Introductory Neuroscience and Neuro-Instrumentation
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Lecture No. 45
Details of Lithography, E-beam Lithography and Mask Aligner

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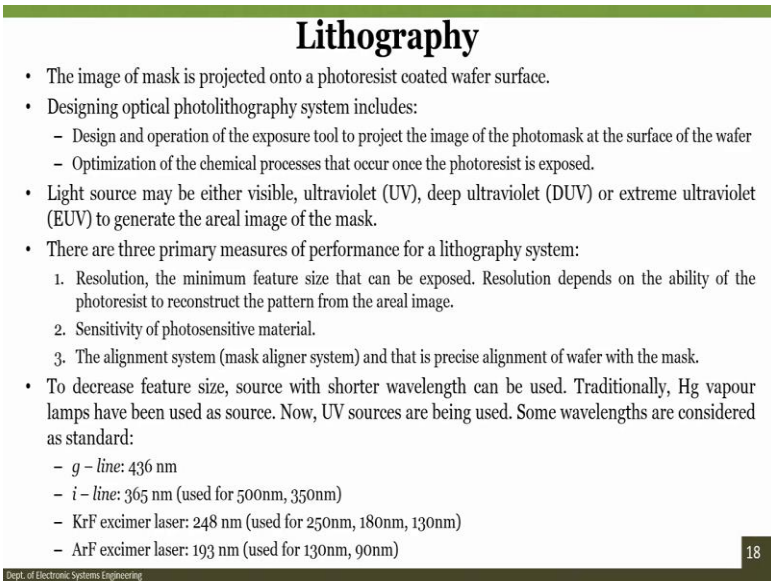

So, in general when you talk about lithography, then it is the image of the mask is projected onto a photoresist coated wafer surface. And designing of optical photolithography system includes the following two things, one is that design operation of the exposure tool to project the image of the photomask and second is optimization of the chemical process that occurs on the photoresist when it is exposed.

So, light source can may be either visible, UV, deep UV or extreme UV depending on the images that you want. Then patterning that you are designing for, there are three primary measures of performance for a lithography system. The first one is a resolution is a minimum feature size that can be exposed and resolution generally depends on the stability of the photoresist to be reconstructed from the real or the areal image.

Second one which is another performance parameter for the lithography system is a sensitivity of photoresist material. And finally and most important is the alignment system and that is precise alignment of wafer with the mask is very important. If you want to decrease this feature size you have to go to from few hundred microns to few tens of microns and further down, then source with shorter wavelength can be used, that means shorter the wavelength, the features can be reduced further.

Traditionally, we use mercury wafer lamps. Now we are using UV exposure lamps. Some people are also going for e-beam lithography, not some people actually lot of e-beam lithography processes are there for obtaining or for patterning a feature size which is extremely small in terms of few nanometer and some of the wavelengths there are considered as standard are g, i, g line and i line consist of 436 nanometer and 365 nanometer, respectively, where KrF excimer laser is a 248 nanometer, it is used for 250, 180, and 130, while ArF excimer laser is for 193 nanometer and generally used for 130 and 90 nanometer processes.

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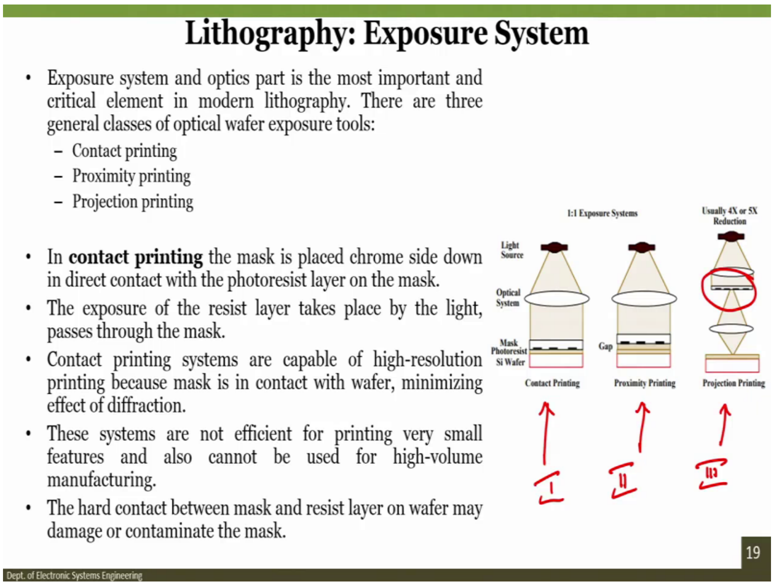

Now, there are three different kinds of exposure system. The first one is contact printing, second one is proximity printing, and third one is the projection printing. So, exposure in the contact printing, the mask is in contact with the photoresist. There is a hard contact. In the proximity, the mask is proximity with respect to the wafer. It is not touching the wafer. There is there is a bit of gap between the mask and the wafer. And finally, projection printing, as you can see that the image is projected through via lens onto the wafer.

So, in contact printing, the mask is placed crome side down in direct contact with the photoresist, it is easy to understand, while in contact printing, the systems are capable of high resolution printing because mask in contact with the wafer mining the effect of diffraction. You see when it is in touch with the substrate, there will be minimum diffraction. However, these systems are not efficient for printing very small features and also cannot be used for high value manufacturing. The hard contact between the mask and resist on the wafer may damage or contaminate the mask.

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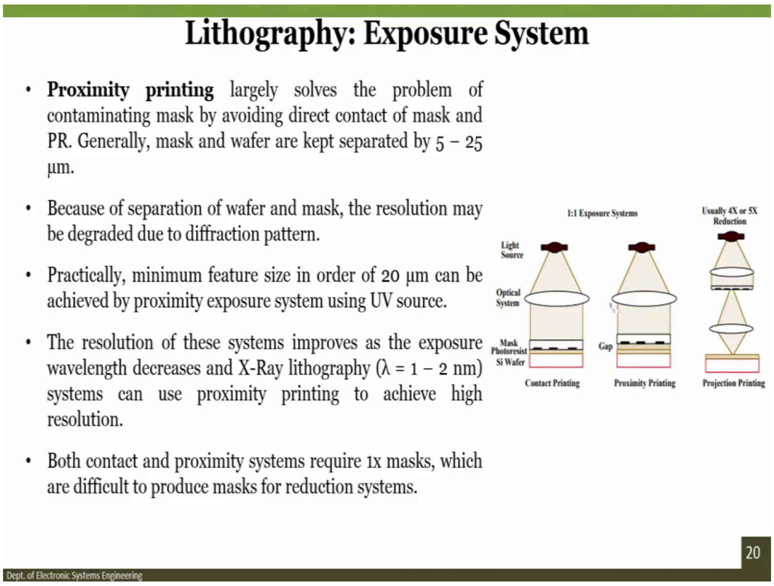

So, if we talk about proximity printing, in proximity printing largely solves the problem of contamination because there is no physical contact of the mask with the photoresist or with the wafer. And generally mask and wafer are kept as a separation of 5 to 25 microns. Because of the separation of wafer and mask the resolution may be degraded. However, practically, minimum feature size you can obtain of order of 20 microns and that is why proximity printing is preferred by approximating or by achieving the proximity exposure.

So, in the first case what we thought that the mask is there and you hold the mask on the wafer with a physical contact. Proximity there is a gap. And projection, of course, there is a projection like if you see the movie hall. There is a projector which projects the image. So, if you see the slide, practically minimum feature size in order of 20 microns can be achieved by proximity exposure system then the resolution of the systems improves as the exposure wavelength decreases, we already talked about that.

So people also go for x-ray lithography, where the wavelength is only of 1 to 2 nanometer. Finally, both contact and proximity printing requires 1x mask. So we do not have to really reduce the mask features because what all features are in the mask will come on the wafer and are difficult for producing reduction systems.

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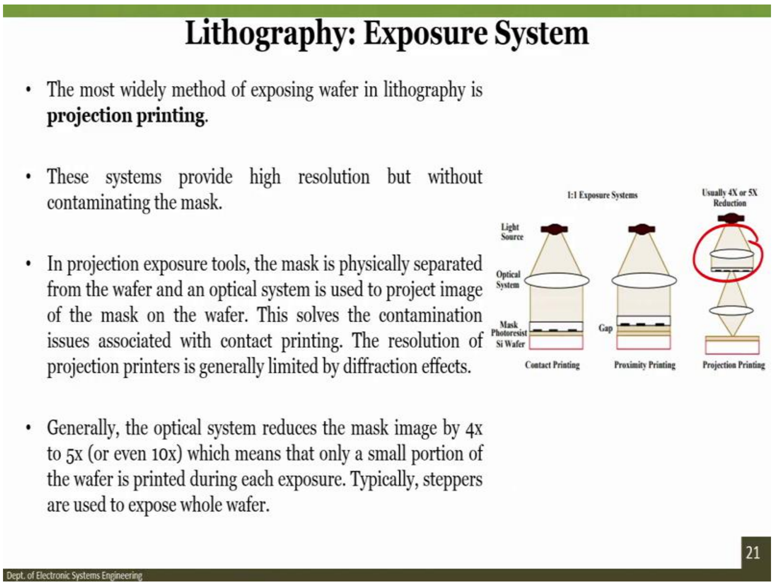

However, if you go for the third one which is the proximity, projection printing, in this case, the system provides high resolution but without contaminating the mask. In the exposure tools the mask is physically separated from the wafer and optical system is used to project the image which you can see here. This solves the contamination issue because there is no physical contact. Also, the resolution of projection printers is generally limited by diffraction effect and that is why the optics is very important.

And generally, the optical system is about, it reduces the image by 4x or 5x. Sometimes in some cases it also reduce the image by 10x, which means that only a small portion of the wafer is printed during each exposure. Typically, in this case, the steppers are used to expose the whole wafer. Steppers means stepper motors. So, let us play two different videos that will help you out to understand this lithography further. I will play the first video.

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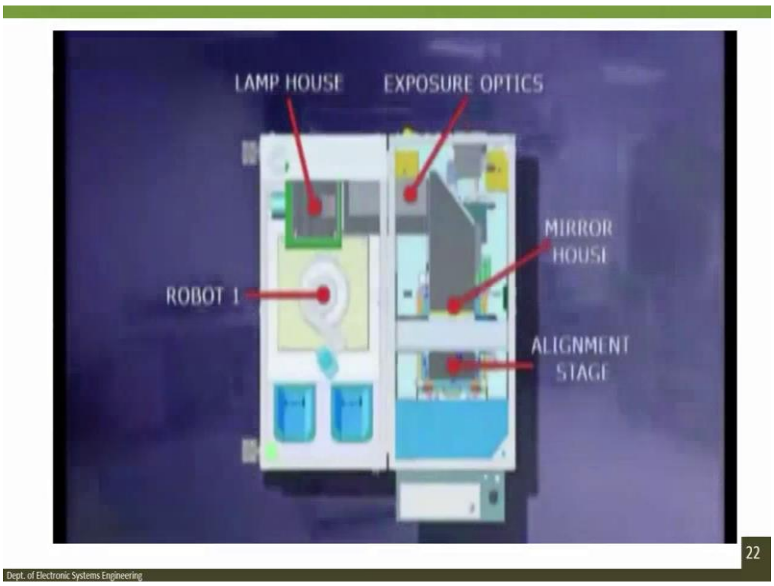

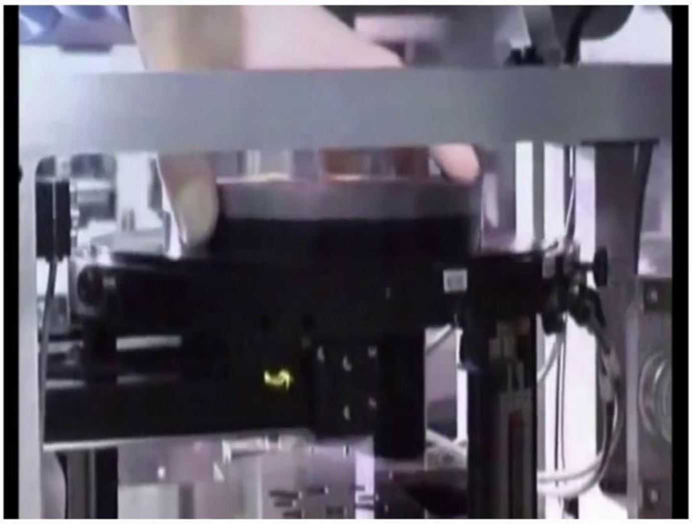

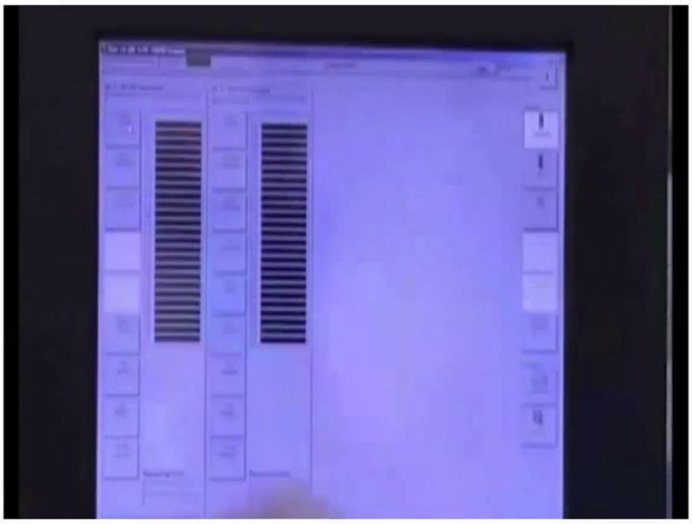

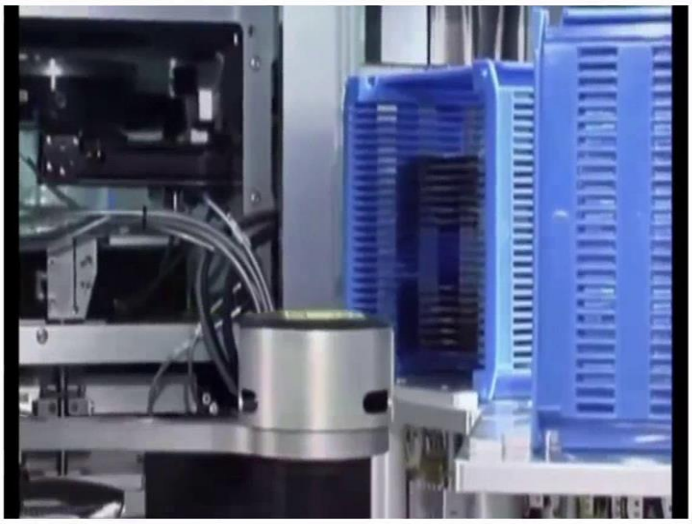

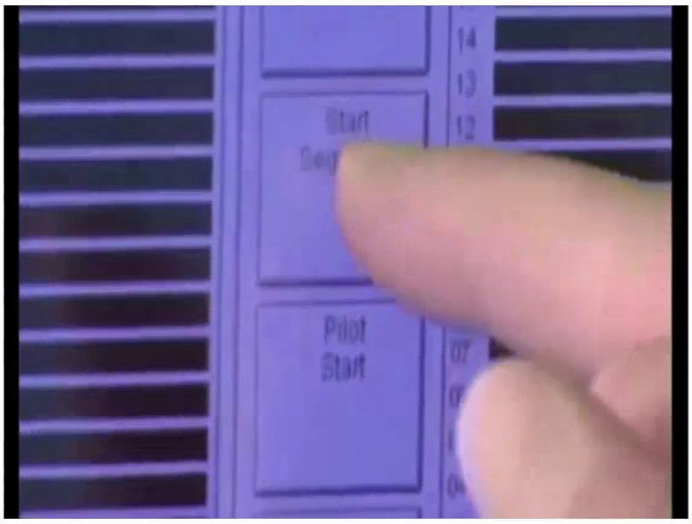
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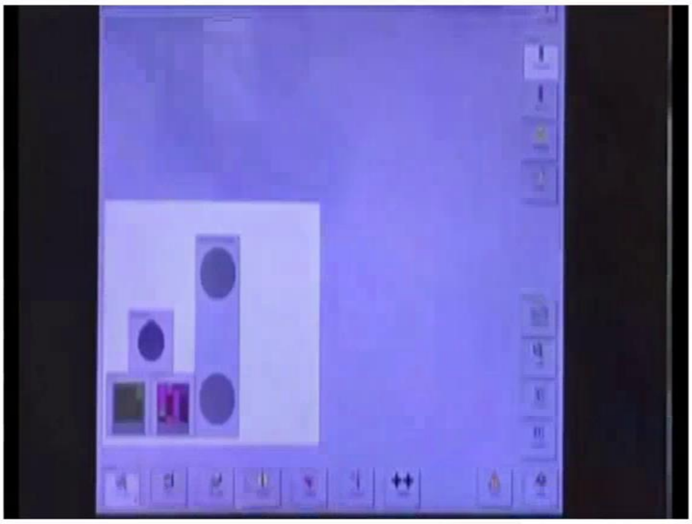

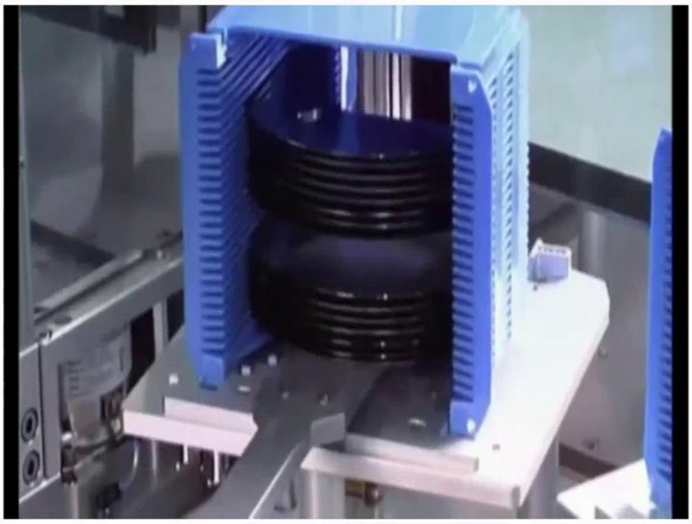


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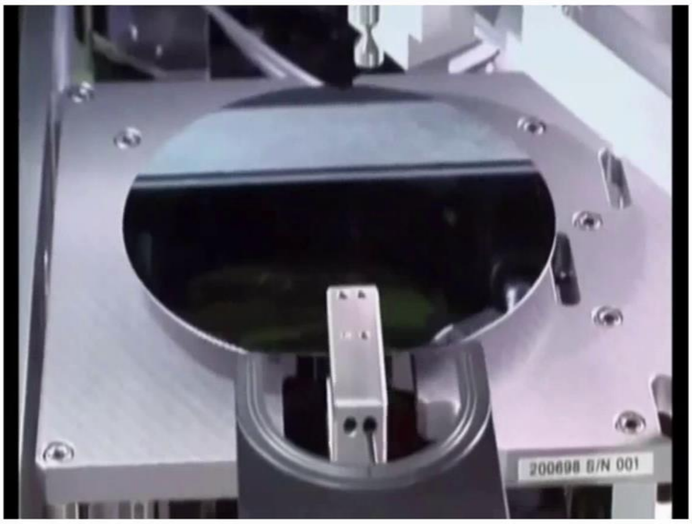
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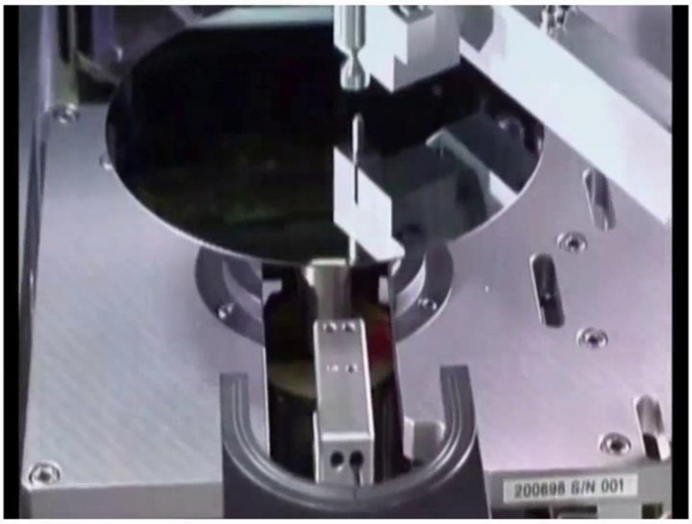
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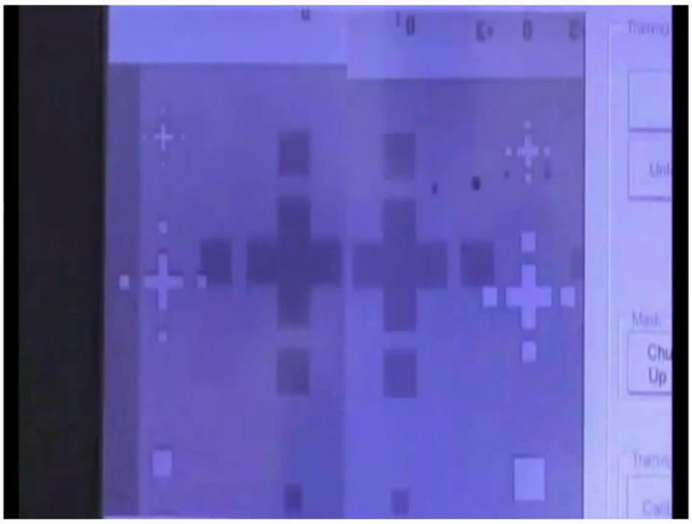

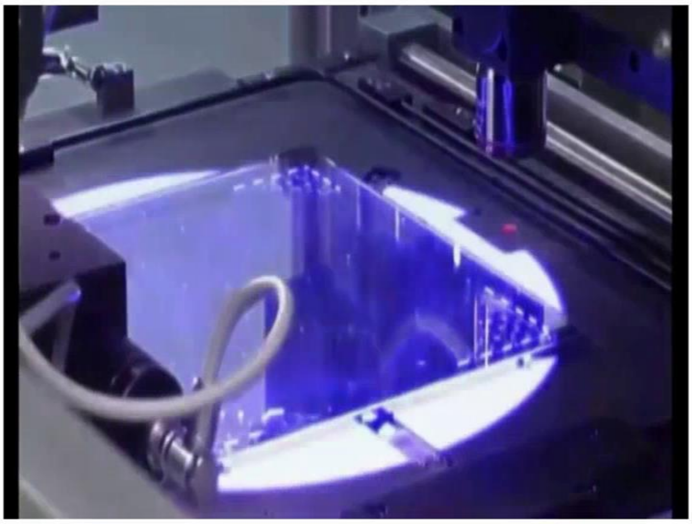

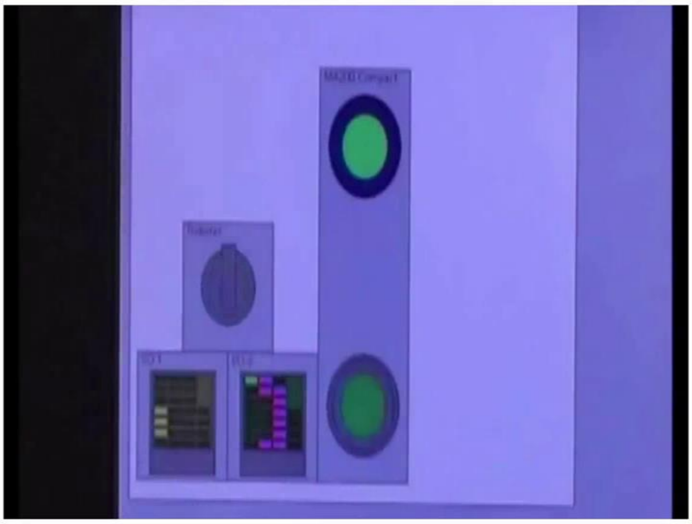

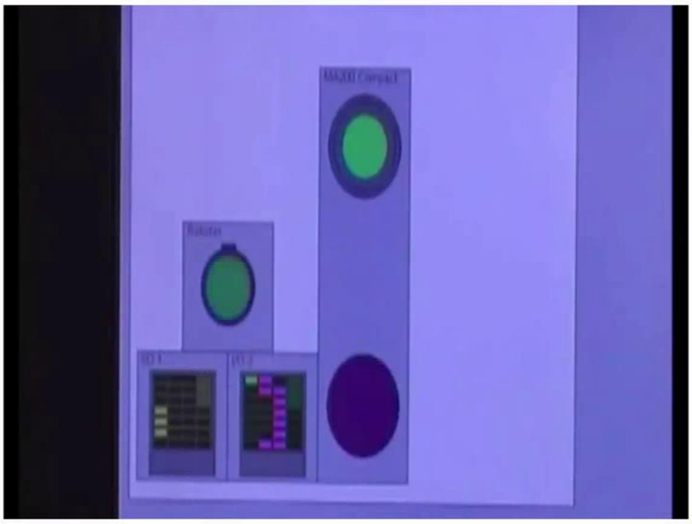

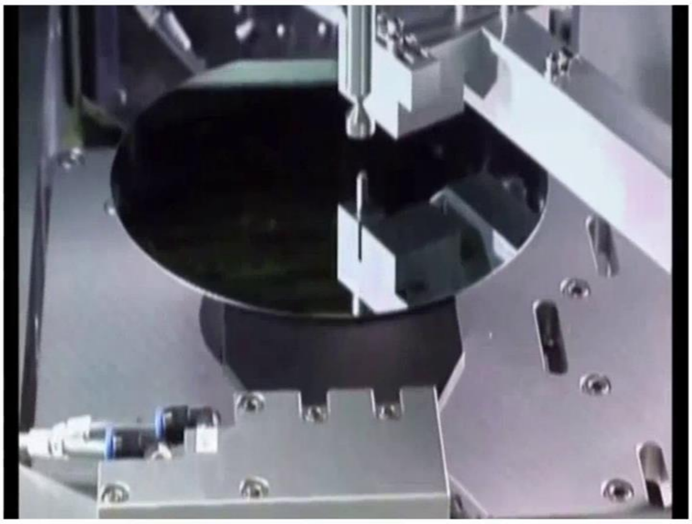

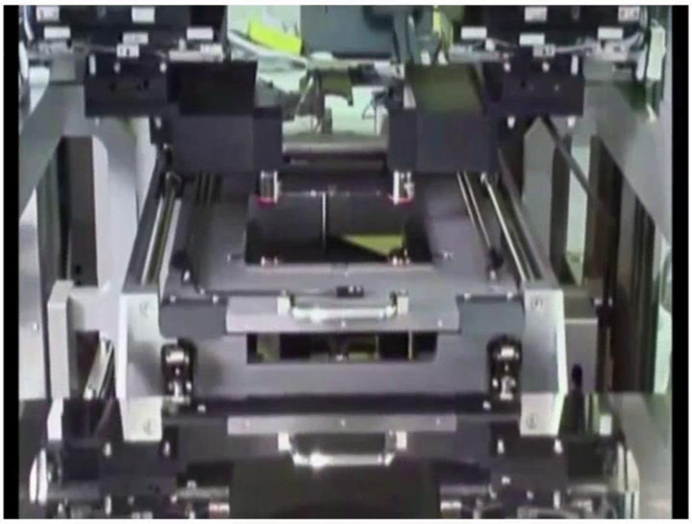

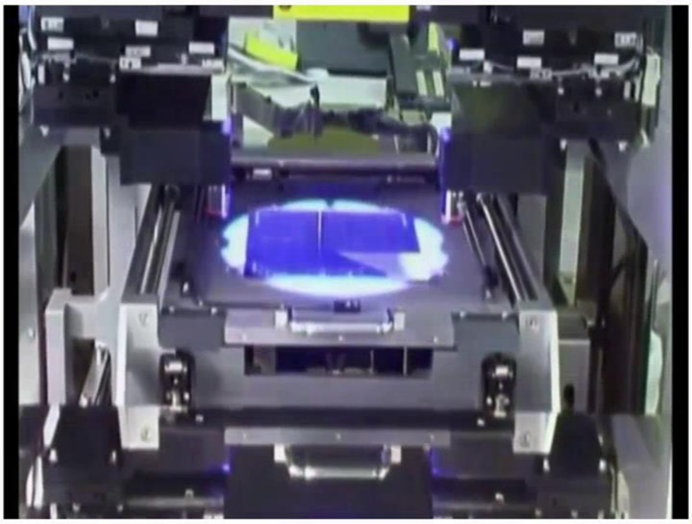

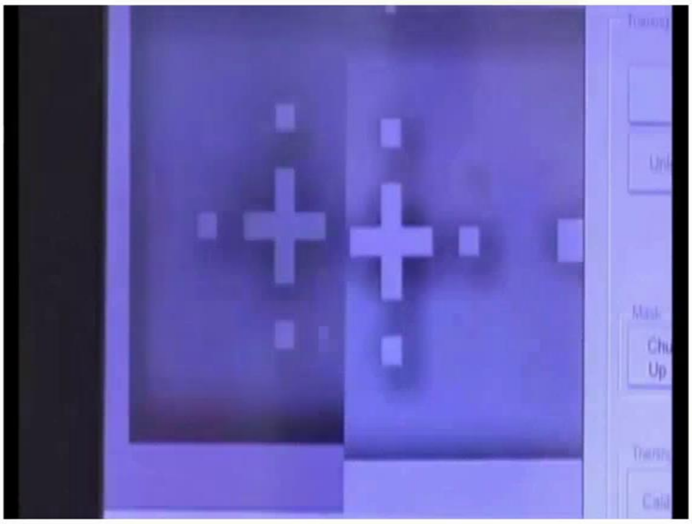
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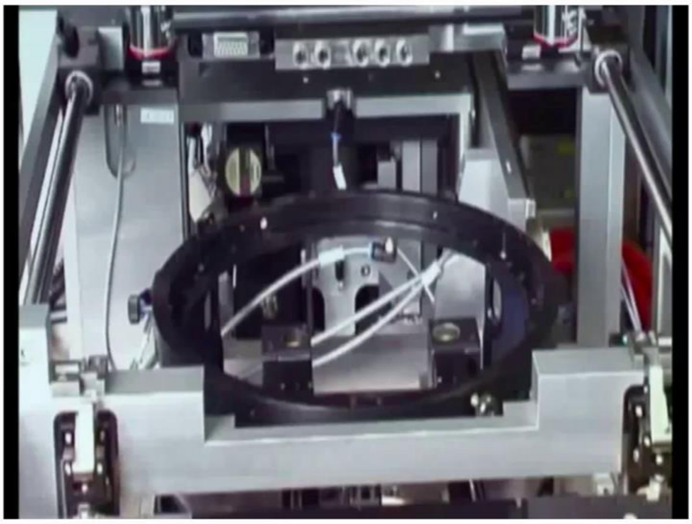

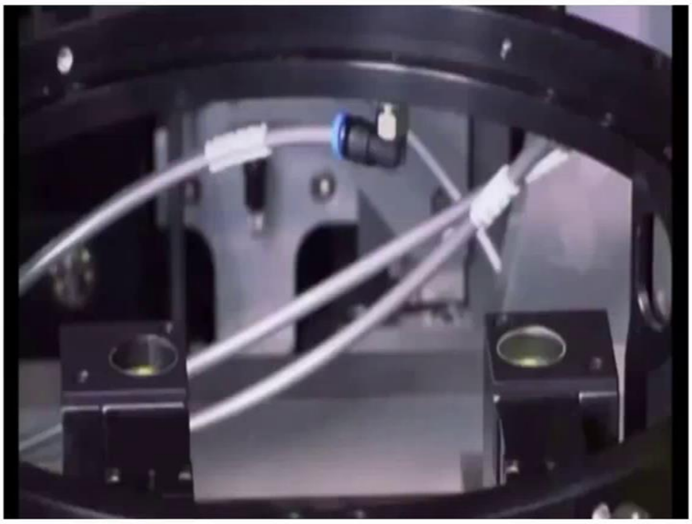

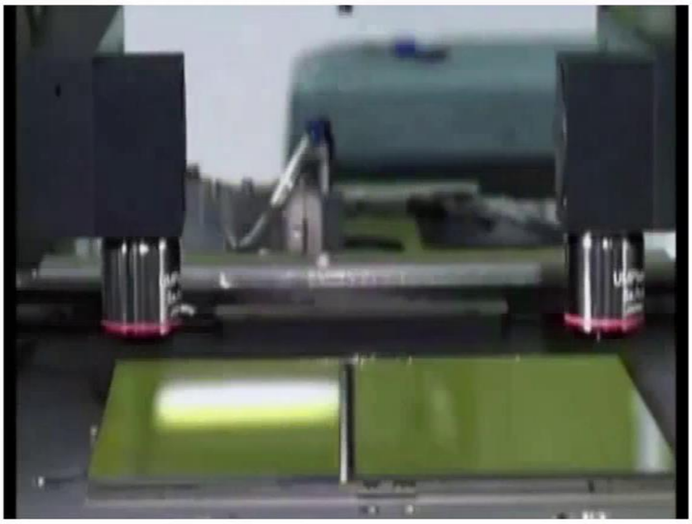

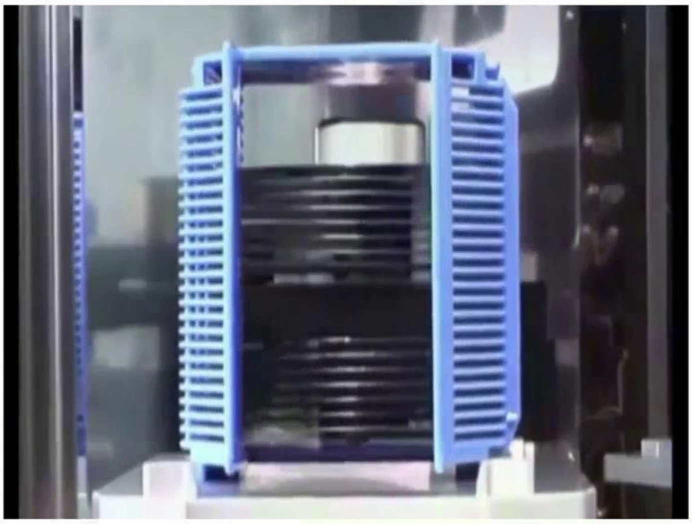


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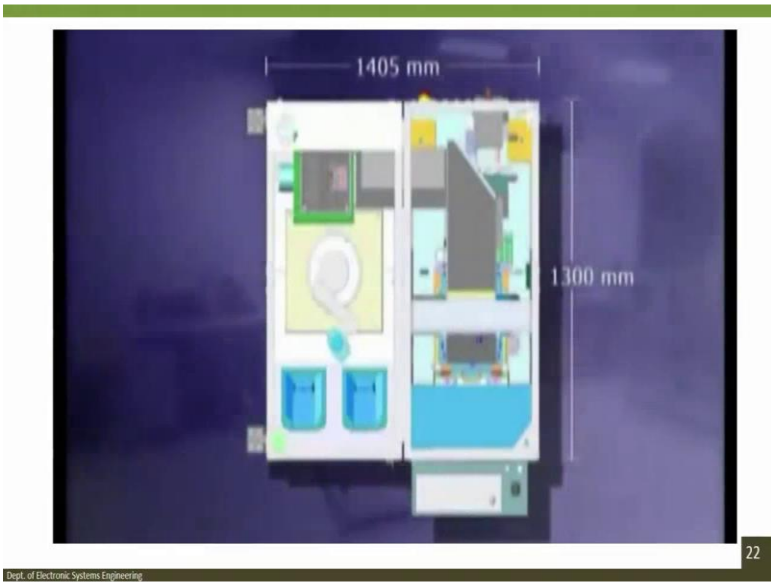

Hello, my name is Ben Heard from the SUSS MicroTec development team. Toady, I would like to present our new generation of production aligner, the MA200 compact, which offers an advanced technology design, unmatched procession and a high degree of flexibility. See for yourself how easy it is to operate. The chuck is stored in the bottom part of the aligner and this is quick and easy to load. Equally easy to insert or the mask holder and the mask. Now, I load the carrier. That is all rist to it and the MA200 compact is ready for operation.

The processes of the MA200 compact can be controlled via a touch screen. For some processes, you can select between fully automatic and manual operation. A robot scans the wafers and determines their quantity, position, and size. And the processing begins. The MA200 compact processes wafers and substracts up to 200 millimeters regardless of their material, size, shape, and thickness.

The machine runs and adjusts fully automatic and is optimsed for the processing of thick resists, such as with thick resist flip-chip bumping, wafer-level packaging, mims, nanotechnology or telecommunication devices. The big advantage over steppers is the exposure of the entire wafer in one step. Thus, a throughput of more than 100 wafers per hour can be achieved with an overlay accuracy in the sub-micron range.

Now, let us load the process down be take a closure look. First, the wafer is pre-adjusted onto the prealigner in preparation for the insuine alignment. A linear transport system loads the wafer onto the exposure chunk which together with the robot arm guarantees the optimal and flexible handling of the substrate. No other mask aligner on the market offers a higher degree of alinement accuracy than the MA200 compact.

With the use of the recenlty developed and patent pending direct align option from SUSS. The mask is aligned directly to the wafer guaranteeing an overlay accuracy of up to 0.5 microns at 3 sigma. The structures of the photomask are conveyed by shadow cast. The patented wafer leveling system from SUSS compensates for topographic variations and vague air. Thus, guaranteeing perfect alignment and exposure resolves. And the entire process is easy to monitor here on the touch screen.

Because of the MA200 compact smoothly designed microscope, during the exposure the mirror housing does not move forward. The microscope is only move sideways, thus reducing the vibrations of the alignment stage to a minimum, resulting in far greater accuracy. The optics of the MA200 compact are optimised for thick resist processing. In thin resists, it achieves a resolution of 3 microns in proximity mode and a sub-micron resolution in contact printing.

A microscope for bottom side alignment is optionally available. It can process substrates with thicknesses of up to 4 millimetres. The MA200 compact is a master when it comes to detail. Our idea while designing it was to create a device that is both for user and maintenance friendly in order to further reduce your operational costs. The electronics and all-important components are easily accessible as well as being arranged in a clear and logical manner.

Because of its compact size, it also saves valuable space in the cleanroom. The MA200 compact is the ideal exposure system for application areas with high demands in terms of package densities and micromechanical structures. I can only recommend that you take a closer look at our new mast aligner in person and we would like to invite you to do so today, the MA200 compact from SUSS MicroTec. And we play the second video as well.

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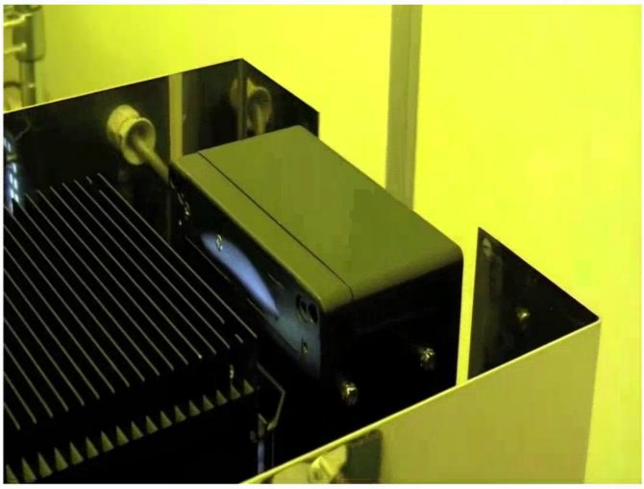


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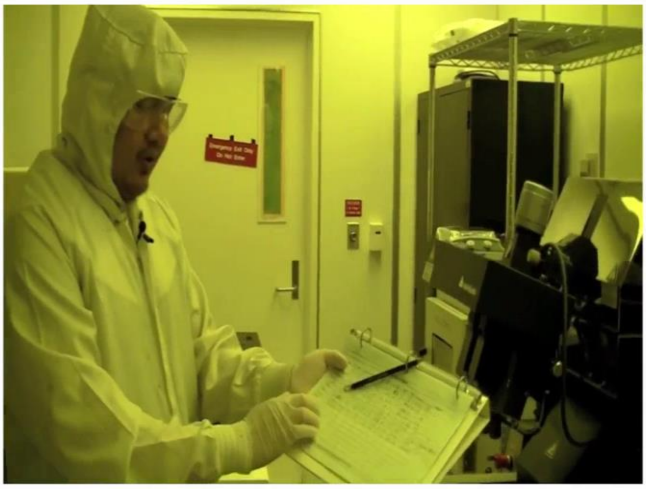

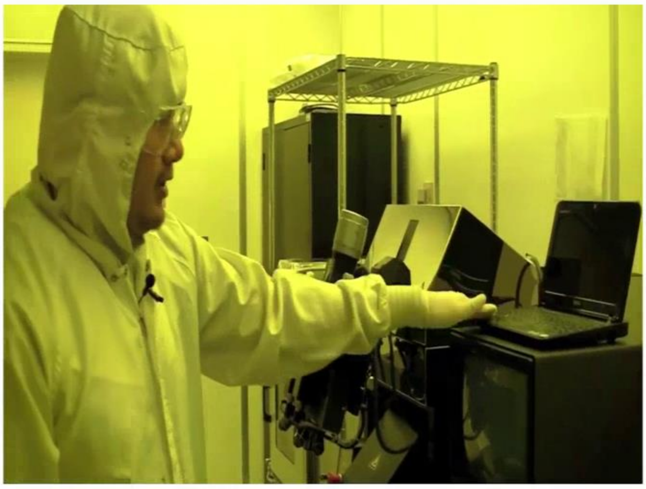

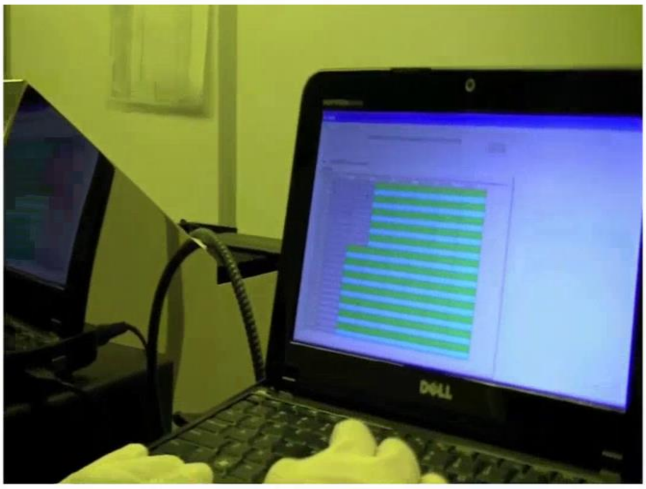
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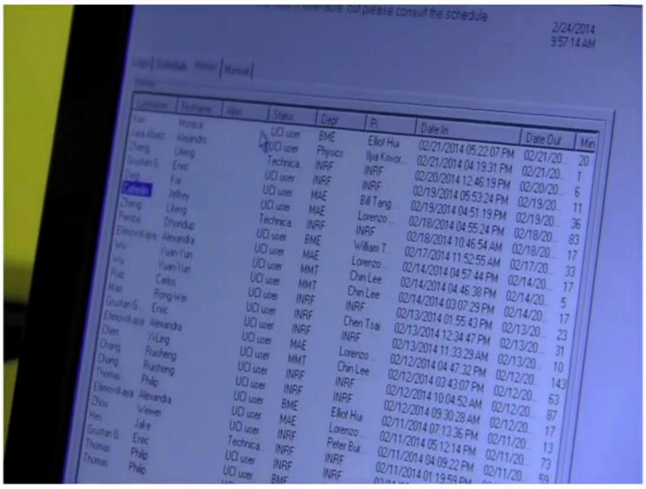
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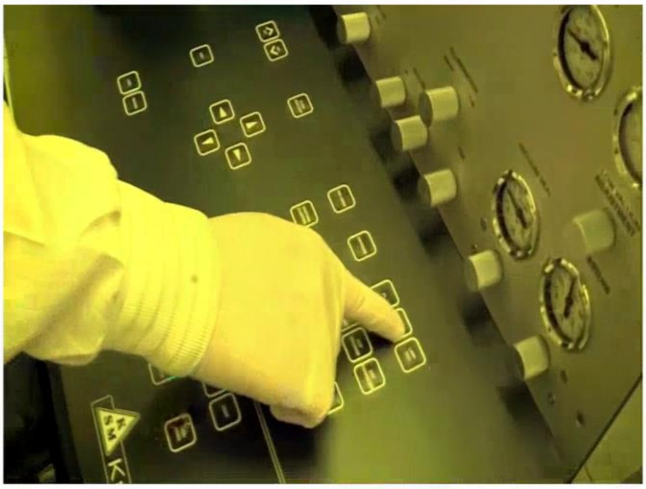

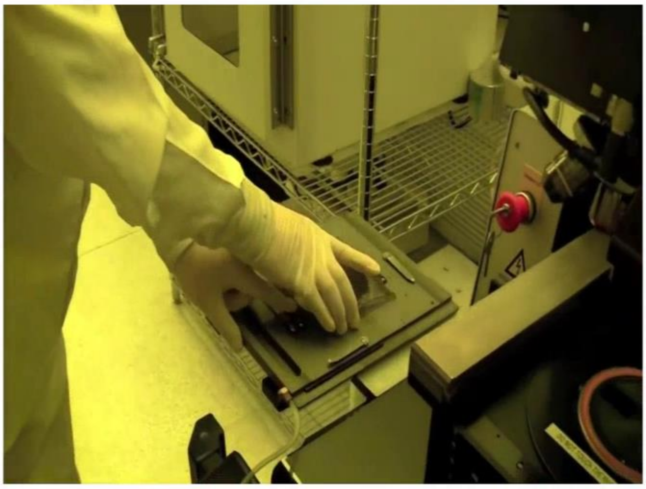

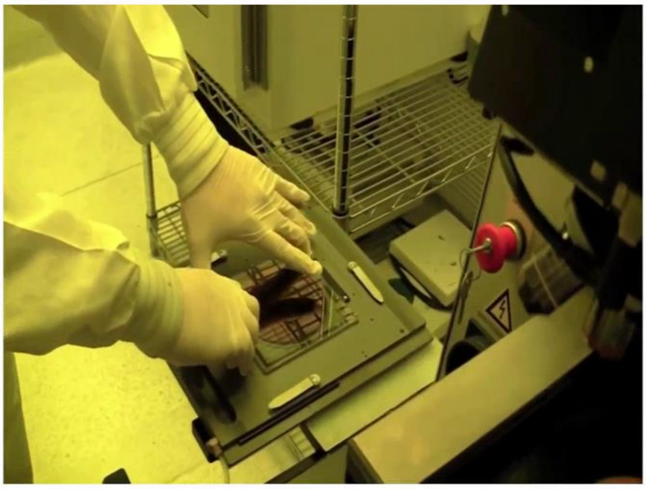

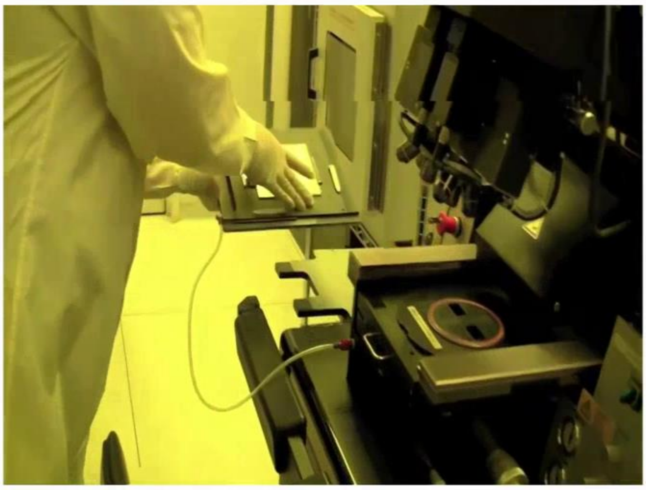

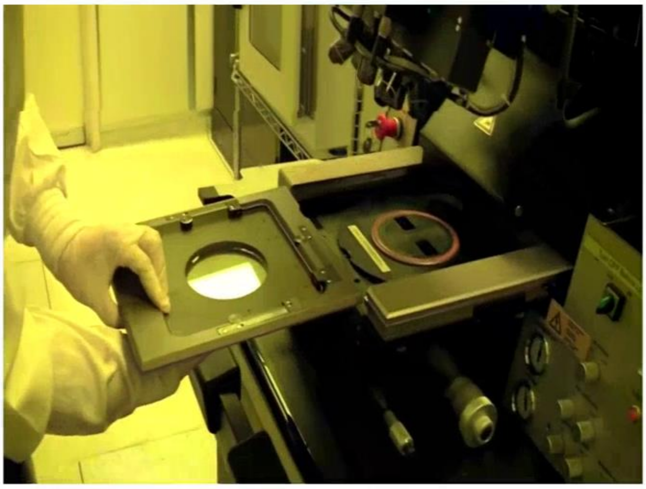

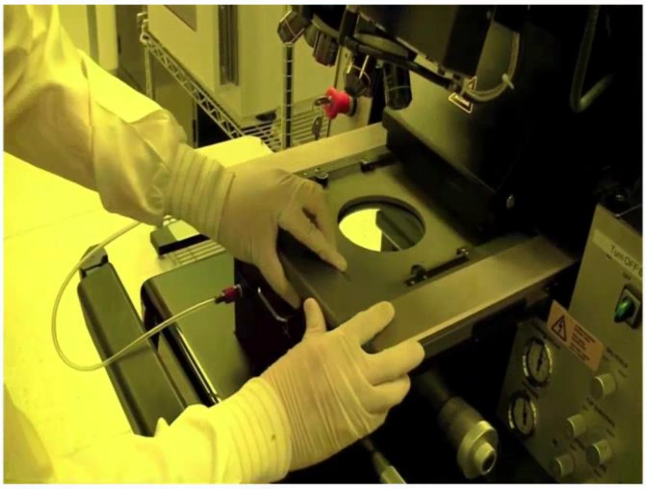

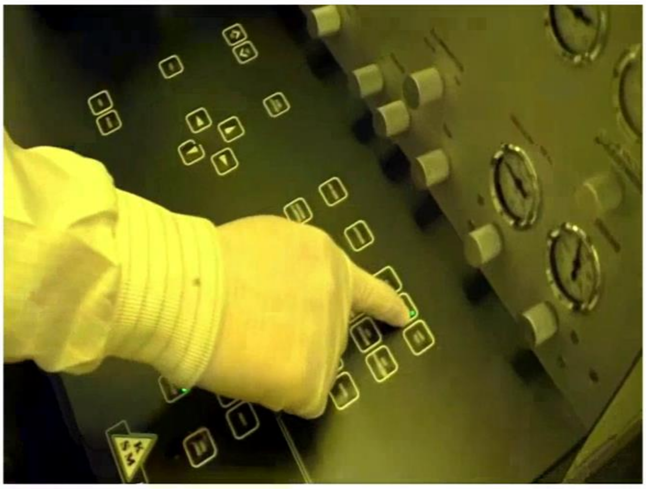

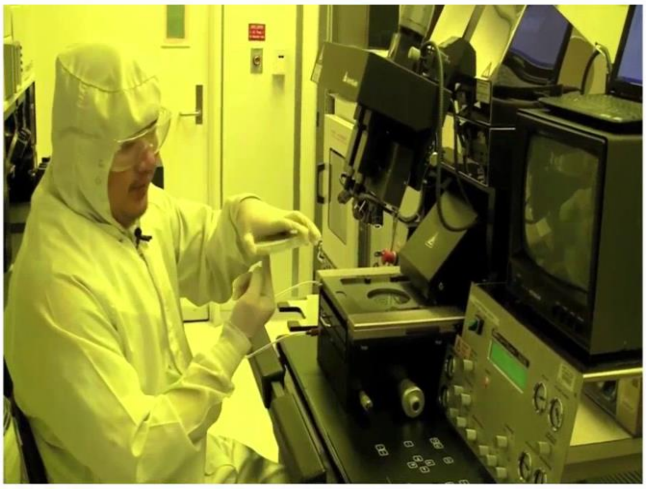

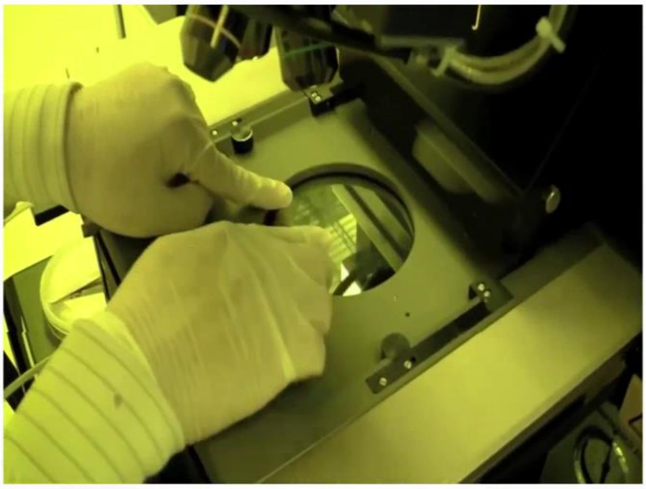

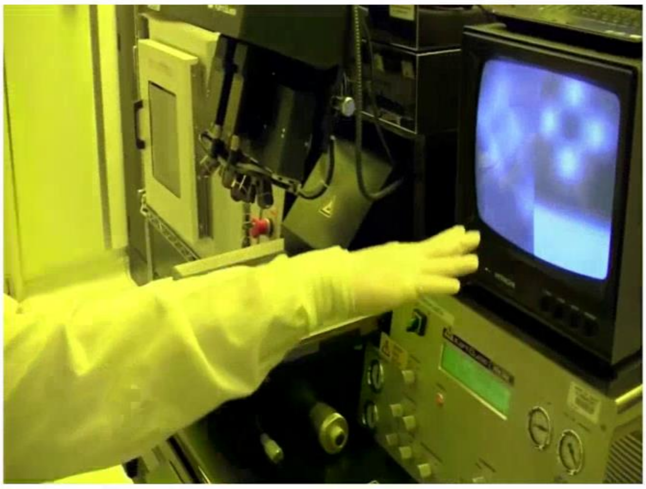

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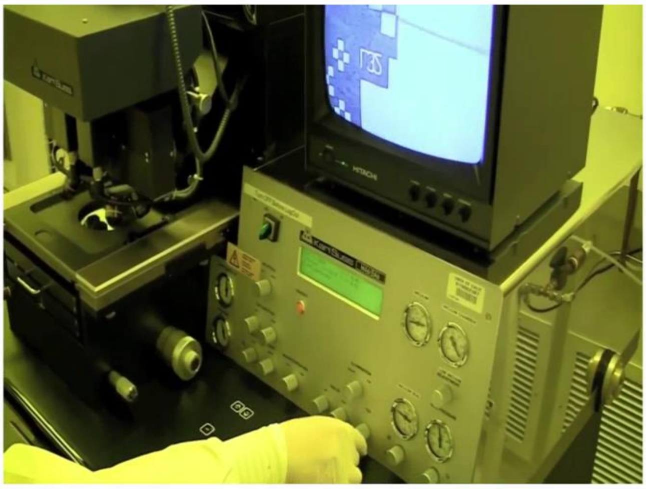

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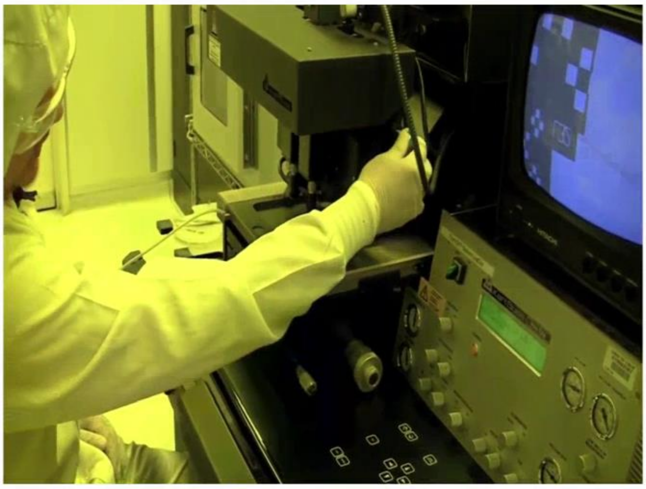

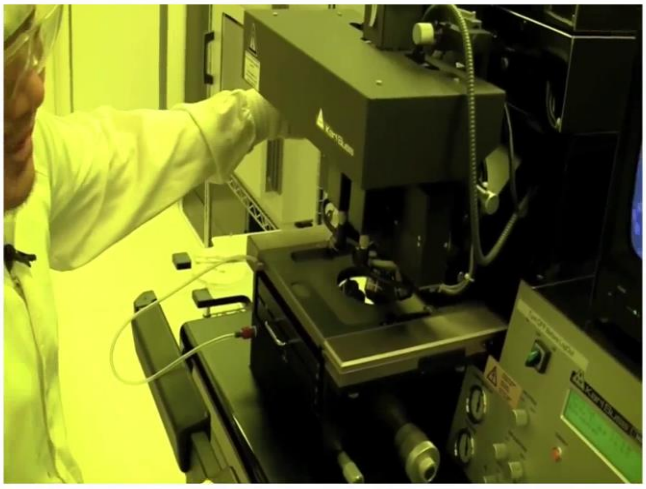

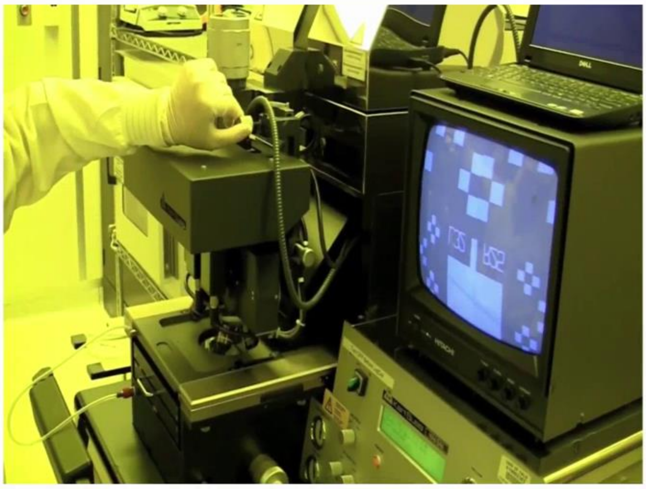

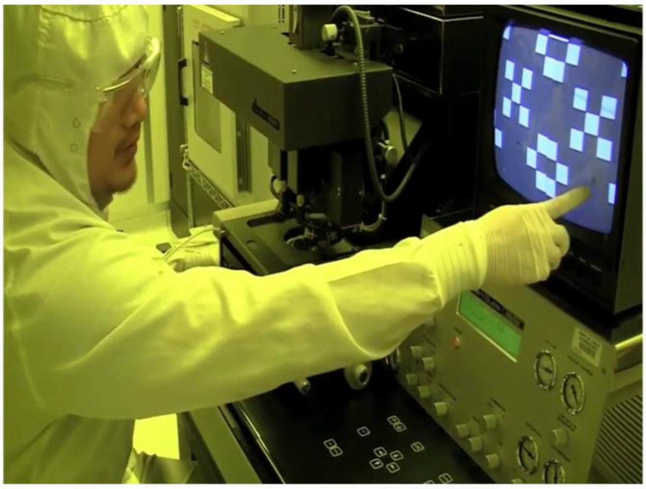

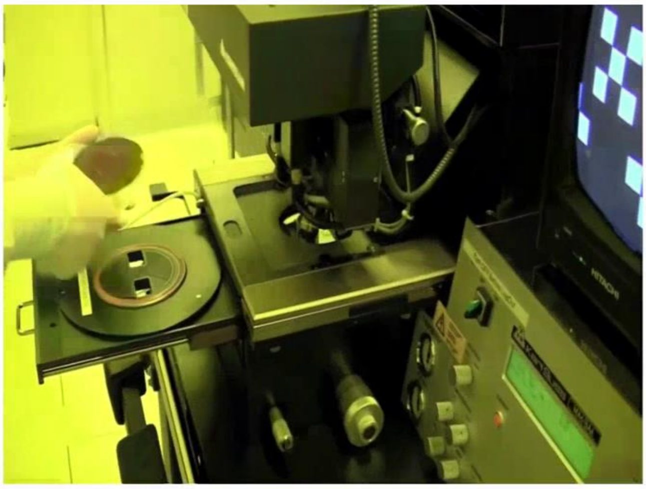

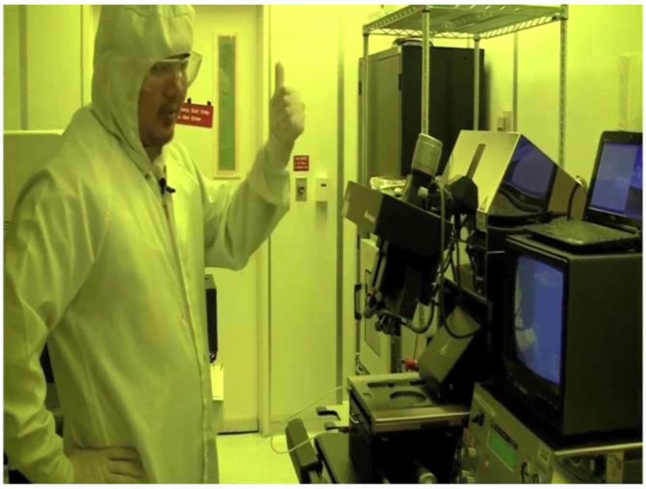

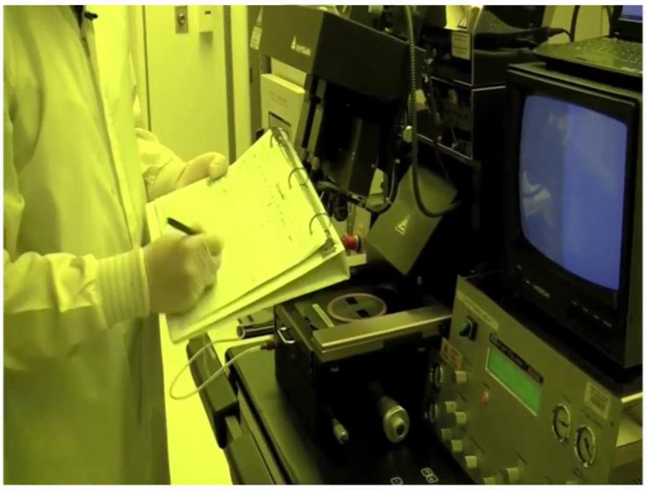

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This is the MA6. It is used to exposure UV light to your substrate that has photoresist on it. So, before we run the machine, the first thing we are going to do make sure the light bulb is turned on or even not blown up. So, we come out to the back and you can see the lights turned on by the reflection here or we can see a light blowing. So, you know that the light bulb is on. But in addition to that, you want to find out how many hours are left in the light bulb. So, you check the power supply.

So hold this button called DS and it is 3226 means how many hours the bulb is being used. So, the bulb has a life span of 4,000 hours. So, when it is over 3,500, we would notify staff and tell them to check it. So, we are pretty close to that. Now the bulb is ok to use and there is nothing wrong with the bulb and the power supply. We want to log into the system. So, before we login, we check the logbook.

And the logbook would say that the last person who used it was Monica on 221. And then you will check what note she had or anything was wrong. So, you can see that there was nothing wrong. So, we are ready to turn the machine on and login. So the login computer is here. You have to login to use the machine, otherwise you would not run. And the login has some more functions. The first screen is the login, where you enter the user ID and password.

You can schedule to user machine at different hours. Also you should check this to make sure nobody else is using it. So, today is 24th and it is 10 a.m. and there is nobody using it. So, we are free to use it. Also, there is a history tab, where we can see the last user and we can see that Monica was last user and she was last one to write on logbook. So, once we know the machine is ready and it is ready to very use we just login.

So, once you have logged in, the machine will be able to power up and what we do now is we turn the on switch on here. So we just turn it to the on switch. Now you can see the machine is turning up and it is important to ready the screen. It tells you a lot of information. So, it says ready for start, press load button. So, the load button is right here. Now you press that. And now it says watch out, machine is starting up. You know whether the machine is ready for load and started up when if the information says ready for load.

So, before we run machine, the one thing we can do is change the parameters. So, you hit this button called edit parameter. And now you can adjust the parameter such as time, some gap distance and type of exposure. So, how do we edit the parameters or change different parameters? We will use the x left and left. So, we move this way, we change the gap, change the type of contact, and then change the exposure time.

So, let us change the exposure time first. So, it is 5 second now, we can change it to 25 seconds. If you hold fast and up, you can change it faster. So, it is a 25. Let us make it 26. Now we want to go slower, so we do not hit fast, we just. So, now we have adjusted the exposure time. Let us change the alignment gap, let us make that 40. And then let us change the tab book. We will make it soft contact. Now, your parameters are changed. There is different type of exposure types from soft, vacuum, hard. If you look at the supplemental to get more information, but right now we will set it as soft.

So once your parameters are set, you can hit edit parameter. What we are going to now is the load the mask. So, how do we load the mask? We press the button for change the mask on the screen. So, we hit change mask. So we need to load the mask. So, we put it over here. So, you load your mask in here by lifting this clip here and putting it in. And when it stand nice, you hit this button called enter and you can toggle the vacuum. So right now the vacuum is off. And you press enter, now the vacuum is on. So, when you come back you can see that it is vacuumed in and it is stuck in well. So, now we are going to put this in here. So, we carefully carry it and we place it all the way in, and when it is in, we press change the mask and that is how you load your mask.

We are going to be doing a backside alignment now. So, what this does is, it aligns features on the back of your wafer to your mask. And how you do it is with the microscope from the bottom? So first thing we do is we have to have a mask loaded and then we turn the screen on. Now we make sure this things as backside alignment microscope is on. So, it is on. But also we need to change this to backside alignment. So, it can be either topside alignment or it can be a backside alignment.

So, this is elimination. So, now the light is coming from the backside. So, if you look here, you can see the light hitting the features. So that is the microscope from here coming looking up and light healing it. So, we can look for those on the screen now. And pretty much what to do is this controls the microscope on the back. So, you can select one at a time and move around to find your features. It looks like we found an alignment marks on the mask. So, we need to adjust the focus.

So, use this top strip left and right, so left one adjust the left and the y one to adjust the right focus. You can also adjust the intensity and you can also adjust the position. So, if I want to move this one up and down, now I hit right and then I will move it up and down. If I want to hit move the left one, it is the similar thing. So, when you find your mask and you think you are ready to do exposure at a y neck, you will grab this image. So, you press grab image one at right here.

So when you press that what it does, it takes a picture of the mask. And now we are ready to load the wafer. You press this button were says load wafer. So, it is a pull slide and substrate on to check. We will just load our wafer on and then when it is done, you press enter and you will bring it up. So, now you can see you are in contact. This is the image overlays in the mask. And these features right here, see they are the bottom substrate of your wafer.

So, how do you move the wafer? We know that these buttons move the microscope. So how do we move the wafer? It is these one is right. It is, these norms right here. This is the y, this, the axis on this side, and this is the tilt. So, again we resample, I can turn this and you can see the background, this image is moving and you could see this moving. So, this is the y position on the left side and on right side is the x norm and you can adjust the tilt with this too. And how you can adjust the focus and you can adjust the intensity or light.

So, you would do that to find your alignment marks and then align them. So, once you have aligned them, you are ready for exposure. And how do you expose? You press the, first you alignment check which would bring it up to touch, you want to make sure that they moved and then when it is in contact, you hit exposure and then when you have the exposure it is going to turn your back away for the light so it does not damage your eye. So, hit exposure and then we just turn away.

So, after exposure, you need to unload your wafer. So, what you do is, you come to the screen and you say pull side unload expose substrate. So, you just pull it out and then this is you can press the enter button and then the vacuum will be released and you can take your wafer out and then you pull back in. So that is how you unload your wafer after exposure. What we are going to now is topside alignment by using the microscope on the top to align to the wafer that is underneath to the glass.

So, to do topside alignment, we need to remove the backside microscope. So, we press this button that turns it off. Also we need to put the illumination to the top side. And then we can load our wafer in. So again you press load, and it says pull slide and load substrate onto chunk. And then you press enter, when you did that. And the microscope will automatically come down because we have the BSA microscope light button off.

So, now it is down, we turn the TV screen on. And what this is doing is taking a print an image from here onto the screen. So, again these buttons right here control the x and y position of the microscope. So, it looks like that we found something here. So, we can turn, it is pretty, the power of illumination is pretty high intensity. So, we can load the power and we can see that. So, we are going to find the mask alignment mark on this side. So, there is, there are functions on this.

This knob right here, so if you move it, this will control the light microscope, the x position of the light microscope and the left side has the same button. So when I move the left knob, I can turn this way, when I move the right knob, I can turn it this way. We can adjust the tilt to make this match up by turning this knob right here. So, that look is pretty matched up. So, what would you do is, you would do the same thing as, similar to the backside alignment. You will align your alignment marks on your wafer to these right here.

So, you can see that if I move this, this always, these knobs always control the substrate. So, when I move this you can see that this has been moved. So, you can tell that is the actual substrate moving, not the mask. So, you try to focus it and you try to find your alignment marks and align them to the features. And then once you have aligned it, you do the same thing and do alignment check, and I will bring the mask up, and then you will expose it.

So, you press expose and then you do exposure again. So, then you turn away so the UV light does not choice. So, after you are done with exposure, you will unload your wafer. So, it tells you pull side unload substrate. So, you pull it out. And then you take it out. Now you finish your sample, you put this back in. Now if you are done, you are going to move this back up and you do not want to bring it back down. This is where you press the BSA button. So, by default, this one will come down. But also to bring this up, you press F1 and enter and it would bring the microscope up.

It is always good to leave it in this position with the microscope up and the BSA button on because that way the microscope does not come on and up every time you using it. So, after that we are ready to a take out our mask. If you want to unload the mask, it is you press the change mask, it is pretty similar to loading in, it is a reverse process. You press change mask, you will take your substrate out. You will hit the enter button to remove the vacuum and then you take your wet mask out.

You press the change mask button again and it was confirm to enter that you know the mask is there. So, now you are ready to turn the system off. So, we want to make sure everything is in the standby position and you started the machine with. And then before you turn it off, you want to make sure you write in the logbook the different parameters. So, the compresses air is about 4.9, nitrogen is about 4.65, the vacuum is about 0.86, it is 0.86, we use the 4 inch wafer with silicon, and we did 25 second exposure.

Now we are going to turn off, first thing we do is we turn off the switch here and also the TV screen and then we can log out here. And there is some messages like did you reset the x, y and tilt position, so we did that. So, you put ok.

So, what you saw in the first video was the automated system which is generally used in industries, while the second video was more on the Karl SUSS Mask Aligner that is EVG 620 and different kind of mask aligners are there. If time permits, we will show it to you how the mask aligner in actual way how we can use it. It is our laboratory. But if you want to like I said you want to achieve the feature size which are less that 2 microns, photolithography will not work and you have to go for the alternative which is your e-beam lithography, where the wavelengths are even smaller and when you go for x-ray also, it will help you to achieve the better feature size.

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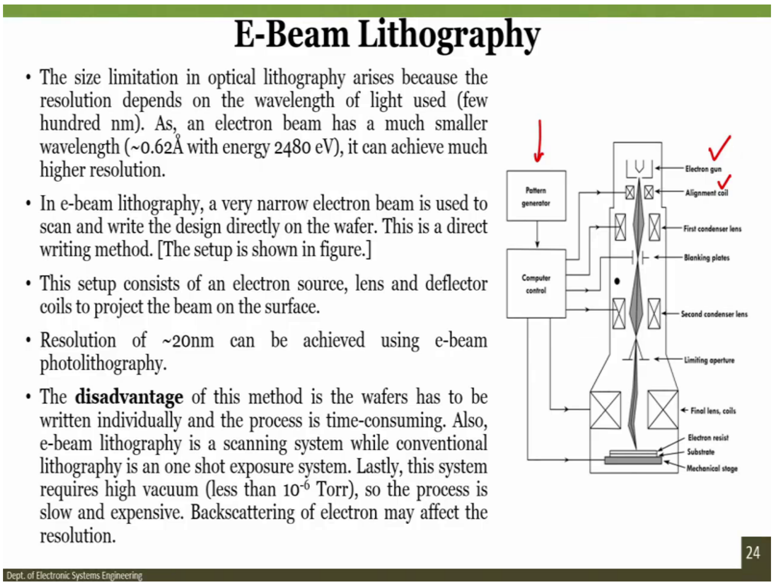

So, if you see e-beam lithography, if you see this particular slide, then in this slide what you can see that the, this is an e-beam lithography schematic. If we start from top thing, so let us start from the bottom side, this one. Though you can see there is a mechanical stage on which the substrate is loaded along with the photoresist. This much is there. Now, the electron beam will scan this photoresist in a raster scanning mode, mostly raster scanning mode, there are other modes also for scanning.

So, if you see this top one is electron gun from which the electron are emitted and then there is an alignment coil, then there is a fast condenser coil, finally there is a blanking plates to further send the electron beam through it, second electron, second condenser lens, then there is a limiting apertures through which the electron beam will pass and finally there is a lens and coils that will help the electron beam to move or reflect. And then there is a pattern generator and of course everything is controlled by a computer. So, this is how the electron beam system looks like. You do not want to worry about it. You have to just know that there is an e-beam lithography system available.

In this particular course we are not going to use e-beam, we are we have strictly focusing on photolithography which is UV exposure based lithography. However, let us see the importance of the e-beam lithography. So, the size limitation in optical lithography arises because of the resolution depends on the wavelength. So, an electron beam has a much smaller wavelength. So, smaller the wavelength, we can improve the resolution. So, that is why it could achieve the higher resolution.

In e-beam lithography, a very narrow electron beam is used the scam and write the directly on the wafer. This is a direct writing method and you can say, we already discussed the setup which is shown in the figure. This setup consists of electron sources, lens deflectors, coils to project the beam on the surface and the resolution of 20 nanometres can be achieved. The disadvantage of this method is that the wafer has to be individually write, that means that it is extremely costly and the process is time consuming.

Also, e-beam lithography is a scanning lithography system with conventional lithography is used as a one shot exposure system. In this case it will scan, then go to next stop, scan again go to next stop, again scan. So, it takes time. It time consuming process. Lastly, this system requires vacuum of water of 10 raise to minus 6 torque which is a very high vacuum. So, the process is low and expensive and the best scattering of electron may affect the resolution. So, some of the disadvantage is also there associated with particular e-beam lithography. But at the same point because the wavelength is small, the resolution can be better or the feature size can be smaller.

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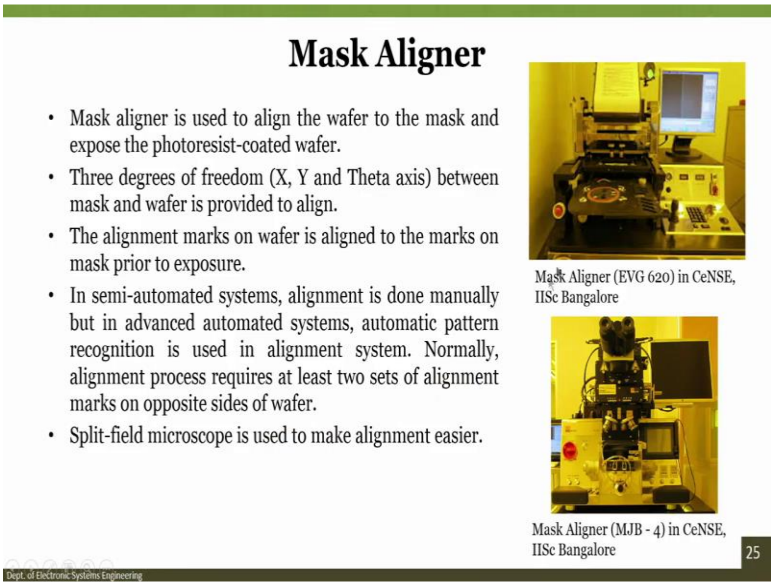

Now, whatever you say you, if you if I talk about the UV exposure, you require a mask aligner and we have both the mask aligner in our institute which is Indian Institute of Science, Bangalore. We have EVG 620, we have MJB4, these are two different mask aligner. It is semi-automated mask aligner. So, generally mask aligner is used to align the wafer to the mask. We will discuss this thing and we will see as an example.

There are three degrees of freedom X, Y and theta between mask and wafer. So, let us at least understand the process. So, I have this, let me just draw the top view. I have the wafer here and on that wafer I am loading a mask. Now, there is some pattern on the mask that we can see. So, the mask is on the top and the wafer is in the bottom and these are the alignment mask.

Now, this is a pattern let us say you have this pattern in the mask. You need to make sure that the wafer is particular, is properly aligned. Here you see, what you see that wafer is tilted, wafer is tilted. That means you have to rotate the mask in anticlockwise direction. So, there should be a rotation mechanism. So, that rotation can be we can rotate the mask by using the theta axis of the mask aligner.

Suppose the alignment is in terms of the, that the alignment masks are too much on the left side, like this. And you have to align it so that you have to move the wafer in mask in the right axis. So, either you can move the mask or you are move the wafer. So, here you have a freedom of moving at X axis, Y axis and theta. I just took an example of theta in X axis, same thing that can be problem with a Y axis, then you can also move the mask in a Y axis position, in a Y axis direction.

So, in the semi-automated system, the alignment is done manually, but in advanced automated system, the automatic pattern recognition is used in the alignment system. Normally alignment mask requires at least two sets of alignment as we have seen that on both the sides of the mask there were two set of alignments, so that we can see that the mask is properly aligned and then split-field microscope is used.

See what is the difference between normal microscope and split-field microscope that in split-field you can see both the entire mask and the alignment marks on the mask simultaneously, while in the normal microscope we can only see one side. Then you have to go to other side, then see this side. That will cause lot of alignment issue. But in split-field, both the alignment marks you can see simultaneously. So, generally it is associated with split-field microscope or indicated with split-field microscope.

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So, let us see some of the videos that are available so that it will help you out to understand how to, can you use the mask aligner. Let me play all the videos one by one. This is not a matched, mask wafer but we should at least be able to see the alignment process. Now I am satisfied with the alignment so let us produced. Now, I will unload the wafer in the same way for in topside alignment mode. We will do another 5 second exposure, remember it.

Today is April 14, 2013 and we are looking at lens MJB-4 ID number 3685, serial number 191. This machine is through the refurbishment process and ready to be lockdown for shipping. But first we will just demonstrate the operation by running a 4 inch wafer in high contact. There is a contact move to the alignment. This is not a match, mask and wafer, but we can at least demonstrate alignment procedure. Move back to contact and press alignment check. It introduces nitrogen underneath the wafer.

Now we can verify that we are still satisfied with our alignment. We are, so we press expose. And asks to double check that you want to expose and it is ready to unload. This machine is also set up with IR capabilities. So we could run the same wafer with transmissive IR wave and reflected light culmination. And to demonstrate that upload parameters, switch to IR, load. I am now viewing the mask and wafer by transmissive light from underneath the wafer. Do alignment check, tilt to expose, confirm and performs 5 second exposure. We are ready to unload.

When I play the video, what you were able to see? You were able to see different mask alignment system. How it can be used? How it can be operated? And in the following modules what we will look at, we will look at the SU-8 as a photoresist. SU-8 is very, very important in lot of application and we will then take an example of patterning a material electrode onto an oxidised silicon substrate. So this is a next module. We will discuss this.

In this module just focus on the alignment system, different kind of mask, photoresist, e-beam lithography, UV lithography, the EVG 620, MJB-4 and other alignment system. Once you understand in detail about these systems, we will go to the next module in which I will cover two very important stuff, one is how to pattern a metal on a substrate and second is the SU-8 lithography. We will also quickly see, because you are learning lithography, I would also want to show it to you what is called soft lithography.

So, we will cover these three items in the next module. Till then you take care. If you have any questions, you can always ask us through the forum. Dr. Mahesh will reply to you as well as the other students including me. I will help you out to answer your questions with best of our abilities.