafer or 4 inches, 6 inches so on so forth. Now, this write here is such a package of box, which comes from a wafer manufacture. And it houses about 30 to 40 wafers, in of one such packages.

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Let me give you a closer look as to, how the wafers really look like. The wafers all stactane as you can see here, in this particular passion. And this again is pact in super clean environment, so that there is absolutely no dust on the wafer surface. So, what we do right here is, first take out a single peace silicon wafer. And I would like to illustrate how the wafer will looks like. So, if you look at such a wafer.

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So, as you see here in this particular fume hood, we have several components, which we have kept inside. Normally not at too maintain the cleanliness on the process, we use this aluminum foils, which you can see here is the silver foil; which is actually a clean surface and it is reusable. So, it is actually a onetime use and throw bases. I can actually cut several pieces and cover this area, and keep it as a base. And all processes typically would happen on the top of such a foil. These components as you are seeing here, some of the glass were which is around are these tweezers, which are meant for handling such wafers have been already clean prior to this, and heated in an oven, so that you get at of all the water around it. So, they are actually adequate for handling a the silicon wafers.

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So, the first thing I am going to do, is to actually un load a wafer from it is box. And make a separate container, take a separate container on wafer box. And transfer this wafer, as you are seeing here, this right here really is wafer box, which is meant for containing a single wafer. For micro fabrication, it is very important that specially when the wafer of moving between workstations, we need to cover the wafer adequately.

So, that you do not have any contamination, has the work is moving between stations, so encoding. So, basically the first thing we have to do here, is to transfer the wafer from this box into a separate carry box, which is meant for holding just a single wafer. One of the reasons, why we do that, is that because we have to actually really protect the silicon wafer, specially, when it is transferred between different box stations. So, this is carry box which is meant for that purpose.

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Wherein, there is led and then, there is a small filter paper which is covered at the bottom. And this is used for handling wafer between work stations particularly, during the various process steps of photolithography. So, we also use these aluminum files to make a super keen flooring, while doing the processes. All the components like this glass where as you seen, has to be thoroughly washed and clean and then, ride in an oven. So that, there is no moisture is essentially micro fabrication is lot about cleanliness.

So, let us transfer the wafer from the box, here as you seen this is the wafer box. This process only has to be done within a fume hood, because this prevents the chances of the wafer getting contaminated by the dust particles of here. So, we take wafer out using tweezers, as you can see here. Tweezer also is very clean tweezer. And the essentially, we use this box at load this wafer. And later on all the handling will be done, using the particular box in subsequence process steps.

And then, cover this with lid ((Refer Time: 06:10)), we closed the silicon wafer box, and keep it in a separate area. One of the reasons is that, we have to extremely careful while handling wafers, because the very fragile and essentially, you can crack even on little impact of stress. So, we have to make sure that this wafer boxes for way, from experimental set up, at least the named of boxes for away, from the experimental setup.

So, the next step basically is the clean water, although it is very, very clean.

But, we still need to do a surface treatment of way for. So, that number 1, it can be made hydrophilic number 2 is that whatever organic contamination is there on the top of the silicon wafer gets removed. So, one of the method doing that, is by using an acidic solution call piranha, which essentially a mix of hydrogen H2O4 sulfuric acid and hydrogen peroxide. Essentially piranha is prepared by mixing 3 parts, by volume of sulfuric acid, with one part by H2O2 a hydrogen peroxide.

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So, highly exothermic process and results on lot of heat release and fumes. A once the solution stabilizes and little bit after mixing, typically use a glass lots to stir the solution. And put the wafer on the solution, and clean it for 7 minutes, about 6 to 7 minutes, so at everything which the organic on the top goes away. And then, the idea is to kind of extract the wafer back and rinse it using DI water for a few time.

So, that you can remove the acidic impurity. And then, dehydrate it is an ((Refer Time: 07:31)) at 95 to 100 degree Celsius. So, let us look at that process now. Piranha is very dangers process as you, as I have already illustrate it. And therefore, you need to use special protect of covering, we are already wearing safety glass, as you have seen before.

Now, what I am going to do is to where a set of polypiling gloves. These are descendent essentially and highly anti-corrosion.

And that essentially prevents any kind of damage or contamination to the operator in case of spill over's. As you see here, you can just wear it over the secondary gloves that you already wearing. And which is the clean gloves and for doing processing. Once this is one, we are almost ready for preparing the piranha solution.

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So, what we do is basically pore about in this case about 90 m l of sulfuric acid 98 percent. As you can see these a very, very dangerous chemical. And it has to be a very carefully used and then, we mixed about the 30 m l of hydrogen peroxide. So, what we do here is the following we use all these pouring etcetera, over this the range, so that in case there is a spill over, everything goes down the range. So, essentially opening this sulfuric acid bottle is also to be done very carefully, you use this clubs. So, basically you open the acid bottle, and keep the cap in safe place, safer area.

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And essentially, now what you do is, basically take this bottle and pour it, in this beaker here, very carefully and very slowly. Your sink here pouring this is not a very easy job, do it just about closed to 100 m l. And essentially again keep this pack in it is place, cover properly. So, that there is no chance of any spill over. And essentially close the led. And we need to actually do a secondary measurement to ensure that the volume, that you are using it is proper.

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So, use measure cylinder for that, and we need to pour exactly 90 m l of here. So, what will do is, you will transfer this sulfuric acid into this measuring cylinder. And go all the way up to 90 m l. So, it just about complete now. So, we take a new container, in which we have to prepare the piranha. And slowly pour from the measuring cylinder, as the sulfuric acid. One thing we have to ensure is to identify the components, which I have already being, used for containing sulfuric acid, because we had wash them later on properly. So that, there is no risk of in experimental is caring burnt, because of improper usage that. Now, you had a pour about 30 m l of hydrogen peroxide. So, this right here is the container for the H2O2. And the reaction is essential in a equilibrium reaction, were there a lot hydrogen ions and hydroxides, which generative.

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And essentially it is an equilibrium process, which codes layer of hydroxide on to the silicon dioxide, nasal dioxide surface. And also creates a lot of heat. So, basically we need 30 m l of hydrogen peroxide. So, we open this and pour exactly 30 m l of hydrogen peroxide in to the secondary container here. And keep it separately in this particular zone, will close this. Because, it is a highly volatile materiel, it kind of evaporates. So, we need to certain that, it is comes back in it is safe zone.

So, after we have independently pour this, we had a mix these two chemicals together in this beaker. And what I am going to do is to, now turn on the fume hood, essentially because this is the very, very exothermic reaction. And essentially, we had also pull down the cover, just about two level, where you can just put your hands inside and do the operation. So, essentially now you will be pouring the hydrogen peroxide in to the sulfuric acid.

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This is a very critical part, because this may actually slot. So, as you see when you pour the materiel, there is a immediate reaction, which takes place. And there was a lot of fumes, which are generated that as you can see. And this fume has to be done an a very, very close environment. And we have to wait for some time, till this fume actually disintegrates, or disappear totally. And piranha is made in that process. So, as you can see the fumes are slowly settling down, because essentially it is the very, very highly exothermic reaction.

So, what you do now is to actually use a glass rod, and stir the solution very well. So that, the mixing between the hydrogen peroxide and sulfuric acid takes place. And then, once this is ready, and mind you, this is the very hot chemical. And essentially, you have to be careful, while even pouring it in to the separate ((Refer Time: 14:15)) as I will just illustrate in the next step. This is the glass rod, you cannot really use any other metal rod for doing this, because the acid immediately produces the salts, from the metals.

And it also deposits the metal and it takes a half, and in the process gets contaminated. So, you had always use a glass rod or the glass container, for doing this piranha making process. Once this is made, you rinse of the excess on the glass rod and keep this rod back in to, the container for H2O2. And this would later on the clean, before we can reuse this again.

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And so what we now do is essentially take this piranha, what we have prepare. And then, pour it over silicon wafer, which will be keeping in this particular petri dish separately. So, what we do is essentially, we take our wafer, silicon wafer and open this. And clean, in order to clean this wafer, we put this wafer back over the petri dish here.

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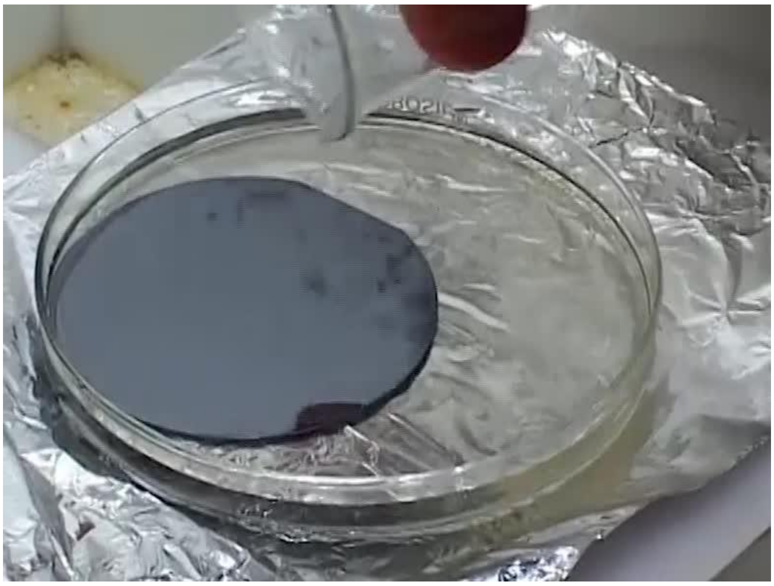

As you can see here, we are putting the wafer in this petri dish. And once we pour the piranha, we can no longer use this metal tweezers for handling this wafer. So, will have another separate step 1 tweezers, for doing this wafer handling, once it is out of the piranha for washing and rinsing. So, now you slowly pour this chemical the piranha over this wafer. And it is extremely hot as you can see. And essentially, it also fumes as you pour it.

And immediately if you can see, there are the organically contaminations over the silicon surface has been immediately remove. And we store all these container later on for cleaning and using it, for different applications. So, now we keep this close and wait for above 10 to 15 minutes, so that the wafer can totally get arranged.

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So, these as you see are now Teflon coated, these two is a soft tips which are coated with Teflon. Or they can be complete Teflon tweezers, which we can use. So, what we are go going to do is to provide a normal rinsing, using distinct water. As you can see here, which is resting in the ((Refer Time: 17:49)) of this particular piranha clean wafer sample. And then, this would be followed by another wash of DI, DI and I use to water. So, that it gives a super clean, surface on the wafer.

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So, what we do is to basically pull it out very carefully, because essentially this is all acid coated now one has to be very careful. And then, hold this over this edge and rinse it inside this with water. And rinse it on both side, as you can see all the water should typically go. And rinse all the acid of the surface of the silicon wafer.

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And essentially, once this is clean, the next stage what we do is, we take this DI water. And slowly rinse it on the surface of this particular wafer. As you can see here, this actually a spot bottle, which is sporting away the DI water on the top of the silicon wafer. So, essentially after completely rinsing it, you basically try to just change it is holding location, to a different area. So, that you can rinse of the acid in the particular area, where it was held before, and this way you can clean whole sample.

And essentially, you can see now that the sample is borealis thoroughly clean, thoroughly; and as a super clean nature on the surface. So, once this is totally clean, we need to now use the compressor to dry this particular wafer. But, before doing that, we need to take care that the acid etcetera, which is actually kept in open, needs to be kept away.

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So, that there is no sporty of the acid in general, so now you take it. So, this is basically an air nozzle, it actually sense in compressed here. And what we are going to do is to actually, slowly use this nozzle to clean of the surface water, as you can see here, slowly from the surface. So, essentially you have to move this thin fill of water in the clean hood, away from the side. So that you are actually left with a clean surface of the wafer, a clean shiny surface of the wafer.

And there should not be any water drop in this manner on the surface, typically all the water film should go away from the surface. Similar cleaning has to be done for the reverse side. And I am going to do that as you see here, seeded from the compressed nozzle side towards the other side. And it is than rinsed of the surface by squelch of compressed air, as you can see. So, this now really is the super clean surface for lithography to take place.

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So, we put this sample, this clean sample back into the wafer box, as you can see. And then, will actually do a heat treatment of this particular wafer, so that it can get rid of all the water from the surface.

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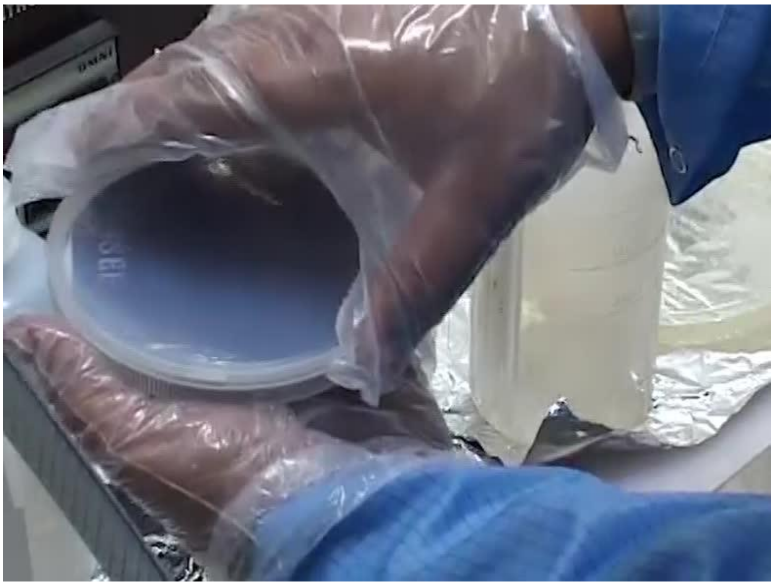

And that way we have a completely dehydrated surface, we need to cover it at this stage. Because, the moment we move it out of this clean area. It can again become dusted, and the contamination of the surface may happen. So, this is how the piranha cleaning process of the wafer is done. So, basically what we do now is to take this wafer, that we just made super clean using piranha process; and take it to a oven.

The oven basically were that we are using here is a gravity effect convection oven, which actually is based on the principle of free convection. There are set of heater coil at the bottom. And there is a current of air, heated air which actually makes the temperature uniform. There is a PID based controller using thermocouple, which is somewhere at the flour of this particular heater.

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This right here is that oven. So, what I am going to do is to illustrate a little about this oven. And then, basically use this oven to heat dry the wafer surface. So, basically if you look at this oven really, it is a shelved oven, as you can see there is a fan, which actually does force convection, along this full area. And essentially, the wafers are kept a various levels, a thermocouple is somewhere of the bottom. That is one at this advantage of this particular type of oven, because it sometimes is not a very good indicator of the temperature that happens.

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This right here is a controller, it is based on proportional integral differential controller. So, as you see here, there are two different reading, there is a set point. And then, there is variable point with the temperature goes up and down, based on what the set point is. Or it to control thus basically, if you can see here, right here there is a set options. So, you press the set option and then, take this up arrow a down arrow. And as you are seeing the figure here, which is the s v or the set value is varying 89.3, 0.4, 0.5, 0.6 so on, so forth.

So, we take this all the way to about 100 degrees, which is important for proper hydration of the wafer surface. And once you reach 100, you basically leave the set key. And this is now set at 100 degree. So, this temperature, which is also a proportional integral differential temperature is actually slowly equalizes the set value after awhile. And basically there is some kind of flickering around the set value, it does that flickering an slowly attains the set value point.

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So, basically now as you seen here, the variable value is has almost reach 100 degrees. And this is time enough for our wafer to get loaded inside, and get dehydrated. So, what you basically do is, essentially take the wafer box, which we pulled out of the fume hood, after the piranha clean. And then, basically put an aluminum foil, on the top of one of these shelves. And then, slowly load our wafer sample, so that we can get it heated and remove any water, if present on the surface of this wafer.

And the whole idea is to have a perfectly dehydrated surface of this particular wafer. So, that, it can be good for a derange to the photo resist, that we essentialist pin code in the top of it, before doing photolithography. So, we keep the wafer in the oven, for dehydration for above 10 to 15 minutes, at above 99 to 100 degree Celsius. The next step is to unload the wafer, and start doing what we call spin coating of the photo resist. So, what I am going to do is just unload it, and carry it back again.

Please note that, we are using the same wafer box for caring the wafer. Again for the constrain, that it should not get contaminated, while owing between operation stations. So, we slowly use are the tweezers, which was again use for the other processes, this is again a clean tweezers.

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And we slowly pick up this wafer from the oven, transported into the box here. And then, convert this or cover this with the led. So, basically now we have a clean wafer, which would take to the next station, which is actually the spin coater; where will be doing the resist coating. So, the next stage basically spin coating the photo resist. And first spin coating the first thing that one you should take care about, is the grade of resist that one is using.

There are many manufacturers of resist in the world. We will be doing negative tone photo resist here, which basically means that wherever light or UV light is used for explores of the photo resist film. They would be a general cross bonding among the molecules. And the resist stays back, and the portions which are unexposed can be developed of. So, really what would have is basically small features, translated from the mask design on to the resist surface. On wherever light has fallen, through the mask window on to the resist. The features remain the other portions are the features go away, after developing. So, the first thing that is important here, is to download the specifications of the particular grade of resist, that you plan to use.

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And what we normally do is, we use a resist from micro cam, which is actually resist maker. And essentially, we are using a great of resist call 20, 25 as you weight, which as ascertain viscosity. And what the resist manufacturer really does, he really puts together, an experimental curves for this particular viscosity. And so basically what he determines this, what is the RPM at which we should spin the resist. So, that the particular thickness can be achieved; and thickness define.

But, the RPM is really thickness of the feature, that we are looking at. What at also does is it actually mentions about temperature steps, that you need to is include, in order to process are the resist, once it has been spin coated and also after the exposure. It also mentions specifically about what is the explores dosage, which needed. And what is the time for which the resist needs to be expose.

So, that it can have enough cross linking and cross bonding. Just said the outside, I said this process of photolithography is about developing cross bonds, between different molecules. And that is essentially driven by reaction chemistry, and has a certain rate. So, it is very, very critical for us to be able to determine, how much temperature is needed, what is the time point. Or what is the time of holding for that particular temperature step.

We also need to a certain, what would be a typical explores dosage, for all the molecules within that small window to get expose. So, that they get cross linked very well. So, essentially I would like to go ahead and make features, which are about 20 to 20 mi microns thick. And for doing that, if you at this resist great sheet to basically get these curves here, where he talks about what is the RPM on the x accesses here. And what is the corresponding film thickness that you will be getting. So, when we are using a certain grade here, which is mentioned in this table here as you see.

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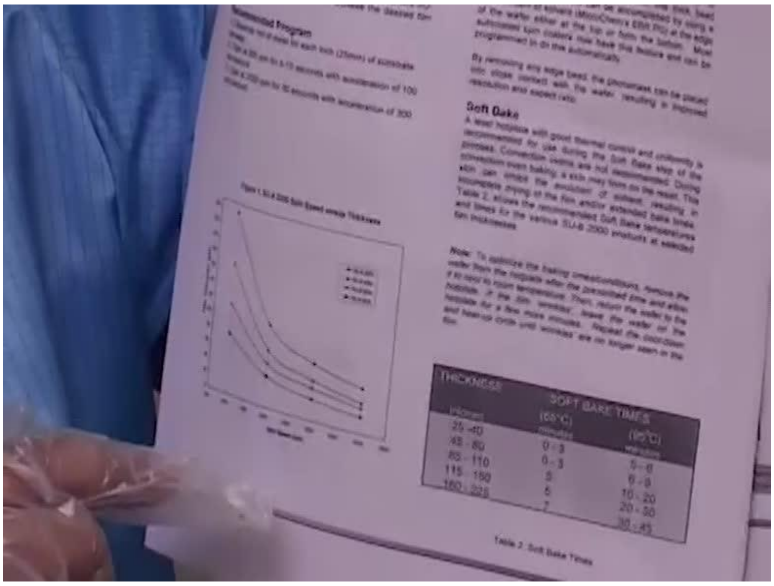

So, SU8 20 25, which is the lowest grade, here is really corresponding to a curve, which is the least this curve essentially here. And so corresponding to about 20 to 25 microns, what we find out is the RPM that you would need for, this is about close to 3500 RPM. So, I am going to in just about in a minutes set up, the spin coater that we have here. And tell more about how to program this machine, so that you can have the particular spin speed at a particular RPM. And you can also be able to hold it, at that spin speed for a certain amount of time.

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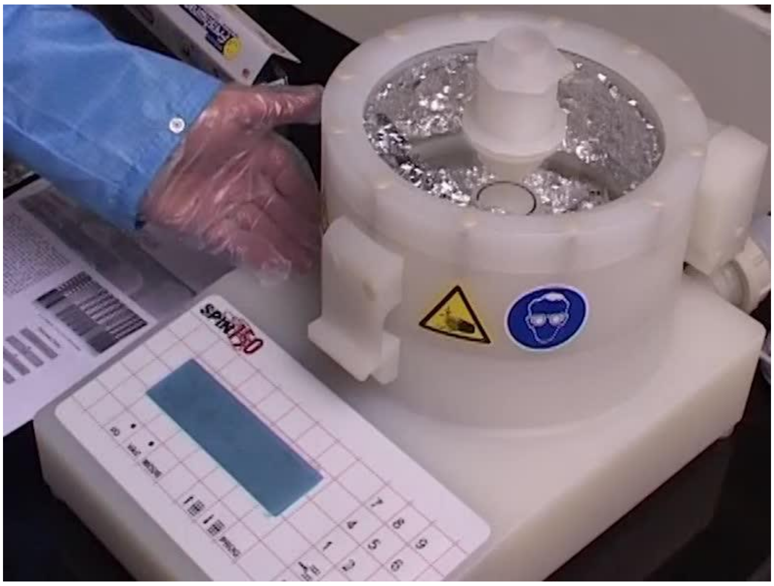

This right here is a, what we call the spin coater. Essentially, if you look into this machine closely, you have a spin stage, which is represented here, which is here in this area. Essentially the principle is use vacuum, for holding the wafer and to the spin table. And if you look closely into this particular area, you have these screws here, which are actually criss cross. And they are placed over the whole periphery of this spin stage.

And the purpose of these screws are that, there is a vacuum track immediately bellow this, which is connected to a vacuum pump, underneath this whole system. And essentially the vacuum propagates all the way up through this small center whole here. And then, also propagates along these screws and kind of whole together the wafer, on the top this surface. What is also important for me to tell you is that.

There is a control which is here, for which we actually use for flexibly controlling the spins speed, also the amount of time for which we can hold at a certain speed. And also what is very critical for different weights of resist is the acceleration; at which you can rotate, in order to achieve a certain speed. So, here in this particular example, but I will be demonstrating, as per the resist manufacturers specifications. The spin speed that we are using is about 3500 RPM.

And also this spin speed has to be attained with an acceleration of about 300 RPM per second. And what it also mention such that, you have to hold at a certain spin speed for about close to 99 seconds, for the spin coating to be uniform. I would also like to illustrate here that, the resist being a thick material, needs a little bit of time for uniform coverage over the whole surface. When we are taking about a circular wafer, what is very important for us to understand is that, first of all the resist that you are putting, should be sufficiently covering the wafer. So, what is the also very important for me to illustrate here. Is that really what we are doing is to spin the resist on the top of this circular wafer, which is about 4 inches or so. And we need to be able to a certain... What is also very important for me here to illustrate, is that the particular spinning operation, should be able to adequately cover the whole wafer surface.

This is a circular wafer of about 4 inches diameter. And the goal here is really that the resist should not have any gaps or any islands, on the surface as you are spin coating at. So, you have to a certain, how much area you need to initially pour or cover, so that you have enough resist. So, that essentially spinning process nothing but, centrifugation. There is a slow coverage of the surface of the resist, which has been pour somewhere in the center, by centrifugal forces.

And so the whole idea is that, you cover adequately and give adequate resist. So that, when it goes radically in all the directions, it should be able to have uniform coverage on the surface. So, for doing this, what we would need to find out first, is how to set up the controls in the particular spin coater. And how to control the r p m time, the RPM per second, the rates etcetera. So, let us look at that in our next step.

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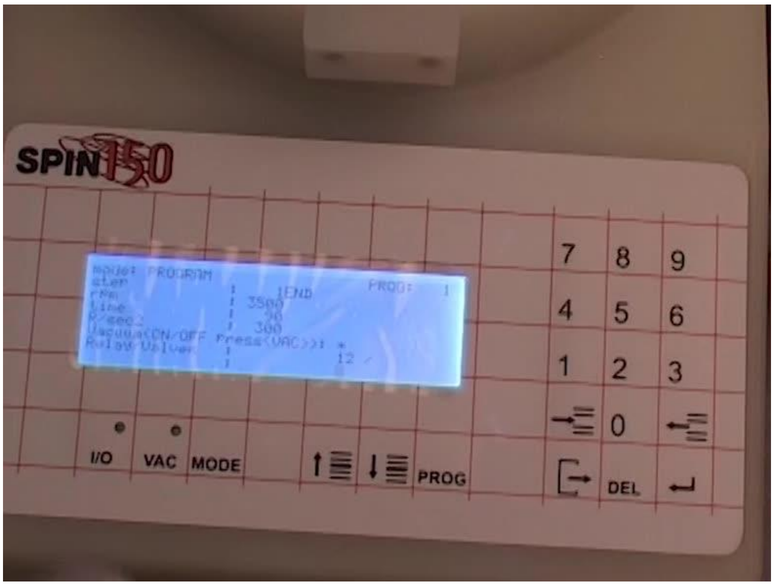

And corresponding to this program number, what all steps are there in the program are illustrated, just in this particular region. So, as you are seeing here on this, in the run mode, the step 1 of the program illustrates that. They would be an RPM of 3500 RPM, which is attained at an acceleration of 300 RPM per second. And the time of hold for this is about 180 seconds; and this is with an option of vacuum operated.

So that the wafer is pulled down, while the spinning happens. And then, finally you have to somehow change this program to suit your requirement. So, what we essentially do is to first use the program mode here as you can see, to go to the number of the program. Supose, you want to make a new program here. So, we find out the or we give a new number here let say, we want to make program 7. And then, we try to see, or but try to illustrate what is there in program 7.

So, we go to the mode option here. So, basically what we now do is, after we are enter program number 7. We enter this program and then, go to the mode option. So that, we can get a detail of what all steps are involved in this program. So, here really are the program is about step 1 and on the it is a one step program, and followed by the end of the program, so it is one end. Now, what we do is basically move to the next option here; and we get this RPM, which is actually 2000 this particular cases, as we can see.

So, what I am going to do is to change this to 3500, which is our requirement. And we can actually hit enter here for the system to take this. The time for which we need to hold this RPM is about 90 seconds. So, we do 90 here and then, enter the data. And the next step is what all rehabilitations per minute, per second, we need this speed to be. So, we put the value for the acceleration 300.

And essentially, enter this value and for our condition, we need the vacuum to be on, while the spinning is happening. So, we just take whatever is the default; and that complete pretty much the program. So, all we need to do is to now actually put the wafer back to the spinning stage, after which will be doing the run operation.

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So, what I am going to do now is to actually, simply load the wafer on to the spin table. And then, we have also see, whether the wafer is actually centered, which I will do little bit later. And what I do is, I just turn on the vacuum, you can see this light, the green light appearing here; which means, that the wafer is now firmed held to the surface. And it cannot come out and it is basically clamped, pretty firmly on to the spin table. So now, it is almost ready to rotate and spin. And essentially, code whatever is there on the surface of the material.

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So, we would like to also have a look as, whether this wafer has been centered. And the best way to do that is to close the led. And see from the transparent section on the top, whether this wafer is really at the center of the spin table. In case it is not, then you can switch off the vacuum. And again change the position in the manner. So, that the wafer can come pretty much of the center of the spins table. And the thing which we are ensuring here is, that there should not be any ((Refer Time: 36:28)) really of the wafer.

And it should actually rotate and it should own axis accesses, so it should rotate it is own accesses. And that can ensure that, there is no under utilization of the resist, which at the very center of the particular wafer. So, basically we have now plays the wafer. And essentially, what we need to now do is just turn on the vacuum here, the light would come on. As you can see here, this is in the on mode. So, basically the vacuum push the wafers. So that, it can set on to the spins table.

And then, we have to also see, whether the wafer is center. And way to do it is basically close the led of the spin coater. And turn this RPM on. So, there is a system actually starts rotating. And see from this top transparent area, where there is any verbal in the particular wafer. Now, as I can see here from the top, the wafer is more or less center and there is very less verbal. So, I really did not do anything about position of the particular wafer. So, I am going switch this on, to see the wafer is moving inside spinning.

And essentially, there is very less verbal and we can do with there, with this kind of a verbal. So, I am going to now spin coat the photo resist in the top of this wafer, by pouring the resist, and then doing all this execution of the RPM cycle. And the moment the resist is spin coated. We also need to take this now, for the twin step heating process, which I am going to describe a little bit. So, the resist as I told in needs to be heated. And one of the purposes why heating needs to be done is that. There is a solvent, which is really a carrier solvent for resist.

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It has really an hypoxia resin, which is dissolved in a carrier solvent, which is actually cyclopentanol, and essentially, the purposes really to transport the hypoxia, uniformly over the surface of the wafer. In the spin coating process that we saw in the last step. And then we need to get rid of this solvent, because essentially that would ensure that the resist film is stable. It is hard enough, it is kind of equi bounded. And before doing explores it is very critical, because the mask would set on the top of the resist.

And so therefore, if there is some untried portion or uncured portion, the resist is going to get damaged. And that is something that we do not want, because that would mean that our surface of the micro features. That we would result, I mean that it would result in, will also be damage, because of that process. So, we need to a certain that the resisters fully cured, before taking into the next exposure step.

Now, I would like to illustrate one fundamental factor here, is that we all know that because of heat addition, there is a thermal expansion. And this is the thin film we are talking about, the resist is really a thin film. And so there may be a rapid, due to rapid heating or rapid cooling. There may be a tendency of the resist film to warp over the surface. And create undulations and that is something that we want to avoid two, we need to be as much planner as possible.

For the surface integral or for the structures integrity to be maintained. And so it is really a good idea, to heat the resist in a stepped manner. Heat it to the lower temperature may be about 65 degrees or so. And then, heat it to a higher temperature. So that, it is adjusted enough and there is no undulation or warping of the film as such. So, therefore, we use hot plates for this purpose. Here as you see in this particular as a station there are 2 hot plates I have. They have been preset to the temperatures of 65, 95 degree Celsius. And each of these steps would have a certain time associated with it.

So, the spin coated resist on the wafer would basically brought an, and the space would be used for heating these. So that, we can get a cured film of the resist on the surface. Typically close this and just start the spin coating process. And let the film that we have set kind of spread over, the whole surface. And create a thin film, which is about 20 to 20 microns, 25 microns of this resist on the surface of the wafer. So now, we have to be, now the resist is actually spin coated now.

And we have to be very careful about removing the wafer, we have hold it from thin corner at the sides. Because, that is typically the area, where there should not be any designs and structures. We will just use the little bit of tweezers space for holding it. And be extremely careful about handling, because mind you at this stage, the resist is actually a kind liquid in nature, we have not cured. And before the curing, the film is like tacky. And then, if you have any stresses or any impact on the film, it is going to create a huge difference.

I make the film not behave properly. Also we need to certain of one basic fan, that the table that we are using for keeping or a lining our hot plate should be perfectly parallel to the ground, because otherwise there may be possibility of the resist, running to one side. First, creating a thicker film at one, which is highly undesirable, because we want a uniformity in the film thickness, which also determines the sizes and nature of our structures and features.

So, essentially now the program has stopped and I am going to slowly pull and the second see here. There is a thin film of resist on the top of the surface. I am going to actually take the wafer box here. And then, slowly use a small amount of space. So, we first thing we need to do is to close the vacuum. So, that we can decouple the wafer from the spin table, we take a very close a very small portion and buy it along with this tweezers on that portion. And then, slowly transfer the resist coated surface on to this wafer holding box.

And then, once we have done it will actually cover at with this cover here, not pressed very tightly. And then, slowly move towards our next step, which is a hot plate and keep it on the 65 degrees sets hot plate. And wait they are about 3 minutes also. So, I am going to put this wafer on the top of this particular hot plate, which has been said an 65 degrees. So, for doing that we have to be again very careful about pulling this resist coated wafer out. We use the exact same area, as we are used before for holding, just in a small edge or a small corner. And then, keep it on the hot plate we have stop watch with the us here.

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At this particular stage, we would like to operate on the stop watch by setting it at 3 minutes, and then starting to operate this. And basically, the idea is that this will given the alarm at the end of 3 minutes, we need a 3 minute heading time for this particular process step of 65 degrees.

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And then, we will go to the next step, which is another 3 to 4 minutes on the 95 degrees. So, this is a watch is now reading about 19 seconds or so. This is actually an alarm system, it would tell you in advance as the time is over will have a beeping sound from, which we can actually figure out, what is the exact time for which resist has been headed. The thing about micro fabrication is that you have to be very careful about the exact whole temperature. This, right here is an illustration that the time is over.

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So, what will do is will go ahead and pull out the resists, now the resists could it wafer now. Again, the same precautions need to be followed, you need to hold the resist from a very, you know small corner here. And then, slowly put it over the surface that we want to mean want to put it. So, I am going to now transfer this resist coated wafer on to this particular surface. It is almost a good a idea to actually coat the headed surf or it hold the headed surface at room temperature.

And let it come back to the particular ambient room temperature, for you know the film to have least possible undulations and wrapping it is possible. Will just cover it, in case there is accumulation on the surface, the another thing I want to point out is that the environment in this, in wish this coating process carried out is a very clean environment. We estimate we plan to actually do these things.

Typically in clean rooms, where the particle contamination may be as low as about close 2000 PPM or 100 PPM depending on what kind of feature sizes your using. So, essentially we will hold this for some 5, 6 minutes, till it equilibrist back to the room temperature. And then, we will actually use the second heading step of 95 degrees. And put this resist back again for about 5 to 6 minutes for the full curing action to take place after which we will do the u v explores of the resist using the mask.

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So, after the from it is location and put at over this plate which has been set to a temperature 95 degree Celsius. We start on the stop watch and set it to about 6 minutes time. So, the idea is that you know after 6 minutes, as we say here the second alarm, we should be able to pick this up. And then, again it equilibrate back to the room temperature before the explores process. So, we are nearing the end of the time the and there is alarm bell now again.

So, what we have to do is the same thing will pull back the wafer from the surface here. And then, put it back again on the you know use just a small area here to keep the wafer hold the wafer though the tweezers. And then, put it back again or it is resting place, where will use a little bit of time for equilibrating it back to the room temperature.

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So, we are now ready after this temperature is close to the room temperature to do lithography on this particular wafer. So, essentially this is call the photolithography equipment. And this is used for explores of the resist to very characteristic frequency of light mostly in the u v area. Essentially, here what you do is to use something called a hard mask, which you can see here right here.

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This is actually glass crow mask, where you can see very closely, if you look at some of these features really are at the microns scale. And these have been made using a laser etching in a film of crown, that in ((Refer Time: 47:02)) that this side, this particular side which has the coating really switch with the wafer being aligned with the wafer.

Because, otherwise if you have the other side seeding in proximately to the wafer. There are diffractions effects. If you see the thickness of the mask, this is made in glass plate, which is about close to 900 microns or so thick. And so therefore, it is very good idea two have the metalize the surface inproximetly to the coated wafer 0.9 mm or 900 microns is good enough, for beam of light to get hugely diffracted.

And so therefore, if suppose we what to do the other where around with this side the glass side sitting on the top of the wafer. The features that would be typically looking at much more in size, because of the diffraction effects. So, what I am going to do now is to tell you, how use the lithography setup to actually do alignment in explores.

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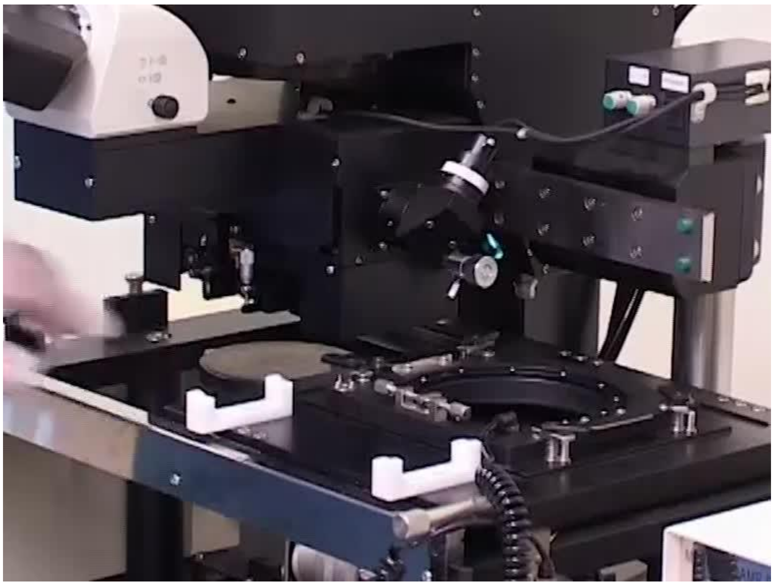

So, here we have something called a mask holder which is actually this region here. The mask is really setting on the top of on the bottom side of the surface of this particular holder. And it is actually facing the wafer which would be placing somewhere here. This is the wafer stage and the idea is to be able to precisely align the hard mask over the wafer surface. So, in order to do that, what we do is to kind of ((Refer Time: 48:26)) this particular points here there are 4 such screws. And then slowly pull out this part from the machine.

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And essentially, as you see this really is a surface which holds, this particular hard mask. And then there is a stand for this application or this mask loading. You have to put it right in that particular spot, it is like a jug. And it ensures that there is no unnecessary toppling or falling down of the mask holder.

So, take the hard mask and this has to be pre cleaned, this off course is a pre clean sample. So, what it should normally do as to put liquid compressed nitrogen or compressed air and bowled by thoroughly. So, that there are no marks, suppose there is some finger mark or something which comes in the top. So, you could use a small amount of vacation and wet a kewpie. And then, slowly rub over it and then wash it an ethanol and then cleared it using dryer dry nitrogen or compressed air.

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So, what I am going to do is to actually align this mask in it is space here and slowly. So, there are two slogs really for that purpose. And I am going to actually make it face down. So therefore, the chromium side has to be facing the wafer surface. So, which is actually given by this dark brown region of the mask. So, I slowly put it inside the mask holder.

And then basically this is only a passive graphic, we need to make it active by using vacuum, which can be operating by using this controller turning on the controller. And the controller power on. And then, actually use ah the wafer holder and the mask for the vacuum to be operated on to the mask.

Now, if you see the mask really is held very firmly. So, now we have it actually mounted and well connected with the vacuum from the system. So, what we do is we take this wafer holder out. And it is pretty much firmly gripping to the mask now. And there is no possibility of the mask falling as you can see. So, we go back into it is position here and then, try to mounted in a manner. So, that it can actually bolt this mask holder on to the top of the wafer surface. So, there are 4 bolts for that purpose you actually try to align them, with the bolt at which are there, the top of the mask holder.

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And essentially, you can actually now use the locking mechanism to ensure that, they firmly get locked over the wafer surface. So, what we do is now actually after mounting this properly, we need to actually bolt it firmly. So, we are going to actually use these set of screw heads to ensure. That there is a good contact between the holder, and it grips really on the surface. So, we are going to just ensure proper gripping of the holder, of the mask holder on to the surface of the stage.

The stage is by the by going to move along with this whole mask holder through the exposure zone, which is underneath the scope. As I will be showing you just a little a bit. And it has to be having a tied grip, for the purpose of proper alignment with the wafer on the surface. So, what we are going to now do is to actually move this explores stage, as the scope actually, from it is current location to near this over the mask holder. So that, I can have this zone here for wafer loading and unloading free.

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And essentially now I take out the wafer and loaded on the surface of the check, which is just here in this particular region. So, essentially now what we going to do, is to take the wafer from it is box. And actually put it in this particular zone here, which is meant do wafer holding. Again we would like to use vacuum as a means of locking this wafer, the spin coated wafer, resist coated wafer on to the wakes explores stage. And this switch right here which says wafer vacuum, actually ensures that the vacuum is used pull and lock the wafer.

I want to just check in whether the vacuum is working well. And I found out that it does not move any more, the wafer is jam with respect to the stage. And then, next step is actually explores to UV. So, in the next step what we do is, we actually now align the mask with wafer by pulling this stage, all the way up to it is position here, or location here. And then, try to actually manually bolted, they bolt the holder in this place. So, that it does not move back.

And also what we would need to do here is to actually go ahead, and moves this microscope stage back, for the correct focus. The idea is that, the wafer has to be zee displaced. So that, it can come in contact with the mask surface, and for doing that, we also use this scope, this microscope. And there is a small IR beam, which is actually there is small red light beam which is actually used for the purpose of seeing, whether the wafer is really touching on to mask surface. And so what we do is in the first stage, we move this particular microscope of the scope stage.

All the way to it is position here above the mask. And then, there is a small lock here, which we used for locking. There is also a control here, where we can actually turn on the red light, which actually is now focused on to the mask and the wafer. And the idea is we should be able to move the wafer stage. And we do it by moving, this is the x displacement, and really this is the y displacement for the scope. So, the scope can position on a particular area.

And the wafer stage can be moved by the controls, which there at the bottom here in this particular zone. And we can actually move the zee displacement a see whether, the feature on to the mask is really in focus. If it is in focus that is an indication, that the wafer has touched to the mask surface. And that is really the squad at which we should do the exposure. It is so fine, align, that if you just go up of that focus point, below that focus point.

It indicates either you are pressing the wafer hard to the mask, which means at the cost of damaging the resist. Or you are going away that means, creating a gap between the wafer and the mask surface. Either even it is not good for us, we have just be able to make a just a close contact without much pressure on to the resist coated surface. Or the reasons why this kind of alignment systems are also call contact aligners. So, essentially I would just like to see through this microscope stage.

And try to find out if the features etcetera, are close I see that, there is a little bit of displacement, which is needed to be done on the z axis, so that the images can be correctly focus. Now, I think we have really pretty good adjustment. And we can do a, we are all set do the exposure.

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So, this right here is also a controller for the exposure time. If you look at the resist manufacturer sheet it gives the exposure dosage for certain thickness of the resist film. So, what we need to do is to calculate from there using lamp power. How much time of explores is needed for the particular thickness, that we are operating. So, because our thicknesses of the resistor about 20 to 25 microns. We can get the correct exposure at the dosage rate, that this particular lamp of was in a time of about 20 to 22 seconds. We use this time are setting for a achieving that. So, you have these different values here in minutes, and you can see right now the setting is about 22 seconds here; which means that the exposure would be for 22 seconds.

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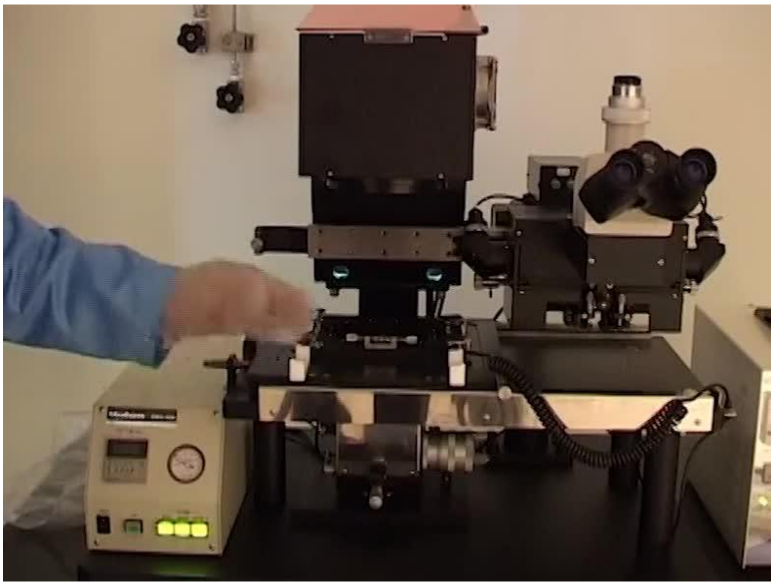

So now, what we have to do is, after all this exposure time setting etcetera, has been done. We need to take care of this microscope stage, by moving in back, because now we also need to do exposure. And so essentially I am going to unbolt this whole stage from here, and then shifted slightly towards the right. And in docket in it is position and essentially, that is going to give me a through pairs for the light. The UV light to go through the mask and fall on to the wafer surface. So, this is now taken care of the mask is there in contact with the wafer. And in order to protect the operator, there is a UV shield, which has to be installed here, before doing the exposure. And we are all set to do the exposure.

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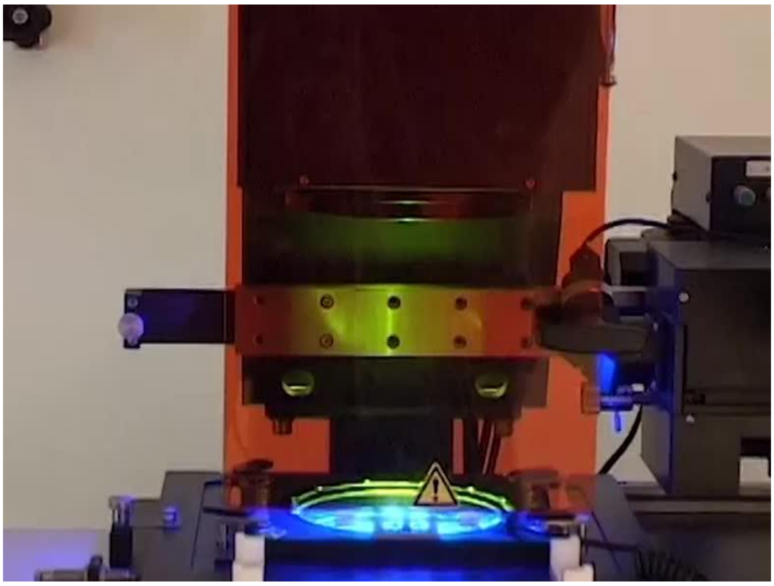

So, I am going to now actually turn on the exposure light. And as you see here, the moment I turn it on, the timer clock has started. And there the light, the UV light is now falling sharply on to the wafer. And essentially, this is the time reading here says, that is rapidly reaching 22 second mark, that we had set before. On the moment that is done, this light will go off, the explores light will go off.

And our explores process of the photo resist is complete. ((Refer Time: 57:50)), it is just complete now. Now, we have to actually just unload the wafer and the mask, separate them together. And then, we need to go for a post exposure big step. There I will be explaining in the next step.

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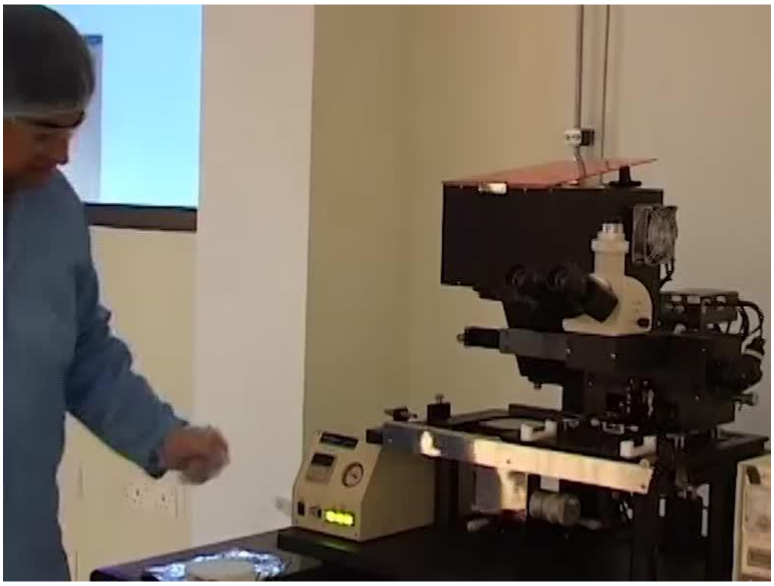

So now, I am actually going to go head and turn off the explores system, because, it has been working for very long time. And now we need to step by step do the processing in a manner, that we need to separate the wafer from the mask. So, a good a way of doing that, is to actually go anti clockwise, so that the masking stage can go down. And I can now take the wafer all the way by using contact mask surface. The next step would be to move or push back the particular mask holder. All the way back to it is resting zone, which is close to this end. And turn of the wafer vacuum, so that I can pull out the wafer.

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And this is actually they exposed wafer, which we are pulling out; will again loaded back into it is resting place, which is this container here, right here. And we will do something called post exposure bake, after this particular step. So, slowly you had a pull out the wafer from it is stage. Now, it has been leased vacuum is no longer coating it. And you actually slowly take it and put it back into it is wafer box, cover it. So that, there is not much dust contamination on the surface, close it.

And set up the microscope back to it is place here. We also need to just reverse the sequence, to pull out the mask we need to just switch off the wafer holder; as well as the mask vacuum. And essentially need to just pull back the mask in the pretty much similar manner, as we had loaded it before. So, this bolts is mostly un tight. So, that they lose, grip on the top of this wafer holder, slowly move the holder back and it is place.

And keep it back here and essentially, move off the mask, as we have done before. And store the mask in it is places and it is box it here. And we can also put this holder back and in it is place. So, that machines is ready for next one. So, the system is turned off, the next stage is basically to take the wafer and do post exposure bake. And one of the reason why, that needs to be done as that, this is really heat catalysis process. If I put the explores wafer in room temperature conditions.

And keep it for longer time and there would be a slope protonation in the exposed area, which would create really the, opening of boxy chains. And cross bounding in the areas, which are exposed however, I would like to passion process. So, that the overall time duration for which the lithography is completed is lower. And for that we need heat based catalysis of the process. And so doing this, what we really need to do is to actually take this wafer, back to our healing station.

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Take the safer back to our healing station and then there again manufacture specification ((Refer Time: 1:02:07)) which talk about how minutes. We need to post explore heat or beak this using the hot plate and the room temperature condition that we had done before. Someone to now actually pull out this explore wafer ((Refer Time: 1:02:19)). And we did in late lab and slowly put it on the top of this essentially this hot plate. And time here that we give for now to heat it for at 65 degrees step is about 1 minute to turn on stop clock.

And essentially wait for long bell to go in. So, that we know that, we have heated for the time cycle that suppose to be. Again we have to deliberate to room temperature conditions and put it back to 95 degree step. So, that can have ((Refer Time: 1:03:00)) properly expose and curried for the resourced firm.

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So, time up is really now. So, we should whatever we have done take it back again, put it back into the place again and the wait until this equilibrates to the room temperature. And go back do 6 minute heating step in next step temperature that is 95 degree Celsius. Basically now we actually put it back on to this wafer surface on to this hot plate surface which is set a time of 95 degree Celsius. And essentially heat this for about 6 minutes of show, and the one thing very good about this process that if we look at closely, you could real see the features.

And coming up on the surfaces you are healing using 94 degrees. Essentially the points which are slightly miss contracted you can see the different contact their in the zone which is exposed. When you develop it using developers those are typically the zone remain back and the remaining portion which were unexposed go way. And that is essentially what negative tone I supposed to do on the wafer surface. So, we going to now pick of the wafer from this particular place.

And you know we have now completed more or less the whole explores baking steps. And essentially we are now ready for next step process which is developing. And this developing is important because, essentially this actually needs to the features really there in generated within the surface. So, I am going to just take the wafer to the few

((Refer Time: 1:04:53)) and there is already developed solution, which is actually already placed the few ((Refer Time: 1:05:00)).

There is a certain time for development which manufactures specifies and this again a is function of thickness of particular result. As we our thickness are in the range of 20 to 25 microns. So, the result maker specify the developing times for this particular thickness, which is about 4 to 5 minute now case. So, let us actually find to develop it. And other important point that I would like to mention is that the result is actually left over on to the surface.

While this developing keeping place and it is expose and of turns why its cloudy as you spear as a proper noun. So, development process is really after the whole time duration is over it is iterative process, where you kind of spear the propanol on the top of surface again, again see if there is cloudy or milkiness to shear with the surface. Any resist, which is left over which is unenclosed would definitely turn milky and cloudy.

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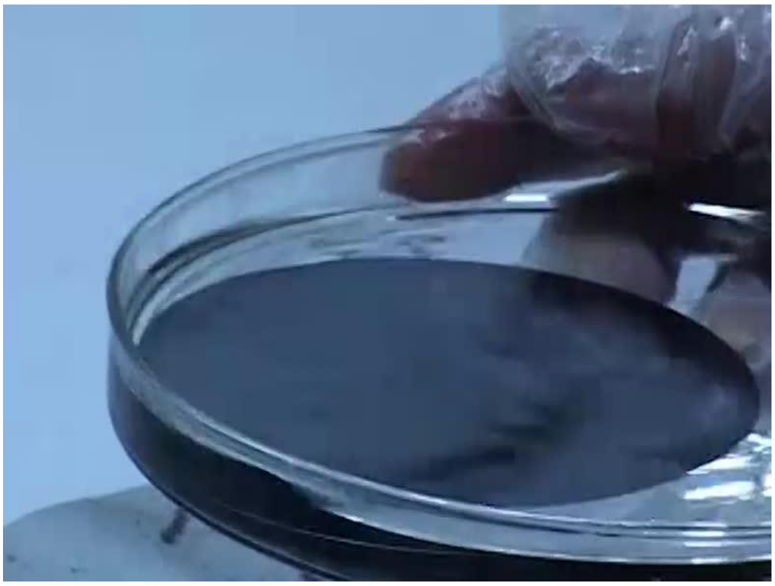

So, have to see when by pouring iso-propanol you do not get this cloudiness anymore, which also means that you development process is complete. And that gives you best resolution of the features and that you are looking an on the surface. One thing you also take care of in this case is that you cannot just simply drop the way first or an into the developer. You have to keep on straining that developers solution time to time. So, that there is no accumulation of the resist which is coming off the unexplosure resist which is coming off one particular place.

The idea is to keep on dissolving the by swallowing the fluid which is over it in particular manner. So, I am going to do that than after 4 seconds I am coming I also spear iso-propanol to see whether this resist that that we have done is actually totally developed or not and essentially start the time now this set to about 4 seconds. And then we keep on giving some salt to this developing action and essentially have ensure that happens. So, that you get good features on to the surface.

So, as you see here in the particular case after the developing happening immediately after you put it into the developer. The feature kind of nicely and beautifully get generated. We need to do proper microscopic analysis later on, but this is really success of process; that means, that whatever you have exposed is essentially keeping their resistor all cross bounded. And remaining portion as been moved and essentially again you have to keep sub leading the as a propanol, from time to time to see, whether you know everything is remaining on the surface.

So, I am going put this for the first time and see this a another beaker that we have put here for spring as a propanol to see. Let us pull this out and this brought it right here is really the propanol. So, am going to see this there is some clouding actions which is happened which means that the resisted presents underdevelopment resisted presents I put it back in to this dissolution and again just a give into few terms and see.

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So, this process keys going on for the stimulated time and the at the end of the process. We will have a really sharp distinguish feature which come out the process. So, basically we had the earlier experiment develop this brief. And the essentially he now whatever was there on this mass as a transfer on to the pay for using the process of the photography.

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And sense in essentially this is not the end of the process, because we really need to measure and calibrate able to see the microscope features. That have been different from the top of the resists which will be using later for our purposes. And after doing that we need something which can create high magnification object. So, in our laboratory here, we have this micro scope it is actually a inverted flows microscope.

But, it does not have an option of in able to at using the bite free dark free and imaging the ((Refer Time: 1:09:27)). Essentially the microscope this from icon there are certain manufacturers of the optical devices precise this needs to be a rested on vibration feed table as you can see. And I would like to describe the very outside a little bit about this microscope and how will do the image the value.

So, here in this particular zone these are also known as a jesters. So, essentially they are nothing but, the lenses and they all have capability of magnify find in different capacity. So, we do have objectives varying from 4 x which means that the image, which is actually seen to the microscope is 4 time actual size of the object all the way to about 150 lattice. So, essentially there are about 6 objectives here.

The way that the microscope operate is a simple you have in elimination source, which is an the back ground, which is actually here you we stores. It pass the through a set of N V filters, neutral density filters, which would cut off the UV light into different intensities. And then finally, the cure of light at the much lower intensity reaches this portion of the microscope, which has what you known as filter cubes. So, I will like the explain, what these filter cubes really do essentially if you look at the way that the filter cubes are assembled.

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These cube have you know two they are cubes which have two filters essentially what are filters? Filters are essentially pieces of glasses, which and the sign to the cut off certain frequencies. And let certain frequencies of flied go blasted. So, in this particular filter cube as you see there is a emission filter, which is a situated at the top there is an excitation filter, which is actually situated here.

And then we have something call the diacritic mirror, which is just place in between this cube in a 45 degrees angle. The purpose of the filter is essentially to take of the unnecessary frequencies from the view. As I told you this microscope also have capability of doing florescence measurement it is almost always important to be able to excite. A certain day the certain wave length of light next we have the day which is excitable in the range of 319 nano meters wave length.

So, I should have something some cutoff mechanism where all these different components of U V, which are coming from a illumination source to this filter should get cutoff except the 319 plus minus may be about 20 nano meters. So, which is also, known as dichroic mirror, which is placed inside the filter cube probably it is not visible from outside. But, the way that mirror operates is also based on the cut off principle.

So, they may be a cut of wave length beyond which the fill ((Refer Time: 1:12:48)) mirror may be able to refract the light and below which it should be able to reflect the light. So, that is how these mirrors are ethically designed. Now, with this combination in mind let us look at the what is the optics. So, this particular filter as you seen here going to face the u v light and it is going to take of the particular portion, which is unimportant and sent or transmit the portion, which is necessary for the particular fluoroform.

Now, each of these fluro floors are designed for a certain frequency. And essentially they have emission frequency range and excitation frequency range. So, whatever the cut of we use to correspond to the excitation frequency of the flora floors. Once this particular portions of light comes in the filter is reflected of the dichroic mirror, which is now placed 45 degree angle and actually goes down this filler queue to the objective. So, you have light beam coming from this end cutting portion of it through the filler.

And then the cut of portion which is necessary portion goes and falls on to the 45 degrees mirror, which is placed in the center of the queue and it goes reflected through the mirror because that is the property of the dichroic. So, let us say we are trying to cut off a 390 plus minus 10 nano meters wave length band. So, essentially we use a filter. So, that the particular package the part of the package of light, which comes out to the filter is from 380 about 400 nano meters.

And the let us say we have a dichroic mirror, which cuts off at 590, which means the anything bellow 590 reflect of the mirror and anything about 590 refracted of the mirror and it goes fast in the mirror. So, now, a just because the reflect beam goes down. It actually passes through this lower end after the filter cube. And reaches through the objector on to the sample this right here, it is the sample stage it is the x, y, z is precisely moving stage, which is capable of positioning the sample, with respect to the objective.

And we can actually many over, over the sample and see the portion of the zone, which we want through focus and image. So, essentially when the light goes and strikes the sample surface, and there is the fluoroform. And there is an emanation of a certain frequency, which is the emanation frequently of particular fluoroform. Now, this frequently actually would come back from the objector.

And come through this hit the mirror and here as you see, the diacritic does not job again. In this case, because of the toke shift the wave length that is generate by the flora since it is actually higher, on the higher side. And so suppose, we have a fluoroform with generates a emition frequencies in the renege of 20 nano meter may be, which is above the 590 cutoff, that is provided by the dichroic.

So, what the light been which is going to come from the fluoroform through the objectives, it going to do is go past the mirror in the reflection more. And essentially you can pick it up using this other filter here, which confer the stream line in to the band that we are looking that. So, any think above 590 is sent out and then, we have try to identify let say a 620 pulse mains 10 nano meters, which is about 610 to 613 nano miters.

Regain and band of the wave length, which actually comes out. And comes through the objective on to the I piece. And that is how we get the image. Now, in a bright filed, dark filed options particularly for lithographic. The problem that we faces, that we cannot image this silicon wafer, which are actually OPEC using and inverted mechanism of light. In glass sample, glass holder are transparent renter to translation samples. That is impossible, there is the light source here in the micro scope, which is actually white light.

As you can see, which can go past at the sample surface, if the sample is kept at this particular stage. However, in our case if I put the silicon and silicon OPEC, the light will not be able to go part. So, this is really not the imaging modernity will are looking that. So, what we use is this principle of filter q and essentially we just remove the filters from both ends. So, therefore, it is just plain light, which we are actually looking act for exiting.

Whatever is reflected of his captured and essentially, we can actually design the dichroic mirror the manner. That it actually gives only in the visible regain of the spectrum. And so typically we can see a mixed coloration, probably white light, which is reflected of in the surface in this wafer. And which comes out and gives a good filing about, what the images on the particular sample. Now, what the objective would also do is to try to blow up in the image and make it well magnify.

And this is very essential for micro features. We are looking at let say a 26 micron features. Or let us say a 50 micro on feature, as we probably know. All of you probably by now know, that the human here itself its about 100 microns.

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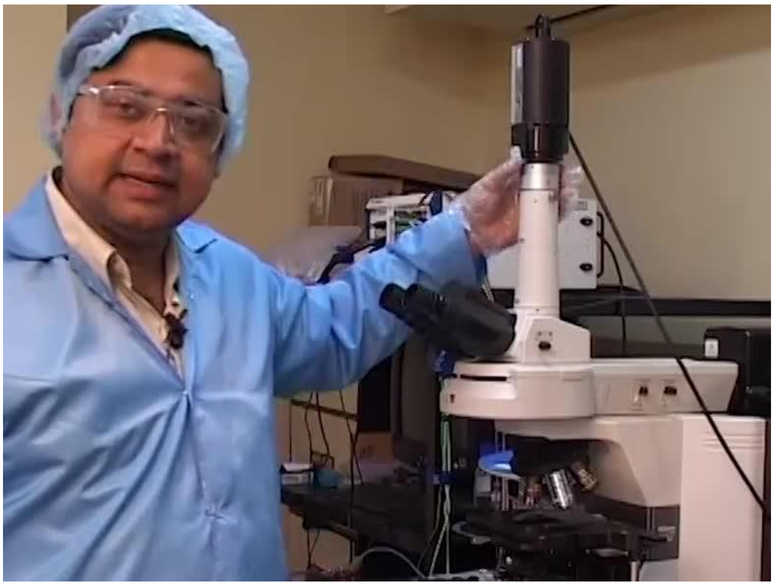

So, we are talking about half of that size, or we are talking sometimes about 1 10th of that size. So, it is not very easy to visualize and to really magnify to a certain extent, and this of the tools, which is use to do that. So, in this background mind, let us go head and try to do some imaging on the resist, that we had actually process that day. And so essentially I would like to close the filter cube. And I would like to tell you know about, how the image you can processing can actually be done using this particular imaging system.

So, I am also going to show you now, how we acquire this images digitally. Of course, through the I piece, this is also known as the I piece, through which the image can be seen. Because, it is closer to the human eye, that is why we call it I piece. And essentially what I am now going to describe the way, that we can digitally occur to these images, and electronically centered, so that we can have digital photographs. So, one of the option that is available to us in this particular scope.

Is this unite right here, which is also a charge couple devise, a CCD camera. And essentially again this is probably the finest form of miniaturization, that can happen, using micro electronic processing technology. So, essentially whatever light intensity, is allowed past the dichroics and the filters. Actually goes past this tube here, and there is small palter cool CCD chip, which has to 1000s of this, millions of this pixels, which are independent the devices.

So, the idea is as the intensity falls on these devices, the intensity of the light, there is the transaction process. There is the generation of electrons from the photon. And that gives you a signal. That gives an aspect about what is the intensity, what are the different textural porpoise from which the light have reflected. And that can be reconstructed simply to make, what we called the real image. Of course, the magnification is done at the outset here, by the objector of the particular objector.

So, the light goes pass in to the CCD here, the charge couple devise here. And electronically transfers, the data electronically transfers to this data cable as you seen to a computer, which is placed right over. So, the data which is collected here electronically go past this data cable, all the way up to this computer here, that you can see.

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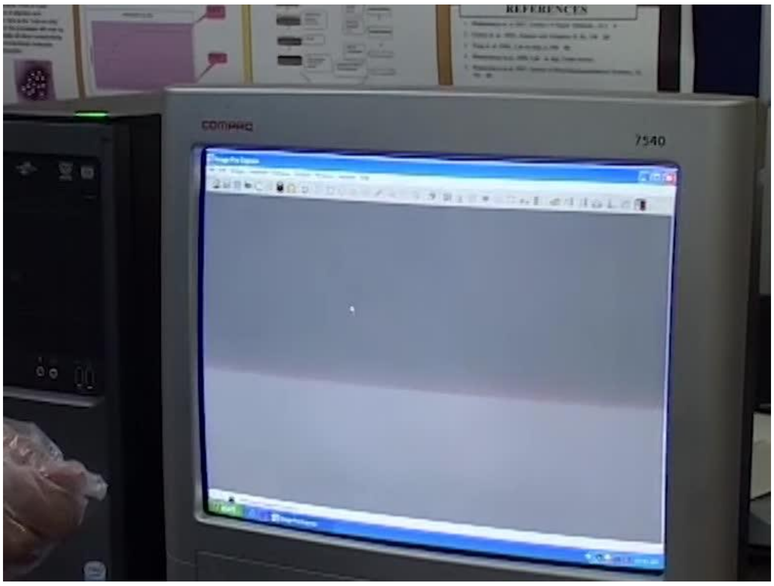

And essentially in this computer, we do have a reader software, which actually also is able to acquire the data from the charge couple devise on the microscope. And read it on the frame digitally using this particular software. So, we have lances the virgin of the software called image prove, which is used to identify the signal sponsor, from the CCD camera. And essentially I am just in about few minutes it is going to demonstrate, how we can read out using the I piece, and how you can see here. Now, the advantage that the software are also offers is that we do a scaling mechanism here. Were by feeding particular scale fact, the magnification factor we are able to generate a coarser, which can give you dimension, as you join a different point on a some image. So, essentially I am going to describe this whole operation, by starting with hover sample, which is the span coded exposed.

And developed of the microscope stage, this right here the x, y, z the stage. So, I am going to actually go head and just simply place this wafer on this stage. And kind of approximately center it, this being of wafer, we do not have a clapping here. But, essentially now what I am going to do, is to actually take this filter set, to number 4 option, which is actually the bright filed option here. And I already describe, what bright filed would mean essentially.

And then, I am going to actually turn on the shutter. So that the light start falling on the wafer surface here, through the 4 x objective. My goal now, it is looking to the I piece and see how this image his being visualize on the top of this wafer. And yes, I can actually now see the images very cleanly, which I have come from the resist. And I am going to actually transmit the data on to the CCD screen, for your advantage, so that you can see it. And I am going to now also position the wafer in an area, were we can relay have a good grass to and you can also scaling etcetera.

So, this right here I have now a very well focused object. I just change the focused a little bit and see I can go any better. I think is probably now very well focused on to the area. The way that you focused these thinks is by lifting the stage up and down, and going in the redirection. You have a libber here and corresponding nob on the other side here, which you can rotted cloak or anti-cloak wise, for the z displacement to happen in the positive or negative direction.

And what you need here is actually looking to the scope in to the I piece. And see corresponding to what z distance, is the image contract, the maximum the image revolution the maximum. You will see that the above a critical distance, if you go any further the image becomes blurry. Similarly below that distance, if the image you know comes it becomes, blurry again. So, therefore, we need to relay a certain the right z level for the correct focus to happen in this particular case.

Now, I am going to actually transmit at use this CCD camera to acquire what is there, for your benefit. So that, you can see what you did or what we did in our last experiment of photolithographic. So, for that what we need is basically try to use this libber to open the shatter for this particular camera. Now, there are three options in this particular libber, as you can find out. And this limber can be actually come out and go back in.

So, essentially when the libber is actually in it is inward position, it only exposes the I piece. And you can only see the image, but you cannot really see it through the CCD camera. But, if you are actually able to push it all the way to the most outward position for this libber. In that particular position you can only expose the CCD camera, and cutoff the I piece. So, you cannot see any think any more by this I piece.

So, I am going to now transmit. So, now this the libber bring in this position, whatever is reflected of the surface of the wafer, is getting transmitted to through see CCD camera in to the computer. And I am now going to actually look at this image, using the software. So that, you can also have a gross on that. So, we had earlier opened the image gross software. So, what I am to do here to go to this acquire menu. And there are different options here in this particular software.

The first option mention video slash digital capture. So, we actually we are able to, so our purpose here is to get a digit limit. Although the capability of system also to get real movies. A particularly in a real time cases, were you may be capturing particular or it may be doing a reaction etcetera, within a small architecture. So, the capabilities of this particular microscope enormous. So, what I am going to do is actually ask this microscope to digitally capture.

And so there is menu which other opened here, it is called q magic menu. And we have different option in this menu including the exposure preview, the exposure acquisition. And essentially you can also have auto calculating of option for the intensity, so that you can get good grass for the image. So, I will actually be able to first see the preview here from the option.

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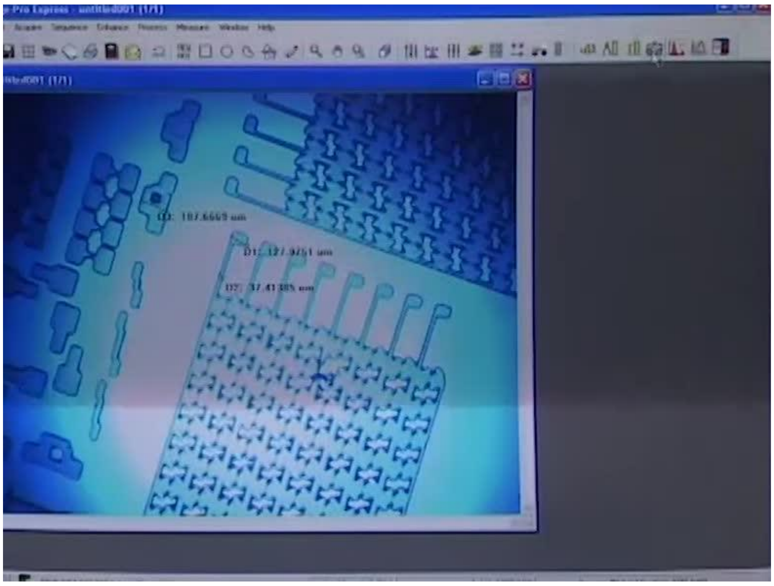

And if I click on it, as you see this is really the image, that I was wanting you guys to see. This is some think that we have developed using for the lithography, on to the surface of the wafer. Now, I will doing the dimensioning part just about in a little bit, but what we need to do is to actually. Suppose, there is out of focus or in focus, you can actually change the focus stage in the microscope as I told you. And we able to get very good focus on these images.

Now, this is probably one of the best force side, that one can get using this images, because I am already calibrating ((Refer Time: 1:27:01)). Now, I am going to actually store this image. So, I go to the snap option here, an automatically photographs is generated. Here as you can see, which actually gives you digital image of what has been captured from the CCD camera. Now, regarding the scaling option, this actually a very easy way out to do scaling.

So, what I am going to do, is to actually a see what magnification we are using, for this particular image. And as you may recall the magnification that we had used was 4 x. So, this image is 4 time we actually size of the image, that is there on the feature. So, I am going to actually go head and use the calibration tools. So, you go to the this option called measure, there is a calibration option. And then, I also want to somehow ask the software to identify the scale, at which the image is proceed.

So, the magnification value as to put in the software, for it to tell what really would be the actual image size. So, what other size are getting in terms of pixels, on this in digital image would be converted by dividing by a factor of force. So, that the actually size of can be option. So, I am going to actually go ahead and ask the system, or give the system the magnification. So, it is providing a standard magnification of an 10 x which is mean the inside value, but hours are 4 x. So, we go to the drop down menu.

An actually go head and see or input the reference calibration. And make it 4 x and let the system understand, it is 4 x. And then, we have an option here of scale, which is actually having the text box, which says measure lens. And distances in the particular image, so I click on this option, an a scale comes up. And then, an actually going to use the courser and connect two points from n to n, to see what distance, it would be talking about.

So, let say if I click on this edge of the image here, right here. And go and click on this image edge here, in this particular area, this distance his corresponding to about 127.9 macron. So, 0.9 is actually relevant, so let us say it is about 128 micron. So, this way we can actually get a very good feel of what the actual, you know distance would be. So, let say we want to just connect these two points here on the small, you know this small piece here.

So, this is corresponding to about 37 microns. So, essentially you can actually measure, say from here to here in this particular figure, which correspond to about 187 microns. So, you can actually very accurately, in priestly measure the size of what has been generated. Mind you this 37 microns is the one only one third the human here is the dimension. So, it is the real small entity to be seen with normalize, but the powerful imaging system or modality that we have enables us to actually see and measure what we have done. So, essentially I would like to actually go ahead and look at other area and let us actually save this image.

So, we save a changes to one title. So, we actually save a by going to this snap option. So, we take this of the snap, because you know we done the measurement see here. So, even this needs to be snap for saving properly. So, we snap it and then go to file and save this as certain let us say experiment photo autograph one and use the same option here. So, this has been saved on the desktop.

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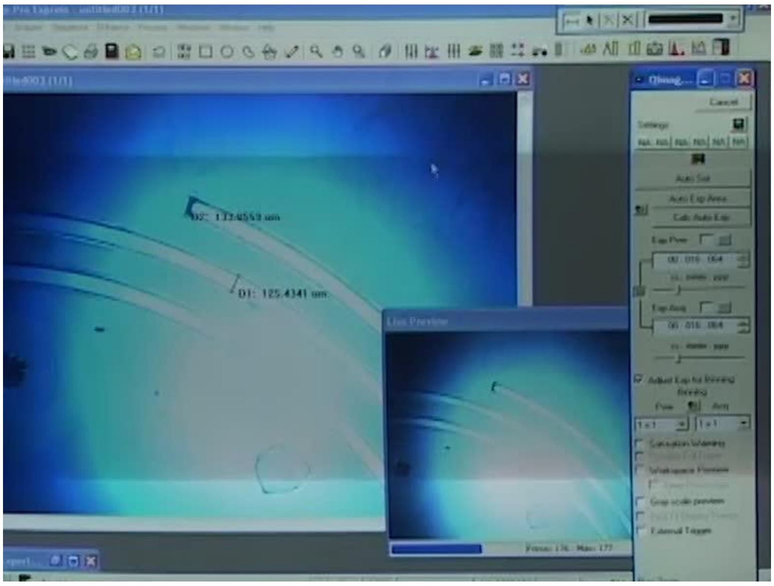

We can go exists by just looking at this particular image here, it does be save and we can see that this image exactly is the same as we had done before, save before. So, we can save these images digitally use them at advantage. So, what I am going to now do is to actually use the different area on the wafer. And would like to show that how or what all features are there on the way for the surface. So, I again basically go to the acquire more and use the video digital capture.

And now I am going to go and essentially do the preview mode, you can see this is what we done before. And I am going to move off. And let this shift to different places. And you can see what all as been return, in this particular in a domain. So, let us actually go to a different area of the wafer, let say we are talking about this channel like, regions here. So, these are essentially the circular channel like religions. I am interest to find out what is the width of one of this.

So, these are actually trencher as you can see in the resist. And let see what width of one of these particular feature would be. So, we can again snap the image based on this put it some were down here. And then, again do the calibration by selecting spatial scale; and calibrating it to 4 x. Mind you the system actually gets back to the default an 10 x every time we taken image. So, we have to actually be careful of feeding the exact magnification factor, that we are using we have not changing. So, we are using the 4 x, so we make it calibrated again, we go to the scale option. And let us look that the size of one of the channel.

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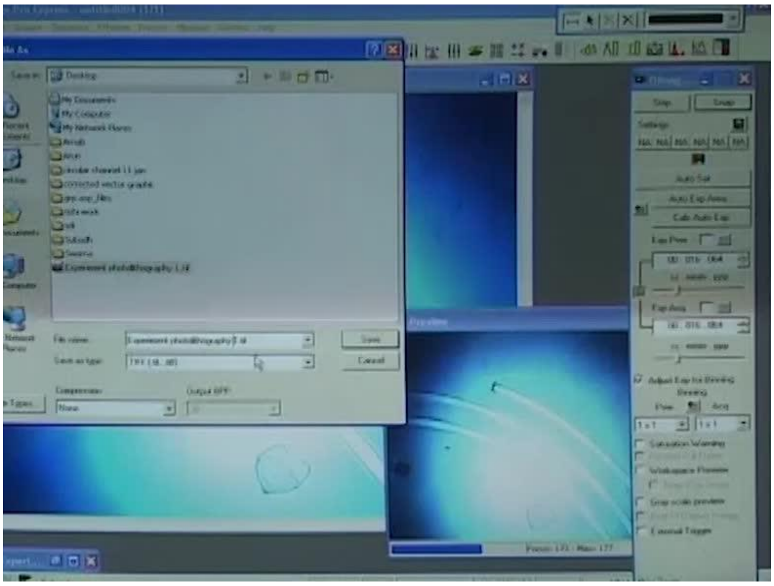

So, this size really is about 125 micron. So, essentially let us also look at one of these edges, how this edges would look like. So, they are again close to about that same 133. So, 125 133 micron, so around 125 to 130 microns domain. So, there are some other areas on the wafer, let us actually do the same of option again do save it. We go to the snap tool and essentially save this file; and make it experiment photolithographic to option. So, we make to here and save this image, close this particular image here. And then, let us go to different area on the way for and look at some other options. So, if you look at some think is return here, on the results.

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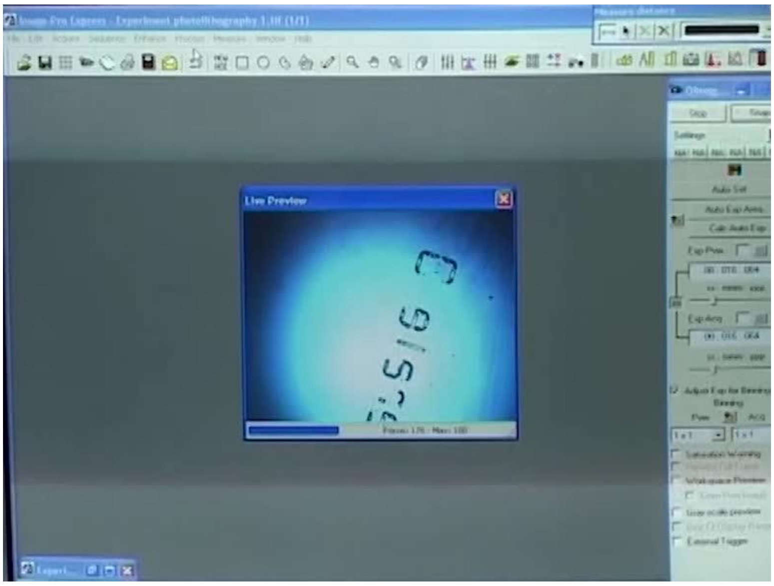

And let us look at different spot, where it may be little visible in a little bather sense. We have to probably to some focusing, in order to he what as the actually return here. And let us, actually focus this is going out of focus, back to focus here. As well as some think like, an the inward damage of what was they are on the mask, his probably. I can see this is the inward at C, this is the inward at E, inward at I S. And in this particular domain, let us actually shift the way for a little bit.

So, that we can exactly see what is on this. So, we actually move this wave for this about little bit. He develop thin film of metal on to such as results. And then, removes of the area, where the results was cross bounded or and unbounded on remaining. So, they therefore, when the result comes of he takes of the metal of also, on the places of the we are staunchet are ((Refer Time: 95:40)) which one open in between, where silicon expose the metal place back.

And you can use this techniques for developing thin inter connects on chips expressly macro electronic chips. You can communicate electronically between to such I length and force by having several 20 microns or 25 micron verse ruining in between. And this gives tremendous advantage, which can be used for sensing, diagnostic signal transaction so on and so forth. So, basically ((Refer Time: 96:19)) lithography can be consider to be one of the fundamental process, associated. The first step process associated in realizing some think and the micron scaled.

Thank you.