Instability & Pattering of Thin Polymer Films

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Lecture No. # 12

Photo Lithography – IV

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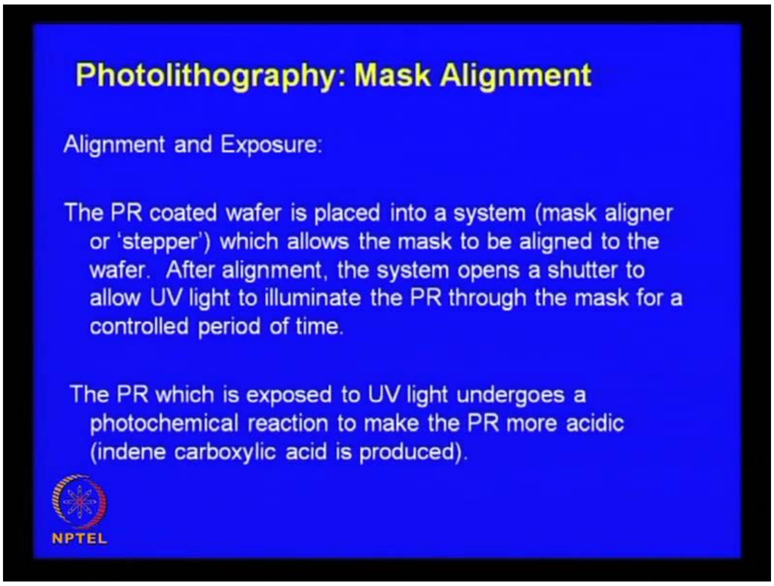

Welcome back, we will continue our discussion on photo lithography on videos aspects of photo lithography, as we were continuing. In the last class, we ended our discussion with essentially talking about a mask alignment. So, we have already talked about what exactly is a photo mask, what it is roll is and then we talked about, how to line a mask with respect to the silicon wafer, which is now coated with a photo resist layer.

And then once the mask is aligned, then you essentially do the final step that is UV expose or many open shatter of the UV light. So, that it gets the photo resist layer under the mask gets exposed at the pending on whether you have a positive resist or a negative resist, the subsequent optical degradation or ((

)) of the exposed areas, we will result. So, that you, you are now the position to transfer the pattern and the mask on to the photo resist layer.

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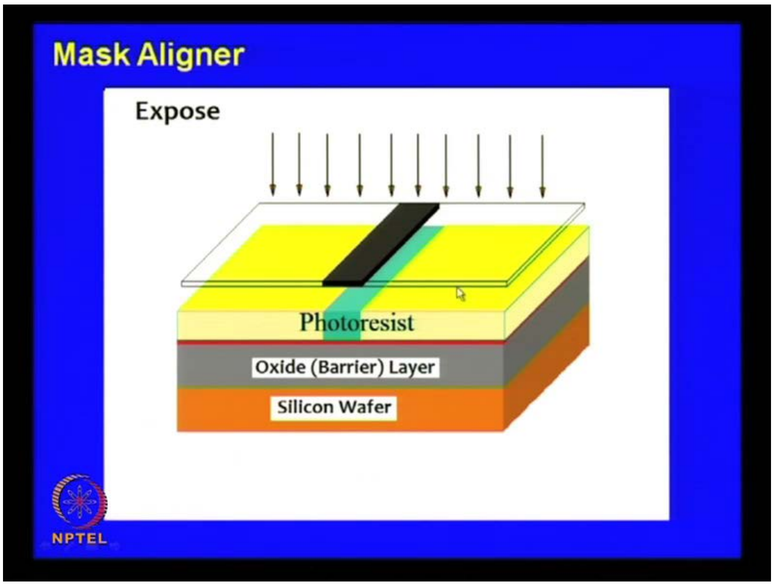

So, I think we will do a quick recap this is what you have; you have a silicon wafer out here, then you have a oxide layer of the barrier which you have zone and top of the silicon wafer, then you have a priming layer and on top of which the photo resist layer has been coated. Looking at the importance of the coating technique, we have discussed in rather detail the basic philosophy of the method that is adapted for coating photo resist that is spin coating. And, let me also point out that we have not discuss the how the oxide layer is grown.

Because from the stand point, though it is extremely important from the stand point of material science or physics, but real it is from the stand point of this particular course, have you really grow an oxide layer is not going to be that important. So, once you have the step ready in this condition, you bringing the mask. So, now probably you understand that this is a quartz glass plate, where you this particular zone have a layer of a metal may be chromium. So, we also discussed how we go about it. So, probably initially a blank glass piece was taken. Then, the entire specie was coated with the same layer of chromium and then over this area and this area probably the chromium layer has been etched out of stripped off.

So, the alignment is ready. So, typically it is not like a hand held think as we show or as we are showing in this cartoon maybe. But typically, you place this mask with on the photo resist layer with the help of a mask aligner, which we will talk a little bit detail today. And then, the stages set for the UV light to shin on it. So, what happens is this particular part, there is the light cannot penetrate and the other parts it can penetrate and consequently there is a structural change of the polymer, depending on whether it is a positive or negative photo resist.

Of course, that nature of change will be different, but reality there is a structural change and this part remains intact. So, you know that if it is a positive photo resist then this part remains intact and these parts, there is a degradation of the polymer. In contrast, if it is a negative photo resist then well this part again remains intact, but there is a trust linking over these areas.

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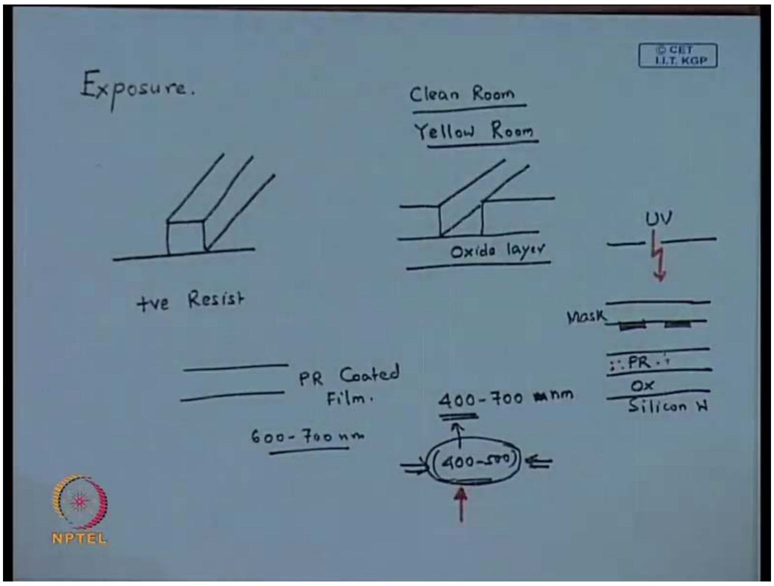

So, you probably now understand that if you, now going for subsequent development for this particular mask, if you have a positive resist this is the structure you are going to obtain and in case you have a negative resist, this is what your structure is going to look like. So, we understand up to this level, this is the oxide layer and today we will continue our discussion from this point. So, talking about the exposure well it is a definite prior of time over which the light is exposed on the mask this is an (( )). So, you have the UV light here and exposure been you allow the light to penetrate on fall on the mask.

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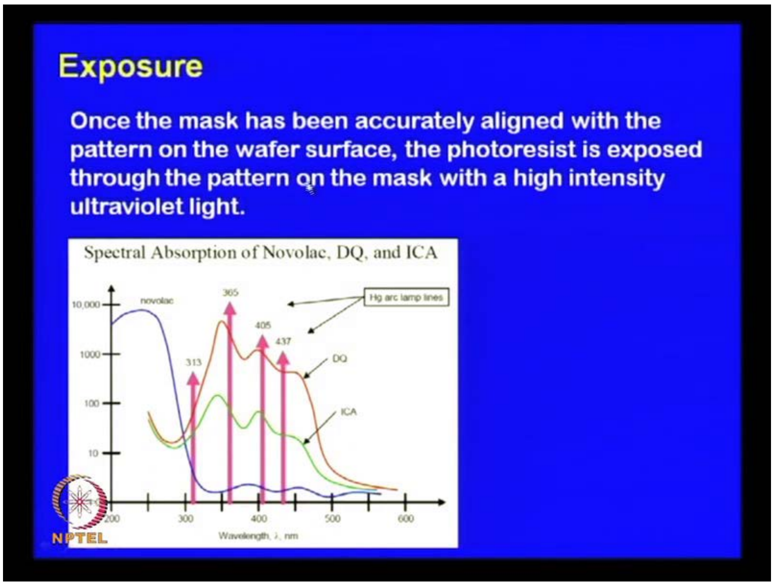

Now, once the mask has been accurately aligned with the pattern on the wafer surface, the photo resist is exposed to the pattern on the mask with high intensity ultraviolet light. Now, if you look at the spectral absorption of a typical photo resist this is the type of absorption peak, you will see that is it absorbs light corresponding to UV wave length. Unlike, so here you see in the visible range the absorption is nearly zero, but still there is some (( )) absorption here between four hundred and five hundred.

So, that is one of the reason why you sort of do your photo lithography processing and exposure in a very specialized environment, very very specialized environment that is I do not know how many of you know about it, but typically not only may be you have heard that there is; their exists something called a clean room in which most micro electronic processing takes place. These are some sort of special type of rooms, especially created environment where the dust concentration is kept extremely low.

But you realize why because we have already talked that for many of the process in steps, even in the presence of one single dust particle is going to be (()) of, but in addition to a clean room where most of the micro electronic processing is done, a photo lithography processing particularly the photo resist coating UV exposure and development is done in another class of room, I do not know this can be quiz question.

What is the room call, what is the name of the room, well I do not know how many of you know it its actually an yellow room and the reason is that at this, if you think of the concept of VIBGYOR, that is of the constituent lights which make white light. You see violet is closes to the 400 nanometer wavelength and red and yellow and red are closes to 700 nanometer on the other side of the spectrum. So, here if you look at the absorption curve you see that this photo resist, they shows a maximum absorption peak at around say 350, which is sub visible spectrum or its in a UV range; however, between 400 and 500 there is still some better absorption.

So, now if you sort of expose this is interesting, if you suppose have a photo resist coated film and you sort of handle it in a normal room, where probably your incandescent lamp or a tube light is going on. So, this is white light you have all the wavelengths between 400 and 700 nanometer. So, the wavelength that corresponds to let us say between 400 to 500, they sort of start reacting or there is some bit of photo chemical reaction within the photo resist layer. Because of the wavelengths present in white light, that corresponds to these wavelengths.

So, you would like to have an environment artificially create an environment, where the illuminating light because you cannot work in complete darkness. So, you would like to (()) artificially create an environment, where these wavelengths are present in as minimum quantity as possible. Now, if you so in a yellow room typically all the doors, windows, curtains everything is all of the covered with yellow sheet, all the light are yellow lights the intention is to sort of keep the wavelengths of the visible light in the range of 600 to 700 nanometer. Because you see from this particular graph, that at 600 beyond say 500 these entire three photo resist, this is a three commercial available photo resist, I have taken the graph from Wikipedia, so these photo resist sort of show very minimal absorption.

So, the issue is that, if you sort of move around with your photo resist coated wafer in white light and you expect that in other words, even before you sort of do a proper UV exposure part of the photo resist, will sort of cross link or degrade and this cross linking or degradation is independent of the location of the mask. So, what happens is there is I mean eventually, we will some structure there will be even though you sort of expose later under a mask its photo resist layer is not to steam, but it has already undergone some structural changes because of some photo chemical, unwanted photo chemical reaction of white light of the components of white light, having wave length in this range with the sensitizer part. (Refer Slide Time: 05:03) So, that is why most of the photo lithographic steps associated with other microelectronic industry or other processes are sort of invariably performed in a yellow room.

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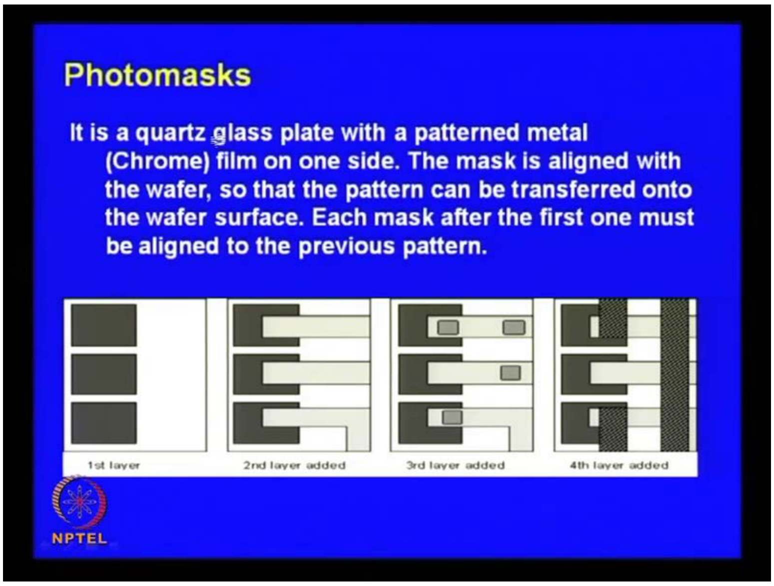

So, this is now you also know what a photo masks is. So, it is essentially a patterned metal film on one side, the mask is aligned with the wafer. This we talked about yesterday, what is mask aligning because for many, many applications, if you see you actually do not need only a single pattern you need multiple pattern. So, the first pattern is you can sort of create on the wafer, but then every subsequent pattern sort of becomes is the function of first pattern.

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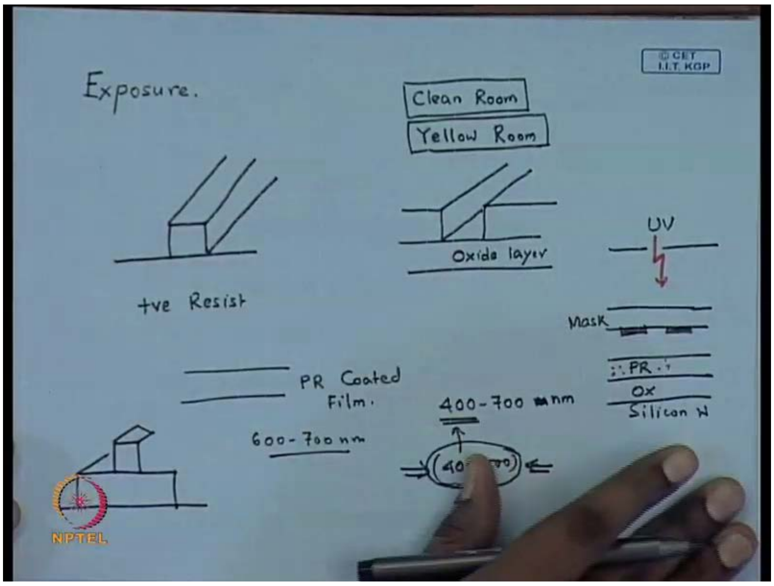

Yesterday we in the previous class we had an example, suppose this is the type of structure, you would like to create.

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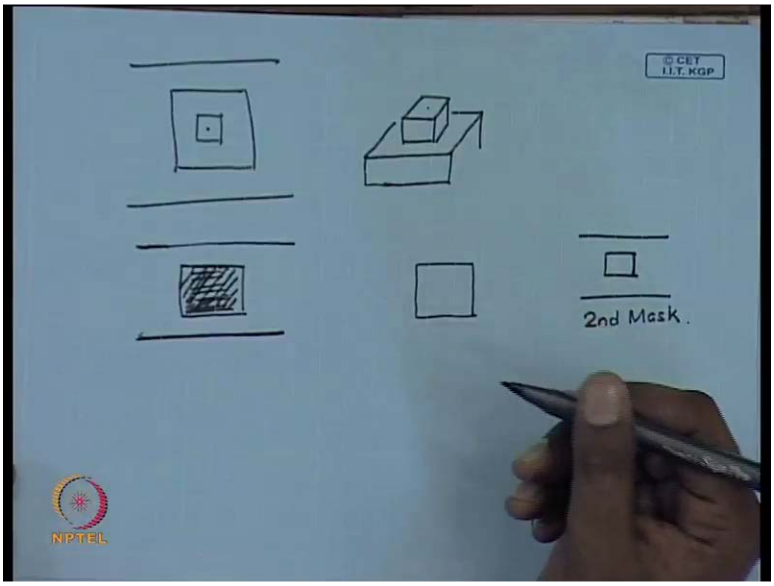

So, well the first structure so let us say something like this; let us say you want to create this type of a structure, if this is the projection what is going to be the isometric, it can be something like this on a let us say an oxide coated layer and their concentric. So, well within the photo resist layer you are probably free to place your mask like this, let us say the easiest way to go about it is that, we take a positive photo resist and take a mask which as the chrome absorbing layer here so, you get this zone.

Now, if you want to create a structure on top of that which is concentric with this one, you would like to take a mask like this; probably the second mask, but now it becomes extremely important to position the second mask on the wafer with respect to the structure created in the first stage or the (( )) about depending on the exposure, that you have done in the first stage or with respect to the positioning of the first mask on the substrate.

So, you have to ensure that center of this and center of this sort of matches only then you can get to your desired structure. So, this is very important and this is exactly, what a mask aligner does. Because if you a sort of doing a sort of simple photo lithography in your lab lecture for a non IC application, non microelectronic application, you want create sub channels from micro fabrication experiment or some array of lines for addition experiment, it is perfectly phi you probably do not worry too much about these aspects. But the moment you sort of start worrying about real electronic application, invariably there will be multiler structure and in order to achieve proper multiler structure without any degradation of quality or any sort of defect, it is extremely important that your sub alignment of the mask for every subsequent layer matches exactly with the positioning of the mask of the previous layer.

(Refer Slide Time: 05:03) So, this exactly is the purpose of a mask aligner, I will show you some more details. So, here for example, you can see that the first layer first create these structure, perfectly fine you want to create something like this. So, how much you want your second structure to inter trying in to the first structure this is the role of the mask aligner, the third one you want to have another structure. So, here you can see the first, second, third, fourth how the mask aligner sort of becomes important.

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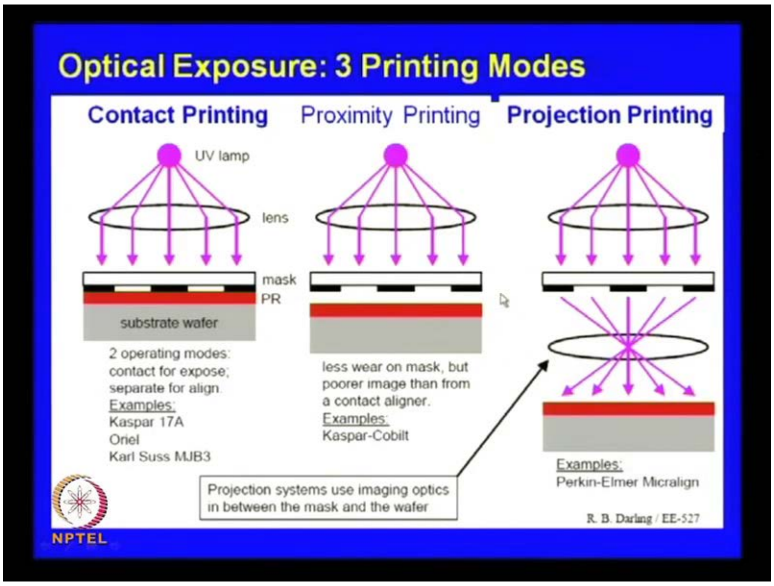

The other important concept again very simplified picture, I will give is that that what is known as the printing mode.

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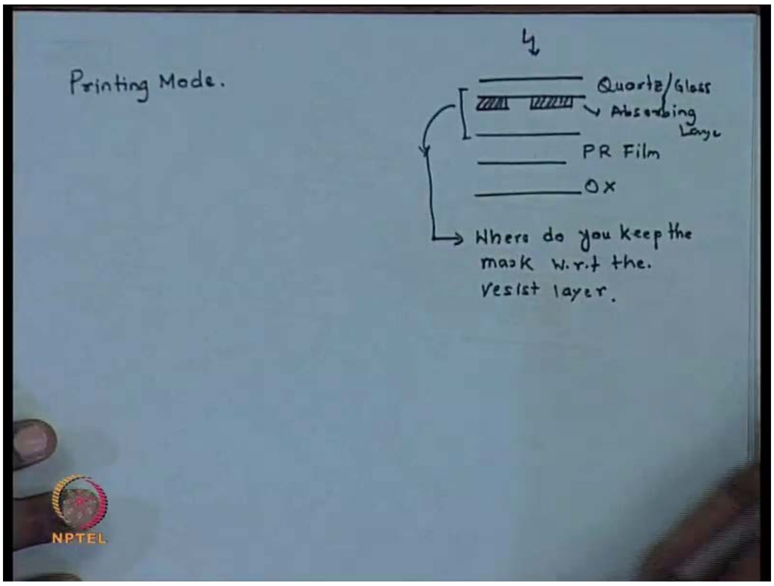

This is very simple, we talk about a photo resist film or coating and then we talk about the mask is the absorbing layer. As he turns out, now you have an UV source somewhere over here, now what we have not talk in any of these discussions, previous discussion before is where do you physically keep the mask with respect to the resist layer. This is an important question, where do you keep. (Refer Slide Time: 13:48) So, as it turns out that there can be three printing modes. The first one, the simplest one is actually the contact printing mode where you actually place your mask right on top of the photo resist layer, there is no physical gap.

The second one is proximity mode or proximity printing it is very similar to the contact mode, but in this case the mask is sort of kept a little away from the surface of the photo resist layer. And the third one is a projection printing, where it is kept at a substantial distance away and in between you also has a condenser and so, it uses imaging optics in between the mask and the wafer.

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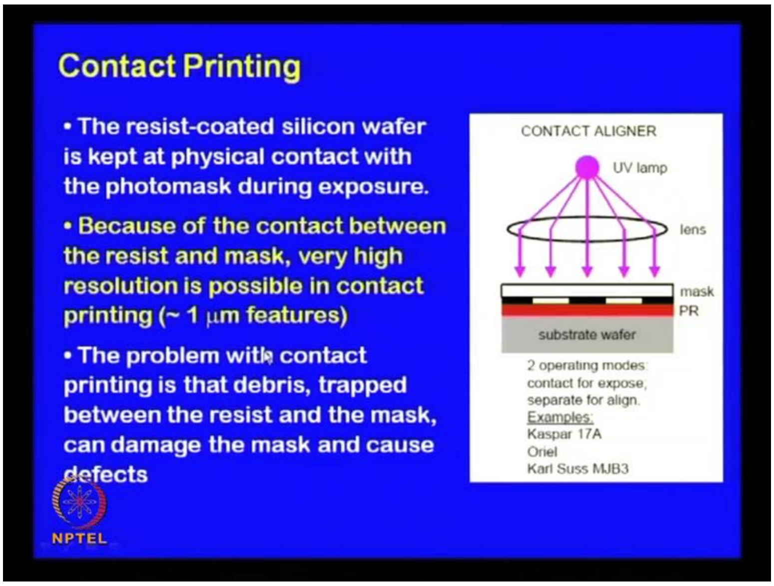

So, let us looking to it in little big detail, this is very, very simple. So, you just take your mask, you just place it in direct contact with the photo resist layer, if there is no dust particle or any other defect these two will coming (( )) much conformal contact, because the mask and the film both are smooth.

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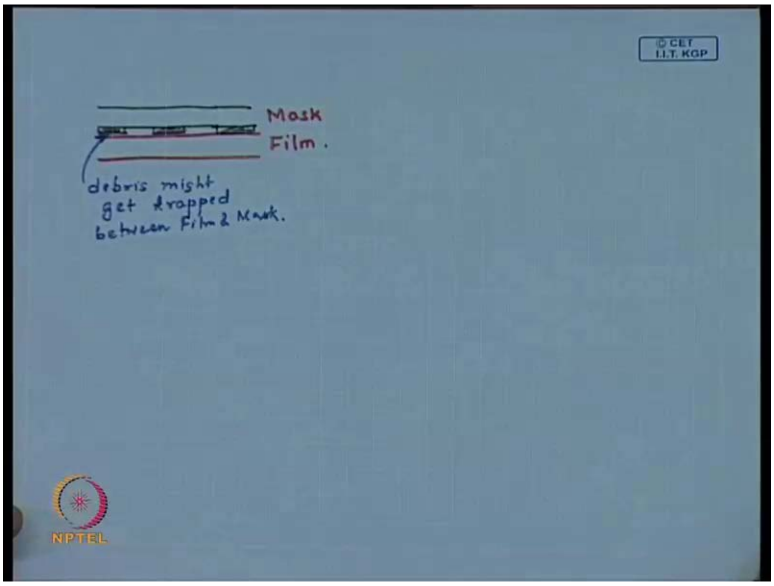

So, this is your mask, this is the film, things are a perfect contact. So, this is again here where you realize probably the importance of a dust film environment, because suppose if you one to sort of implement contact mode printing and then you have a dust. So, what is going to happen the dust particle, sitting on the films surface that photo resist surface or on the mask we will prevent the two of them coming in conformal contact that will destroy the pattern transfer completely. So, this is classic example where you can realize how a dust free environment is extremely important for proper implementation of photo lithography.

Because the mask is in contact to with the resist very high resolution is possible, this printing mode gives you the highest possible latter on resolution, however there is a practical problem with contact printing, that is the debris what their might be some debris that get generated, because of the exposure of the photo resist layer due to UV. As, UV shine you know that there is a structural change of the photo resist polymer layer, which can sort of (( )) cross link or disintegrate particularly in the cases in disintegrate there might brief some formation of some debris. And these debris sorts of get trap between so, if there are some debris formation of some debris, where does this debris go they have no place to go.

So, this debris might get trapped between film on the mask (Refer Slide Time: 16:06). So, that can eventually lead to the damage of the mask. So, that is not a very desirable think, because mask again is a pretty expensive entity you really gone to one to is use the mask only for once. So, essentially there are the operation in is very simple. So, one is the contact which is for exposure and then separate for align, so you place the mask on the film you exposed then after exposure is over, you physically detach the mask from the film and film is taken for subsequent processing mask with the minimal amount of cleaning may be is sort of pre processed.

Now, particularly in ordered to the; however, I mean we are as I told you as are telling you repeatedly, I am giving you a contextual picture. So, that thinks are thinks remain understandable to you and which is predict much for the at the level which we are talking.

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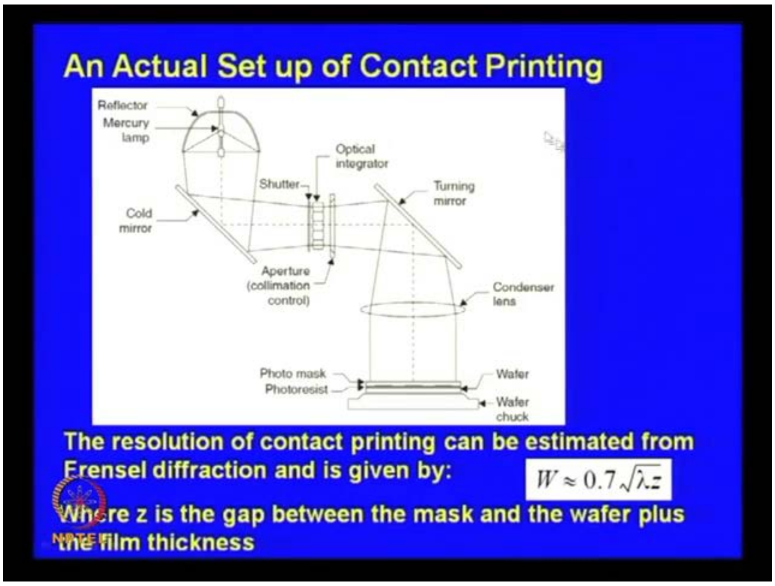

But, this is sort of event for the contact printing this is something the actual set up looks like. So, you have a lamp over here, then you have a cold mirror, then the shutter is here, a turning mirror, the condenser lens and then finally, the photo mask and the wafer and the wafer is mounted on the wafer chuck. So, this is how complicated this schematic I have deliberately included, so this gives you some idea how complicated the actual processing steps are, but this picture when you look it also tells you how simple the basic physics governing the entire thing is the resolution of the contact printing, by a sort of can be estimated from the essential diffraction and which can be the given as 0.7 times under root lambda in to z, where z is the gap between the mask and the wafer plus the film thickness.

So, this is essentially not only we will probably realize, what the gap between the mask and the wafer is in the subsequent slide plus the film thickness. So, this is simple to calculate you know, because this position etc is not manual you have an automatic position at so, you can calculate z and you can find out or estimate what sort of the diffraction, what sort of resolution you are likely to get.

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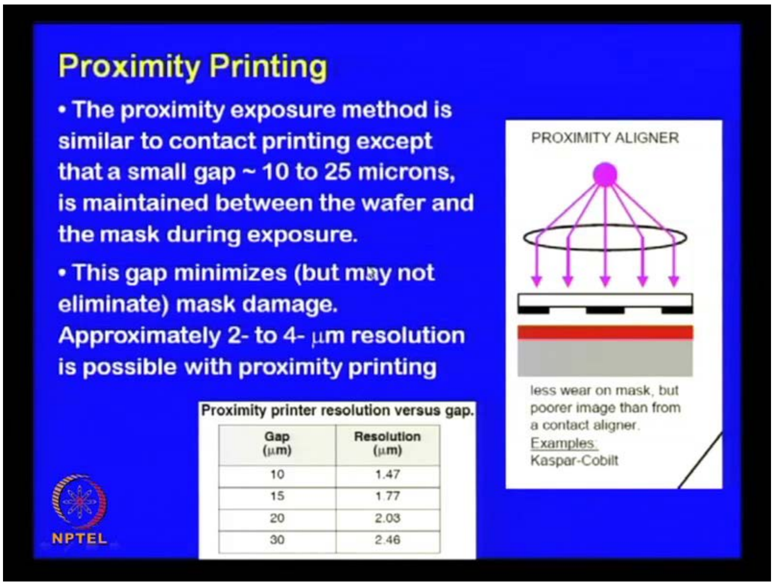

Now, particularly in order to overcome the possibility of likely mask damage, because of the debris the concept of proximity printing was started getting more popular. The proximity exposure method is similar to contact printing, except that a small gap of let us say 10 to 25 microns is maintained between the wafer and the mask during exposure. This gap minimizes the mask damage not full really minimize, but minimizes the mask damage.

And the resolution however, this consent across the resolution is not as tight as you like to be you typically get in case of a contact printing, but please realize that in industrial stage at the pressure moment at the present technology uses neither of contact printing nor proximity printing. So, this table sort of gives you an idea about what sort of resolution, you might get as the function of the gap between the mask on the films. So, here you can see that this is the mask, this is the film, unlike a proximately aligner where the things were indirect contact.

Here, the two are not indirect contact so there is a physical gap. In this gap, as we say as it is return in the slide sort of varies from 10 to 30 microns and this table sort of gives you an idea about how the resolution wash and as the gap distant increases. So, higher gap distant sort of ensures that are protection of the mask again possible debris related damage, but it come at the cost of loss of resolution. So, let us say from a gap of 10 micron which the resolution is the particular case was, let us say or use 1.4, 1.5, close to 1.5 micron it goes raffle all the way up to something like for 30 micron gap size it sort of goes to 2.5microns.

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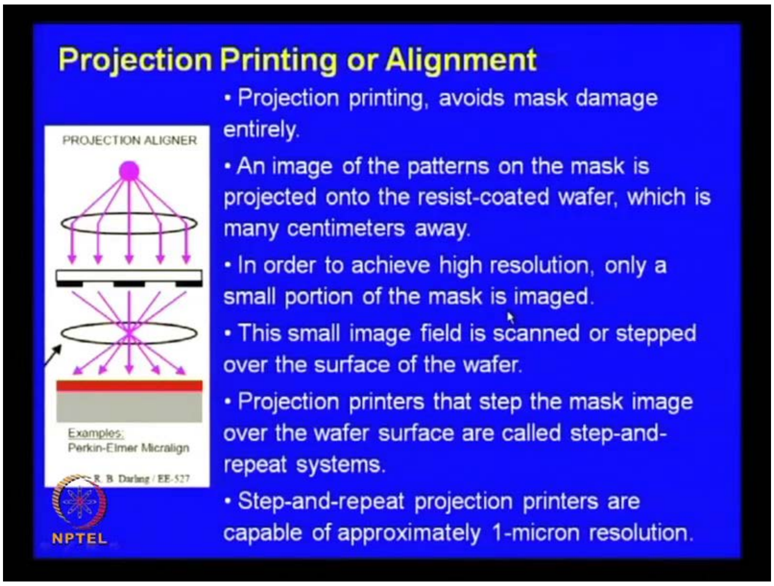

So, this is how this is what is proximity printing mode. The most widely used and it also comes with its own advantage is the so, for projection printing mode. Well it completely eliminates mask damage, but that is not the only think. So, the issue is that here you keep it at substantial separation distance the mask and the film are no close to contact and there is an additional condenser lens between the two. So, an image of the patterns on the mask is projected on to the resist coated wafers, which are a few centimeters away in order to achieve high resolution only a small portion of the mask is imaged.

Of course, if you have a wide area then and it owns condenser lens it sort of field. This small image field is scanned or stepped over the surface of the wafer I am just coming to its projection printers that step the mask image over the wafer surface are called step and repeat systems. Again, something I will talk essentially is the idea is very simple that you keep the mask substantially away from your film and then you have a lensed in looses form of the simplest form, you have lensed in between. So, that acts as a condenser are sort of creates an image on the film surface

But, in order to have a high resolution only your portion of the mask is imaged. So, now, if you are let us talking about a large wafer, your technological limitation is that you if you want to you sort of use a mask for the entire wafer, your resolution is going to be loss, because you cannot wear lens we will not be able to focus the beams of light at the appropriate location.

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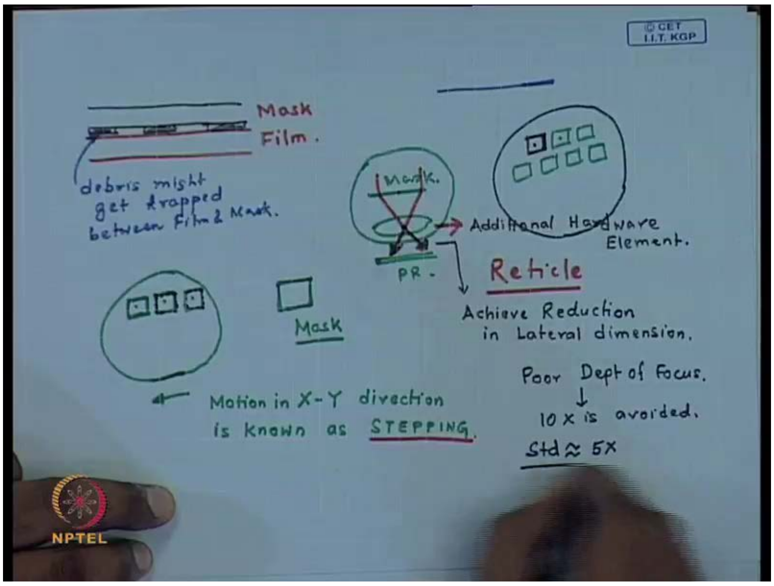

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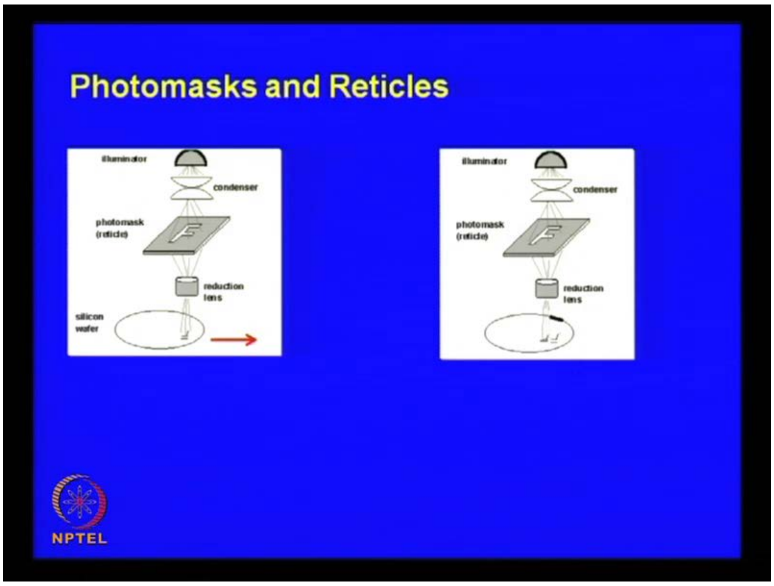

So, what you do you sort of very use small section of the mask, if you get the structure here, and so if you want the same structure to be repeated over the whole wafer, what exactly what can be the approach. So, suppose we want the same structure here, here, here, here everywhere. So, you exposed it to once you get this structure. So, the easiest thing to do would be once the exposure is done at this place here is the mask, here is the lens, here is your photo resist coated wafer.

So, once it is done may be you just sort of rested it or you just with the help of mechanical motors, you just shift you wafer from this location to this location and then repeated the experiment. This is exactly what it means so, you see here you have a wafer let us say you have this is the photo mask and then you do the exposure you get the pattern once, and then if you want to reproduce the pattern you just remove the wafer in this particular direction.

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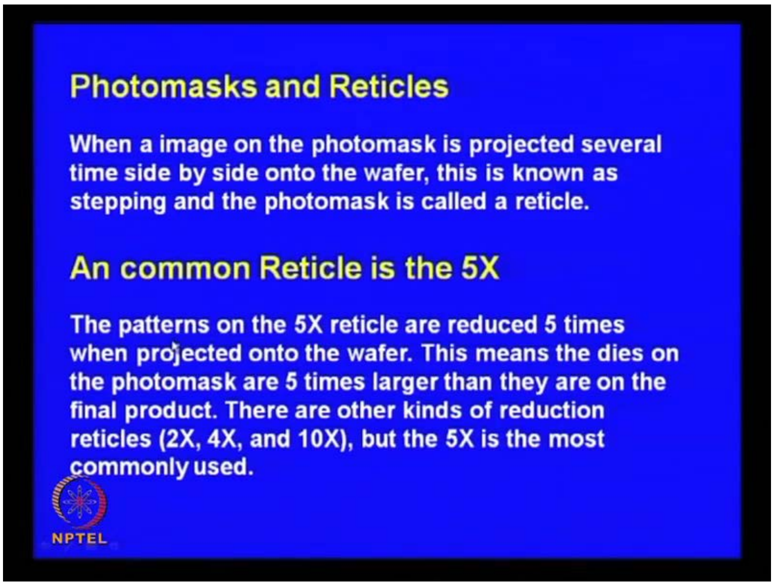

So, this is the actually this entire action of the wafer moment etc, sort of automatic these and here it is when it is what brings you to the concept other entity called reticles. When the image on the photo mask is projected several times side by side on to a wafer this is known as stepping. (Refer Slide Time: 22:49) So, this is exactly what return was in the previous slide I just did not go to the detail. So, the idea is that you have your mask like this. So, you bringing the wafer may be you get your first exposure here and then instead of removing the hardware, you allow your wafer to move mechanical in an automatic fashion in to this location and then do the same exposure with stepper motors, that is the reason you sort of some times this is stepping.

You can control this motion, very accurately then once the second one is done you again move it now to this location. So it is like this. So, what it says here and image of a photo mask is projected several times, side by side on the wafer. So, here to here what you are what doing you have only one pattern on the mask, but you are projecting that several times. You have one pattern on the mask, but you are projecting that several times you have one pattern; you are projecting this pattern several times.

So, here is the mask you are projecting it several times over here. So, this is a replica of the same mask pattern and how do you project it you do this by keeping your this part of your hardware intact, so the mask remains in place, the lens remains in place for the photo resist coated wafer you sort of make it move. So, from here to let us say here, here, here then here, here it likes this. So, this motion is motion in the X Y direction is known as stepping.

This is actually achieve this stepping operation is achieve by a special class of motor called the stepper motors and the when you use the photo mask along with stepping same mask, is typically refer to are called as reticle. Well, there is another thing since in this particular exposure mode you are actually using a lengths between the mask and the photo resist, you have an additional hardware element in comparison to in proximity or contact mode printing, which is a length essentially the simplest form is the condensing lens. So, the moment use a lens we can sort of have a magnification or size reduction based on where you the relative distance between the mask, lens on the film.

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So, that is precisely what is done typically along with projection, there is also a future size reduction that one tries to obtain and a 5 X reticle is predict common industrially, the patterns on the 5 X reticle are reduced 5 times when projected on to the wafer. So, that is the simple concept that along with this condensing action, you also position your film photo resist coated film or photo resist coated wafer with respective to lens in such a fashion that you sort of achieve reduction in lateral dimension. So, if you sort of do not achieve any reduction it can be one X, but well there are lots of reticles available 2X, 4X, 10X. The critical question to ask is why not having well, if it is higher than the depth of focus sort of becomes very, very poor.

So, any think more than 10 X is avoided industrially standard this close to 5 X, so this we have already expense I think now this makes better sense to you. So, this is a reticle and you have a lens, the reduction lens. So, let us say it is a 5 X1. So, whatever is the future size you get a 5 times reduced future replica on the photo resist layer, you do the exposure then once the full step is complete, the stepper sort of move from one position to the (( )) sort of p programs second position and you repeat the same step again. So, we get other image of the same pattern on your resist layer.

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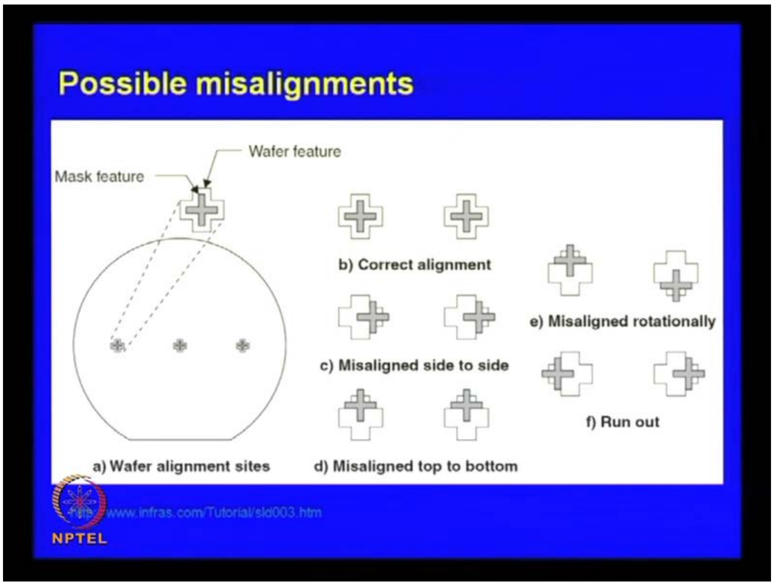

So, it also in these are some of the things or some of the steps, you may be achieving with the are you need to archive with the of mask aligner, the steeper. Now, there can be of course the possible misalignments.

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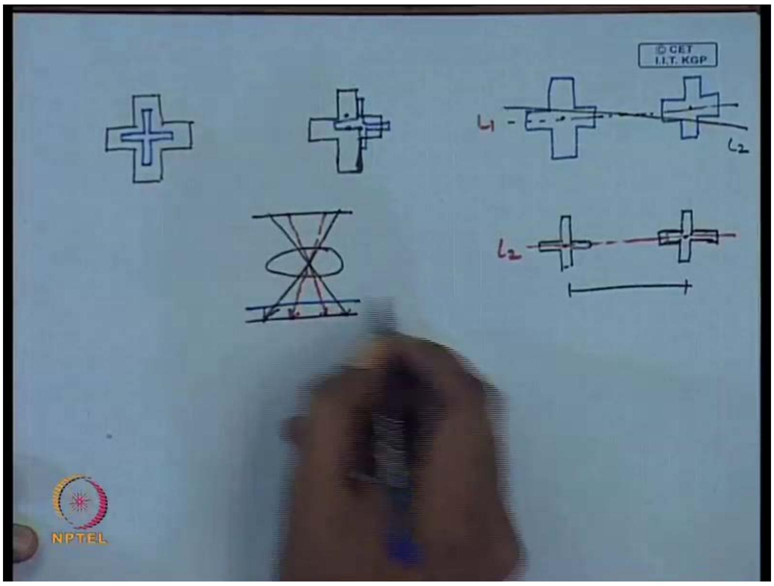

So, for example, this is very nice example what you want to create is structures like this. So, this is the first structure and these are the, this is the second structure. So, this one if you see over here this is indeed the correct alignment that is what exactly you want to do. This one, if you see misaligned side to side. So, what has happened when you were bringing in the second mask, this is the first pattern or the area corresponding to the first exposure? So, when the second mask was brought in instead of a center matching or coinciding with the center of the first pattern, let us say it is center was here.

So, what happens this was the position and see correspondingly this is what as happen, misaligned rotationally this also very interesting. So, suppose you were using a mask, which the first mask was like this, the second mask this was the first mask, it have let us a two of this structures the second mask was let us say the idea was that, when you place the second mask these two center to center to distance and the center to center distance here is identical.

So, when you place it will sort of automatically if two structures like this, but in this particular case when you see a rotational misaligned, what has happened that when you were placing the mask this lined and this line, let us say this is line L1 and line L 2. There was a finite angle between L 1 and L 2, see this is L 2 you see sort of it gets to a little bit and you get result and structure like this. Misaligned top to bottom is very similar to misaligned side by side it. So, instead of here the position sort of shifted to here may be and consequently you got a structure like this, I will give you a minute to think of how you can get this type of misalignment which is known as run out.

So, any guess here you see side to side or top to bottom, you see the both the futures sub shifted in the same direction, here or here both the futures have shifted in the same direction. Here also, you can realize that this was the axes of the (( )) structure, this was the axes of the (( )) structure. So, this makes finite angle theta between the two and consequently you see misalignment like this, but what can be the reason for a run of type of a misaligned. Well, it is only possible If you are using this is important to realize now, but this type of a misalignment is becomes only possible only when you are using a projection type of a printing mode; projection printing mode.

What has happened here, the positioning of the photo resist layer with respect to the reduction lens has changed from the first exposure to the second exposure. Therefore, he did not achieve the same reduction or the projection plane at which the sample or your layer was kept, has varied due to whatever region between the first exposure and the second exposure. So, while in the first case it has projected here and in the second case, what you would have expected a smaller mask. So, you would expect that mask with the smaller feature here, but what has happened that the layer has got shifted here.

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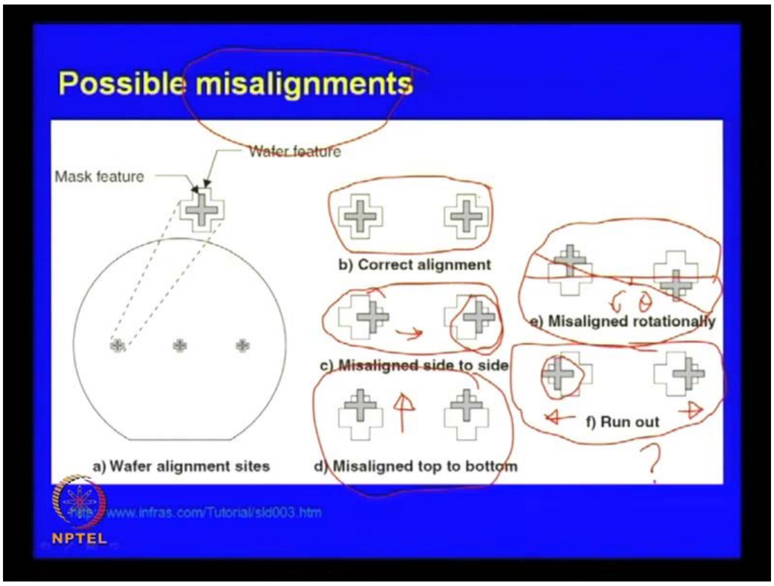

So, this is large now and if you have two such structures. So, one has sort of shifted in this direction, other has shifted in this direction. Think over it, see the slides couple of times more and correlate it with the discussion. See, we have already had I think it should make sense to you. So, these are some of the possible misalignments you can have while operating a mask aligns.

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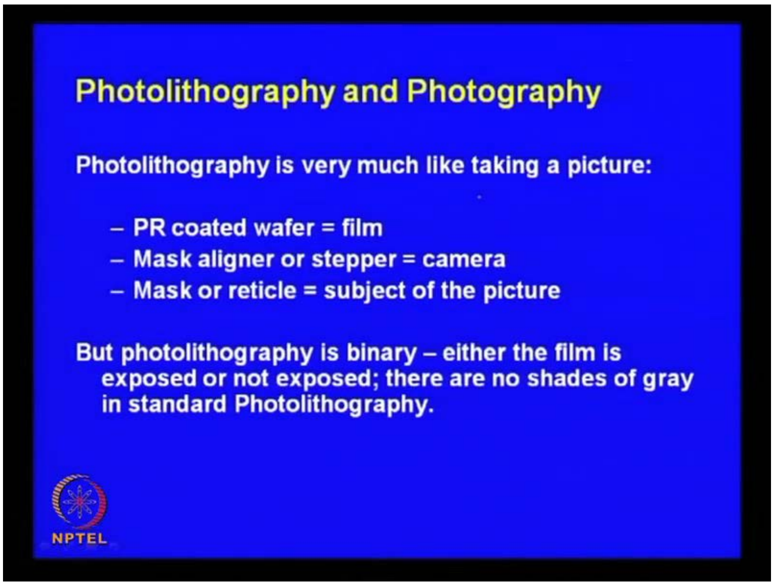

Now, up to this stage you can probably realize or understand that photo lithography and photography you can probably draw a comparison. It is a you can record if you convent, if you record photography, conventional type of photography which was popular lets event ten years back or five years back, may be when the era of digital camera was not so popular. So, you can record the photo resist coated wafer to be your film, the mask aligner or the stepper to be your camera and the mask or the reticle, essentially is essentially the subject of the picture.

So, what you do in your camera you tried to focus on something you want to take picture. So, you have a camera which is essentially the lengths, along with the exposure electronic and you have a film on which the imaged gets produced. So, suppose you want to take a picture of one of your friend or some beautiful object what you see outside the class room. Secondly, so what you we will do. So, that is the image what you want to capture, you capture it only film frame or on your essentially that memory, that digital display what digital represented and digital camera come of it, forget it I mean let us keep our discussion limited to a classical film camera. And then, this is been achieve with the lens and the exposure is control by the shorter or whatever.

So, exactly similar here the object what you are trying to capture is the pattern on the mask, we are mask aligner of the stepper is if equivalent to your camera hardware and photo resist layer is equivalent to your film on which you want to have you pattern. So, that I always give this to be a very simple comparison between photolithography and photography, I mean not only the names are similar, but you can actually correlate them very nicely. But in the present form photolithography whatever we have talked you would like to keep photolithography to a more of binary mode. So, which sharp edge is that is 0 or 1 of black or white there is I mean though there is something call gray scale lithography which is pretty recent development and which can be useful at times.

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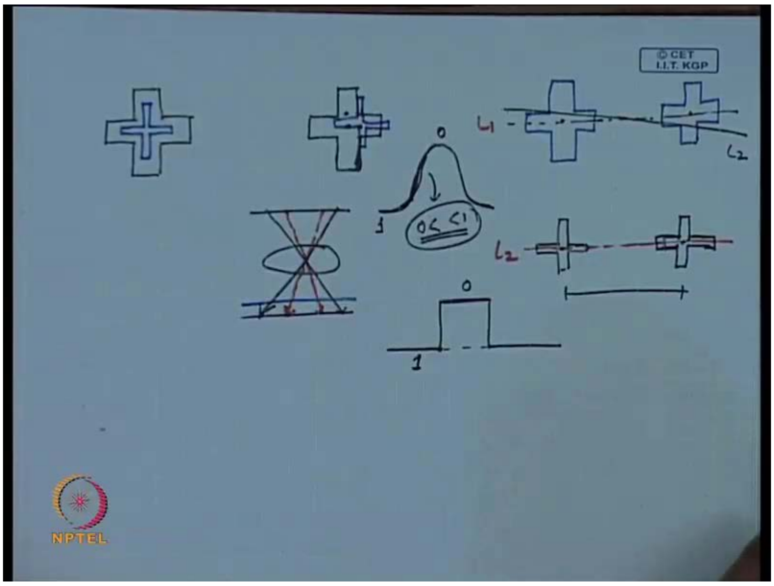

But typically, here what you would like to have eventually after developing is a structure like this with a very high fidelity. So, this is very sharp. So, let us say this is exposed and not exposed areas of the photo resist layer; you really do not want some exposure pattern or absorption pattern within your resist layer like this, which we sort of we got as. So, if this record as zero and one completely exposed and completely unexposed this will… If you scale these areas will have values between zero and one which is not desirable in photo lithography. So, that is aware it sort of again has its distinctions with a camera.

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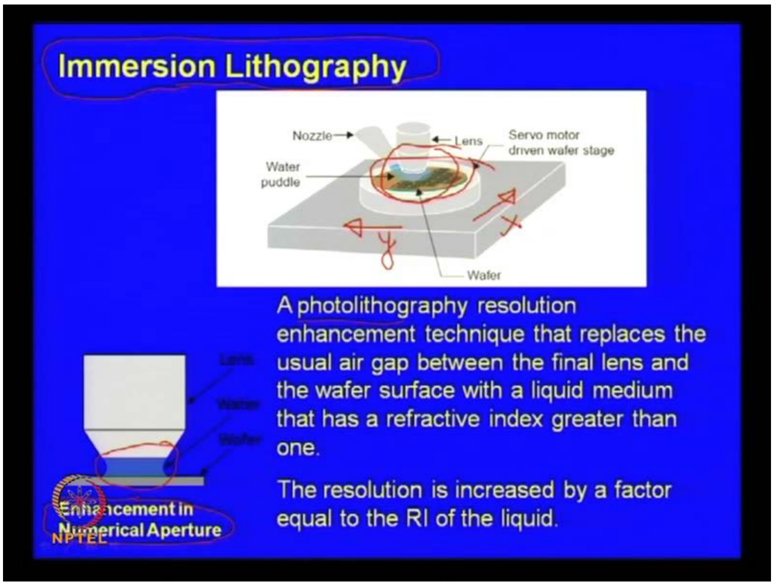

There is another concept of immersion lithography, which is an extended concept of photo lithography and it is essentially aimed at enhancing the lateral resolution I will talk about it in a little bit detail latter. But what happens here is that it is extension of the projection mode lithography, where you sort of have a lens and then you have the photo resist layer, what this suggests that the so, whatever were discussing here both these everything was here, what this suggests that the lens we have are there is a liquid layer between the lens and the photo resist coating.

Now, what thus this liquid layer does it essentially enhances something what is called as the numerical aperture. I will skip the details for here so, here you can see the schematic I mean it is essentially, this is the mechanism of a stepper you see here, and there is multiple numbers of similar types of structures. Now, you know this is mounted on a stepper which is capable of undergoing x and y motion, in x and y detection in a controlled passion and then you sort of put in a liquid reservoir, on a you sort of have a liquid pool over here, which essentially enhances the numerical aperture or the resolution is increased by a factor, which is R I times of the refractive index times of the liquid, I will deliberately skip the detail.

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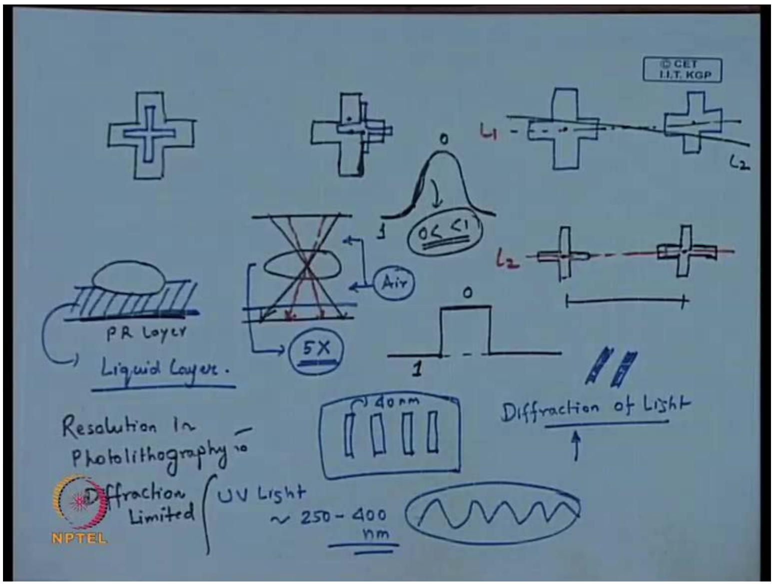

So, here you can see that firstly by way of using projection mode a reduction reticle you could sort of archive five times reduction in size and then you would like to further enhance on the numerical aperture to achieve as small size as possible all because of the fact that eventually you are trying to create very narrow domains, because if you remember couple of lectures back, we did talk about what is the state of now I 54 processors, 30 to 40 nanometers line weight. So, that is what you want to achieve the question to ask is you might ask that if it is 30 to 40 nanometer, there should not be any problem we just create a mask, we choice a 40 nanometer white zones.

Somehow, by some electron beam or some other technical which is possible, which can be extremely expensive, but it can be possible and then place it in to in front of the UV lamp and you sort of achieve the desire reduction in the desired size, latter will do it. It is not so simple, because of the fact that there is some issue I mention in probably in the first or the second introductory lecture, that is the diffraction of light.

This is the same thing that was responsible, we regarded as responsible for the occurrence of rainbow colors on the back side of a c d are which is essentially the origin of structural color. So, because of diffraction what again in very simple word it means are that all the wavelengths of light? So, if you have something, some opening which is very very small and which is significantly small are comparable to the wavelengths of visible light. All the wavelengths of light of almost, none of the wavelengths of light can sort of to this because light has a wave nature.

So, you really cannot take a mask having any future which is very very small and can use conventional optics, let us a UV light which has a wavelengths let us at between 250 to 400 nanometer, because the light just will not pass. So, this is one of the reasons why you will often find that the resolution in photo lithography is diffraction limited. So, in order to overcome this is necessary is to go on searching for light source, which are smaller and smaller wavelengths.

So, you go for something UV with even lower wavelengths which some time is refer to as d UV or d p UV or may be things like X ray or a centrotonic light source, but the moment you change your conventional optics to something more sophisticated, your cost you have to think of this because this is something that the technique that sort of files extreme in application in industry.

So, the cost implications are going to huge. So, this is where photo lithography at the present sort of it is trying all its level, because if you remember Moores law it says that every secondary the number of transistors that can be placed on a cheap sort of dabbles. So, what it loosely means that sort of future size sort of reduced by a half in a two to three years time. So, already there is we have reached a regime of 30 nanometer, 35 nanometer. So, may be in three years time let us say 2014, we are talking about 50 nanometer periodable line width.

Now, the question is whether because of diffraction limitations using conventional optics can you sort of any where stretch photo lithography to that limit or you have to think of some other technique or some other optics. These are the critical questions that are coming up. Even you might wonder, I mean all these listening to all these that where is your chemical engineering knowledge going to sort of coming to play.

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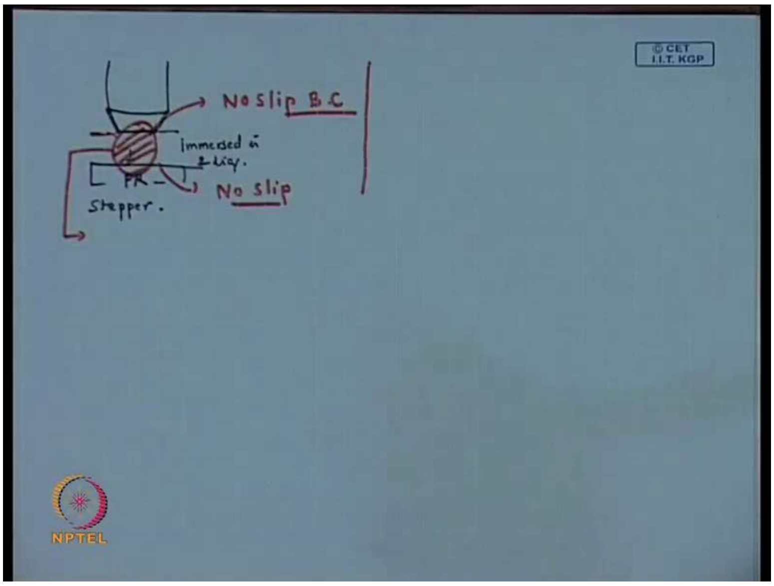

If you now think of immersion lithography, this is a classic setting that is actually lot of research; full dynamic research that goes on here. So, here is a lens, here is the photo resist layer. And, this is now immersed in liquid and you now know or realize that this photo resist coated wafer is actually mounted on a stepper. So, once your exposure is done at one location, what would do like to do, let us say this is location one somewhere down here is location two, it would like to sort of the stepper would like to move to from position one to position two.

Now, the critical question to ask is in industrial process he would also like to optimize the time, but how fasters slow this stepper should move. Because if the stepper moves too fast there might be a meniscus failure or the meniscus between the lens and the resist layer might get detached. Because what is happening if you sort of look back to your basic film, mechanic concept the no slip boundary condition is sort of valid at both the inter faces, because of discuss effects and things like that. This is not the right course to all the details, but in your basic fluid mechanic course and sure you have done that.

So, there is lot of research that is going on what can be the critical speed of stepper motion, I mean industrially we want to sort of reduce the time for movement from one location to the other as minimum as possible. But probably it cannot be as fast as you would have probably been able to do in air, because of the issues he because now you have to really worry about the meniscus; integrity of the meniscus. So, these are concepts these are early as which are extremely inter disciplinary nature and these problems can be toggled by chemical engineering and mechanical engineering or few dynamic approaches.

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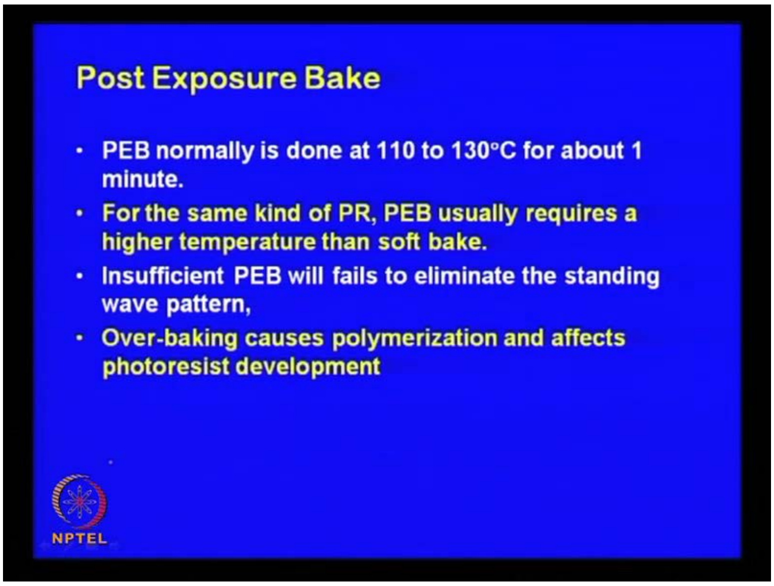

So, continuing our discussion after your exposure is over, there is a step called post exposure bake. Post exposure bake is typically, done at a temperature between 110 to 130 degrees centigrade for roughly about hour and then for the same kind of photo resist, the same photo resist I would say rule of the (( )) post exposure bake is slightly at a higher temperature than soft bake. Insufficient post exposure bake, will fails to eliminate the standing wave pattern, this I will just tell you what it means; for this sort of fails to eliminate, this we will be not will there fails to eliminate the standing wave pattern. Over baking causes polymerization and affects the photo resist development. So, over baking at this stage what it leads it sort of leads to polymerization of the areas which was suppose to be dissolved away during the development stage.

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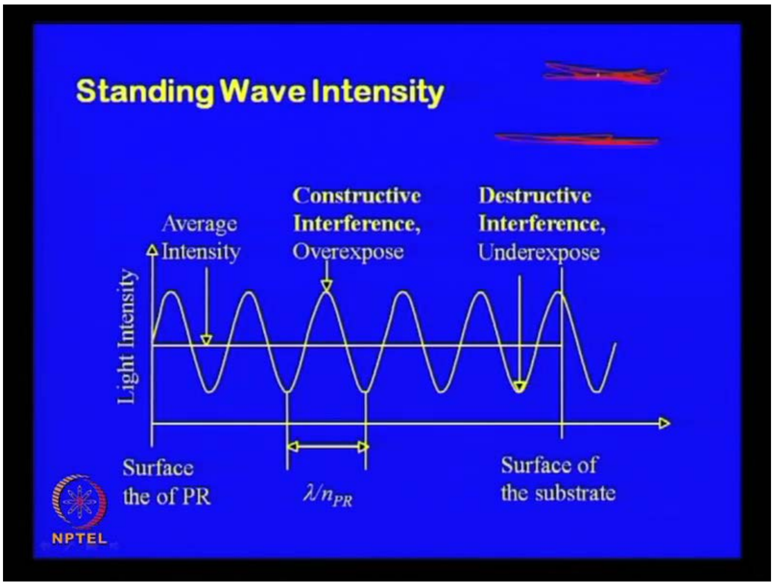

So, this is exactly what is suppose this is the surface of photo resist. So, this is now you have the photo resist film, between let us say these two inter faces, this is the photo resist here interface and surface the photo resist oxide inter face. So, you this particular graph.

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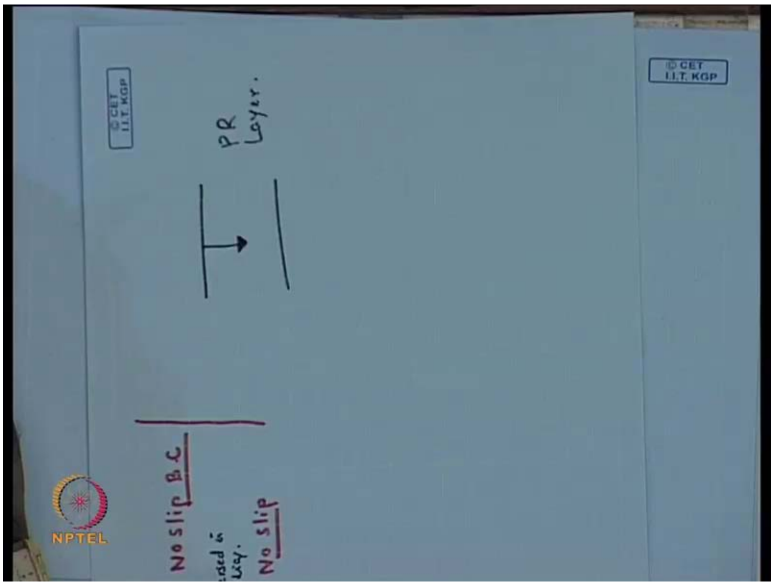

So, this is the photo resist layer and you are essentially looking this way. So, this is the X axis. So, the graph actually is drawn like this. If you look here it is drawn like this. So, this is where the light sort of falls and this is along the depth of the photo resist layer.

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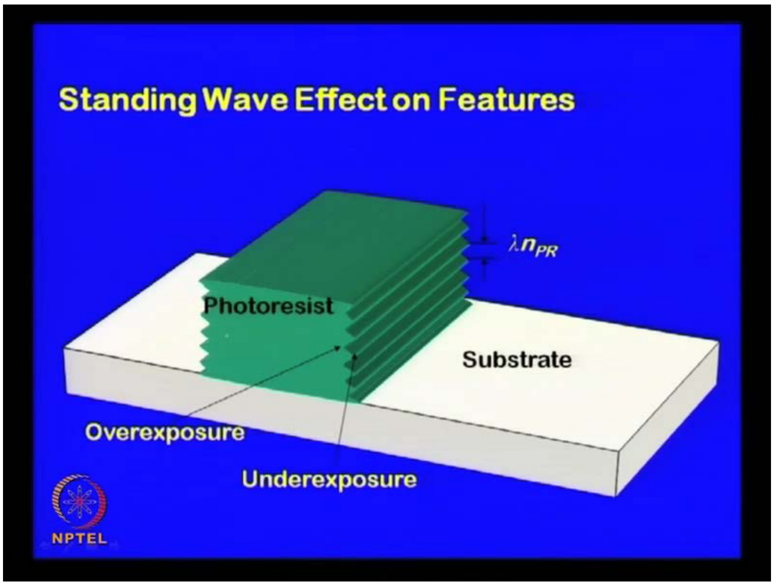

So, what happens again is due to interference of the different wavelengths, what eventually it result is the standing wave effect on the feature. So, because of this interference, the intensity sort of varies like this which get replicated on the photo resist layer. So, you have you get the structure like this.

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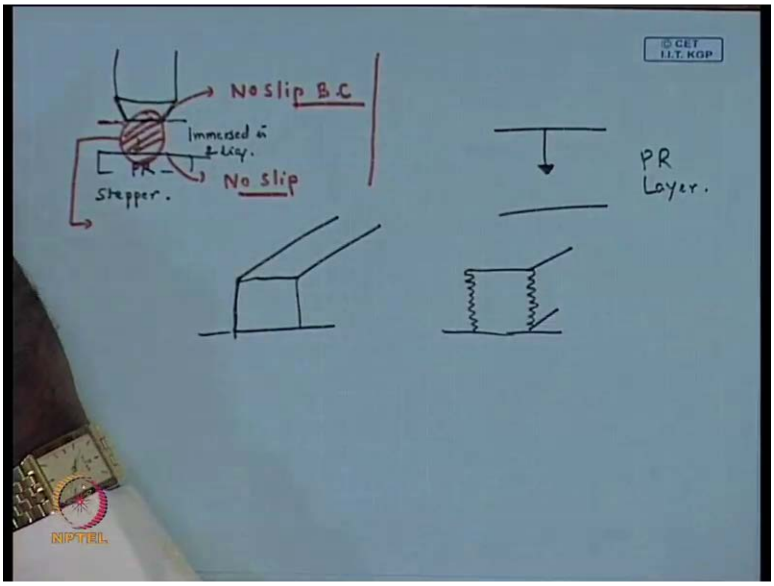

And however, as we have told that typically you would like to have a very sharp edge, but instead of any feature, but what you land up getting is not a feature with a sharp edge, (Refer Slide Time: 50:04) but you get features like this which is extremely detrimental from the stand point of your application and the waviness of this standing wave future is correlated to the lambda of the light source, you are using and the interference, I am not going in to the details of the interference, but you can just have a look there are some constructive.

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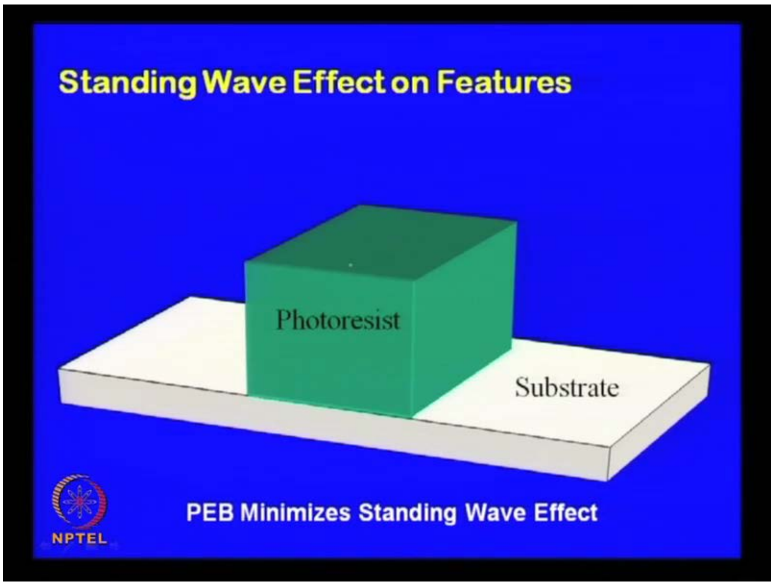

So, this is the average intensity of light and what happens is due to constructive interference and destructive interference, some areas across the depth will get overexposed, some areas will get underexposed. This results in this type of a standing wave effect on the features. Your post exposure bake actually take care of this standing wave effect and because of that is annealing, it minimizes the standing wave type of structure.

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So, once post exposure is done then the next stage that the final stage I would say is the development which is the process step that follows resist exposure is done leave behind the correct resist pattern.

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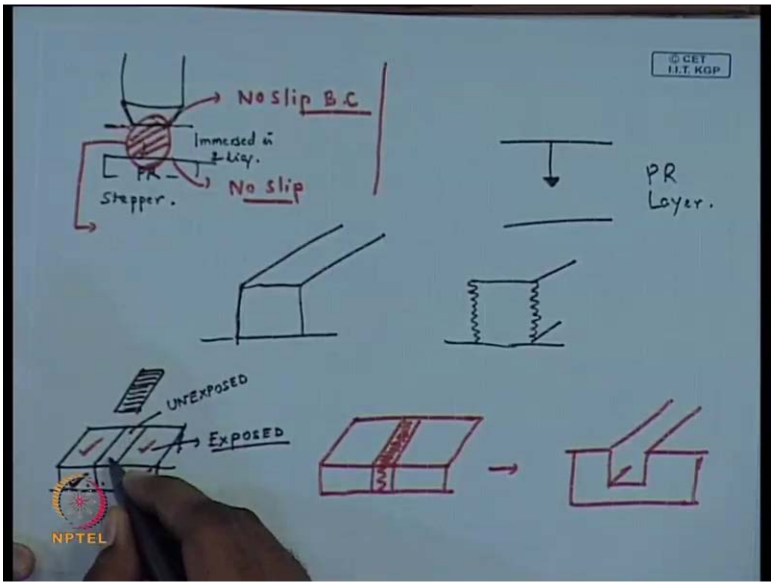

So, this is the stage where using a mask like this. So, this is the unexposed areas and this is the exposed areas. So, it is this stage the developer solution so as we told initially, but every photo resist sort of comes with it is own developer solution. So, suppose if it is a positive photo resist then your developer solution will wash away these zones. In contrast, if it is a negative photo resist the developer solution will only wash away these zones.

So, this is the stage of development there also quiet a (( )) issues associated to it. So, it must be understood that a good development process has a short duration. Because of the fact that you are using a developer solution which ideally you would like to wash away these areas and you do not want it to affect this particular area. Now, the critical thing is that the developer is nothing but and if you look this areas essentially the material is the same; is the same photo resist only part of the photo resist layer has gone some sort of photo chemical reaction has and has sort of undergone some structural change.

However, the material remains in the same and the developer solution you are using essentially therefore is a solvent of this material. So, if you sort of use the developer for a very long period of time, what is going to happen it along side sort of dissolving these areas, it will also sort of affect this structure. So, that will sort affect the structural fidelity what things like that. So, this is important that a good development process has a short duration, it is also minimum pattern distortion or swelling keeps the original film thickness of the protected areas intact and recreates the intended pattern faithfully. So, it recreates only this it does not affect the thickness of this layer and it does not sort of lead to any sort of distortion of the pattern.

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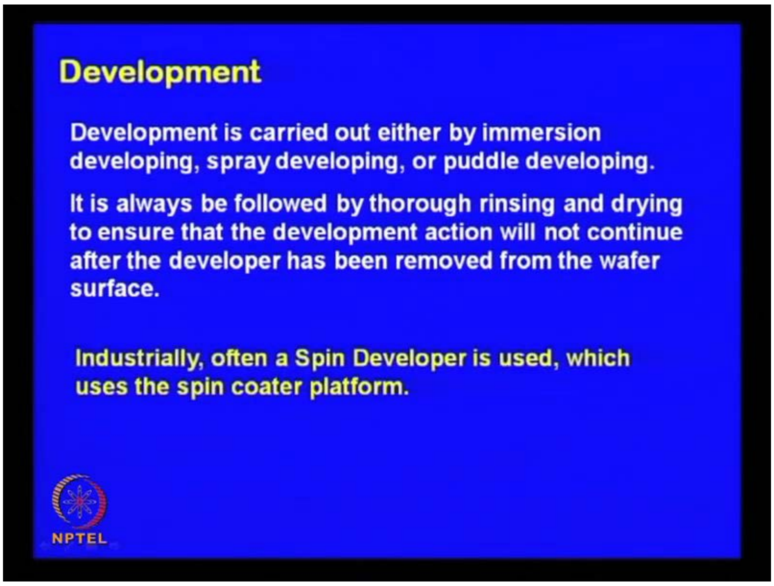

So, development is carried out either by immersion developing, spray developing or puddle developing. It is always be followed by thorough rinsing and drying to ensure that the development action will not continue after the developer has been removed from the wafer surface. Industrially, often a spin developer can also be used which typically uses the spin coater platform.

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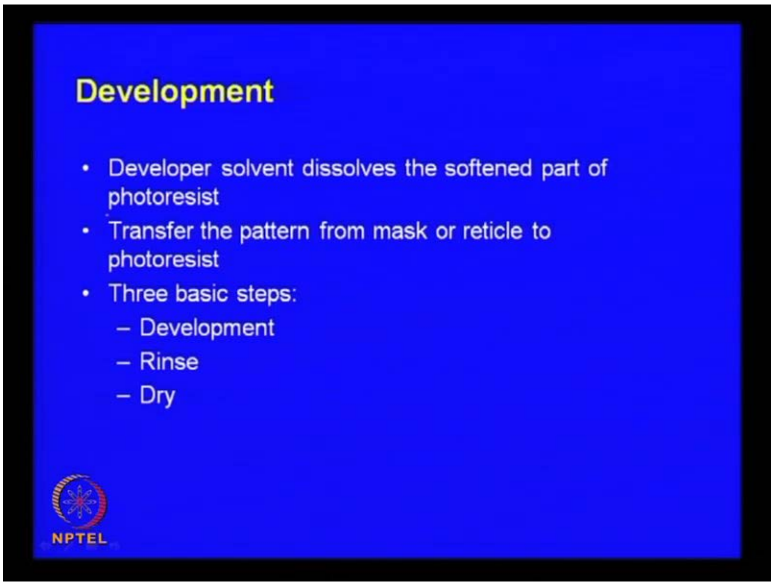

So, a development solvent dissolves the softened part of photo resist, transfer the pattern from mask or reticle to the photo resist. And three basic steps are development, rinsing and dry. We will pick up the later part of the concluding part of photo lithography in the subsequent class.