Instability &Pattering of Thin Polymer Films

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Lecture no# 13

Photo lithography-V

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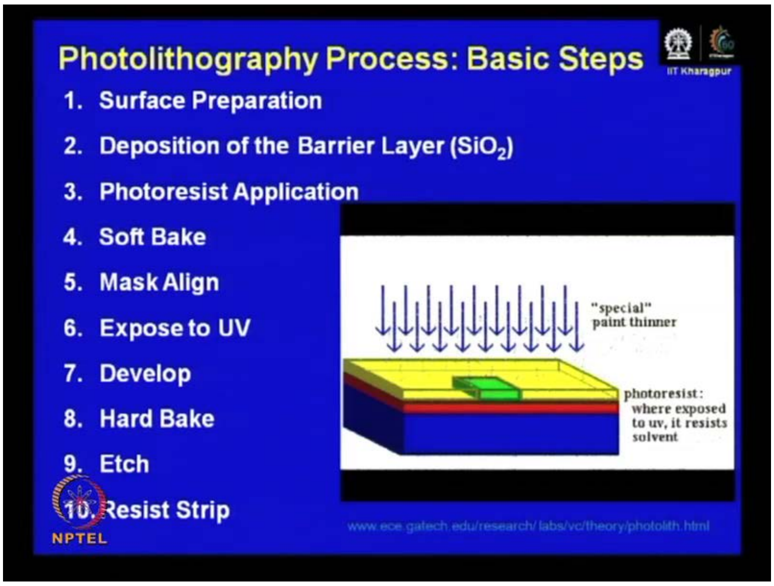

Welcome back, today this lecture we will continue our discussion with photolithography and most like this is going to be last lecture on this topic. So, let us have quick recap as to what we have talked about, so far about photolithography. So, we refer back to this particular UV sequence, where you take essential silicon wafer which is let us say dope with p type initially grow the oxide layer then you coat the photoresist layer then we place the mask place at, expose it UV light. And depending on the tone of the photoresist there is hardening declaration remove the mask then. So, up to this level we have already talk and then comes the stage of developing, which we will sort of start our pick up the discussion from this particular topic and we have talk in the previewers lecture up to the level of UV exposure of exposure and followed by the post exposure making sequence.

So, today we will get started from development and then continue our discussion on the remaining aspects of photolithography. And after we finish again let me sort of tell you, that the picture of the discussion we have had, so far on photolithography something at very, very premier level, it is no were flow where event close to the industrial the setting. But I am sure with discussion at least some basic idea about how the techniques are the method towards.

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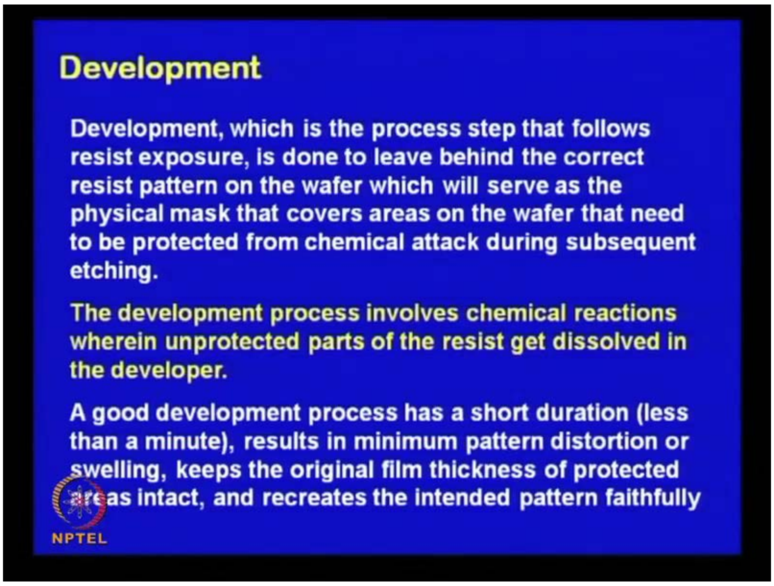

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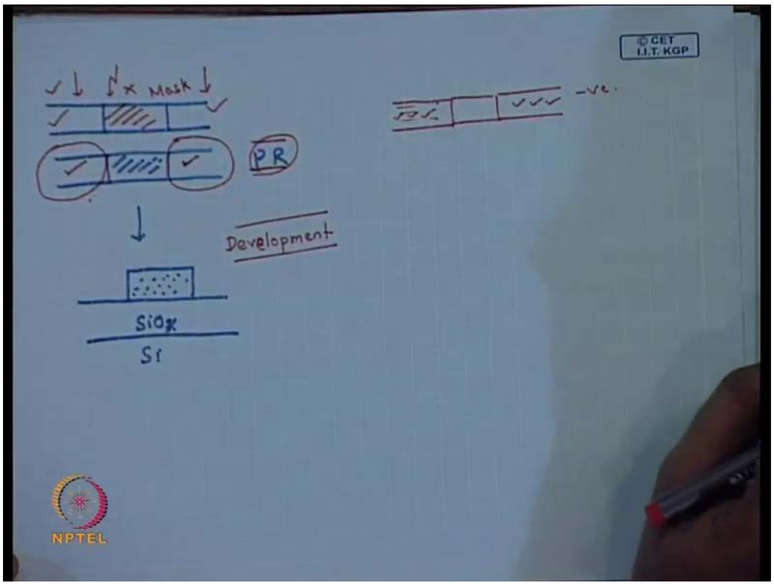

So, development is the subsequent, next subsequent step which is the process step that follows resist exposure and is done to leave behind the correct resist pattern on the wafer, which will service as the physical mask that covers areas on the wafer that need to be protected for chemical attack during subsequent etching. So, as we have talked about depending on photoresist. So, here something your quit conversion with so this is so, the mask this is the photoresist layer. So, depending on the quality of the photoresist this particular area will higher degrade or will crosslink and it is… So, the next subsequent step is that we have this silicon wafer oxide (( )) silicon wafer and now you would like to retile x this part has crosslink.

So, by the process of development you would like to remove the photoresist parts of photoresist each have not crosslink. So, this is for a case for a positive photo resist. So, this step is accomplished by this stages got this process is accomplished by the process of development. Essential idea is that use a chemical solution or a solvent in which the unexposed, the exposed part will dissolve, but this crosslink part, this part will not dissolve depending on the tone of the photoresist it can be the opposite also. So, here we have a… so, let us say this is the mask, this part the light could not cross, this part the light has crossed. So for a positive resist these are the parts which has regarded in if you have negative resist, then well this are the parts upon expose, exposure this are parts that will start of crosslink.

So, in case of a positive resist, you want the UV exposed the degraded parts sort of dissolve away in case of a negative resist, we would like to this all way the unexposed part. So obviously, the first thing that emerges out from this discussion is that every specific photoresist has its own developer solution. I even this very quickly solvent, because after all you are washing or dissolving the same chemical composition wise is same photoresist here and here, but only due to the optical exposure there in certain specific changes in the property.

And so, the solubility of this developer of this photoresist layer in this developer is critical for perfume in the development in a desire fashion. (Refer Slide Time: 02:00) The development process involves chemical reaction where in unprotected parts of resist get dissolve, as we have already told. A good development process as a short duration less than many difficultly results in minimum pattern distortion or swelling keeps the original film thickness of the protected areas and intact and recreated the intended pattern faithfully.

Now, this short duration is very very critical from the stand point of development, because if you have a longer duration even the parts which are not, which you do not would not really to dissolve will sort start dissolving. Because after all do not forget we are a using a solvent which is indeed solvent for the entire material only parts of the material due to the U V exposure of optical exposure as underground some changes in the property. And therefore, you do not one those areas two short of dissolve way to achieve your desire structure.

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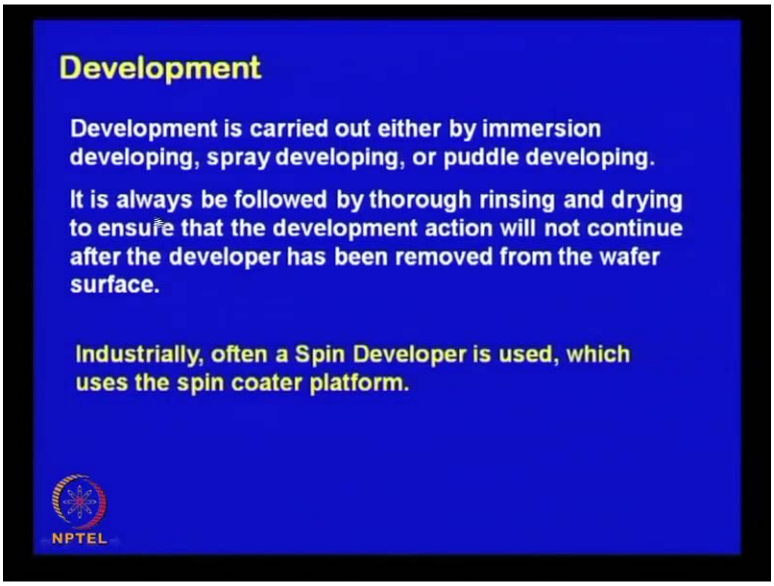

So, development is carried out either immersion developing, spray developing or puddle developing it is always followed by thorough rinsing and drying to ensure development action will not continue after the developer has been remove from the wafer surface. This is very, very important right offer development, the pattern wafer now, we have a wafer which contains the pattern on the photoresist layer. It is very important that right after development the pattern wafer is dried, because if you do not dry it thoroughly then some amount of developer solution, some remnant solution will remain on the wafer or on the structures.

And so, even after taking it out from immersion bath for example, the remnant or trapped of the residual developer solution that remains that within the solution will continue with the develop. So, called development dissolution process which will damage the fidelity of the structure of the industrially of an spin developer is used, which uses spin coated platform to develop. So, essentially the same platform which you use for coating of the photoresist layer can also be used for development, you of instated of polymer solution. Now, on this exposed silicon wafer, essentially dispense the developer solution spin coater and by the action we have discuss details about the spin coating.

So, what happens is the during the centrifugal forcing the flow of the developer solution of the solution on the spin coater platform it set of washes away the parts it is desire to dissolve. And then, subsequently it is followed by a right sequence, because in immersion what happens it of an very difficult to control the sort of dissolution of parts which are not desire to disserve that becomes so problems. So, and again that repeat there is take it out then you drive. So, if you have a process like that in between it sort of it is difficult to sustain continues mode. So, more and more industrially sort of fifteen to the spin coater of platform for development which is often refer to a spin development process.

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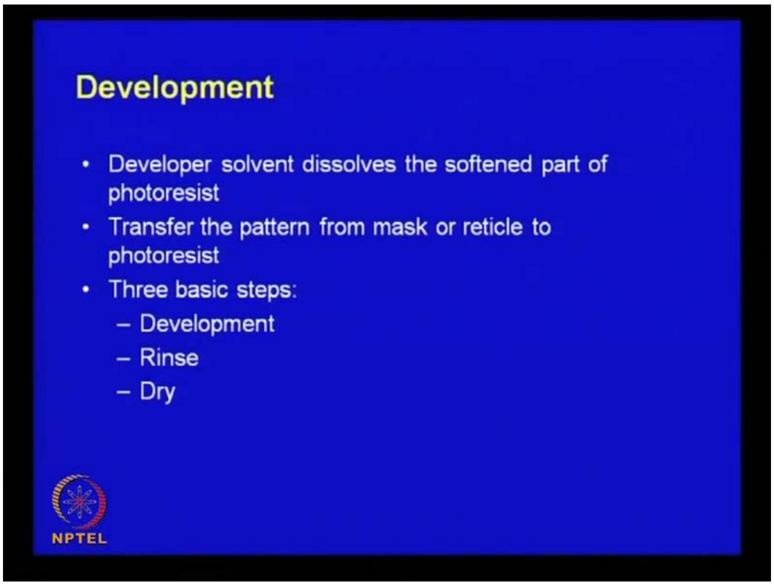

So, here again is a quick recap of for we have discuss developer solvent dissolves the softened part of photoresist transfer the pattern from mask or reticule to photoresist and three basic steps are there development rinse and dry.

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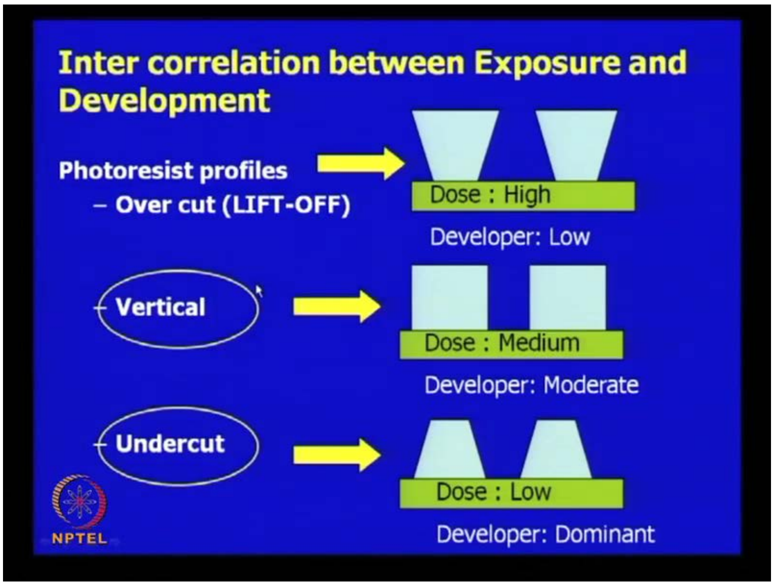

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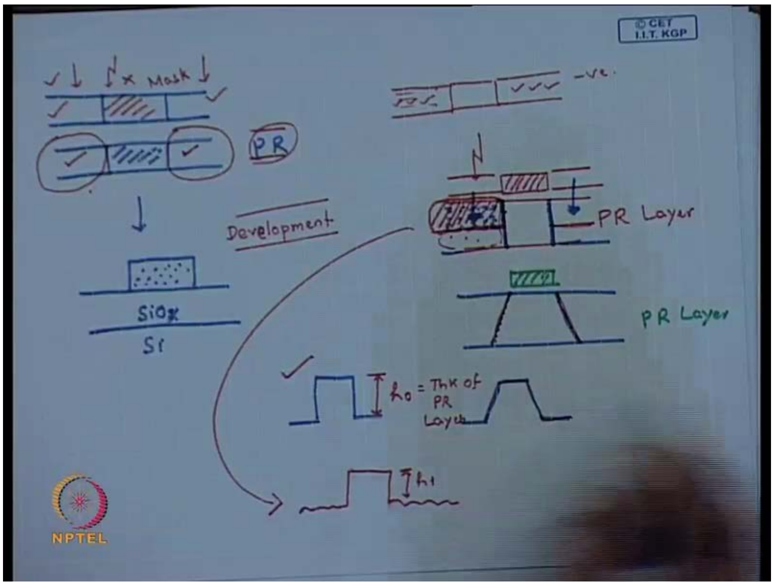

So, here this particular slides sort of gives you a quack idea about inter correlation between exposure and appropriate exposure and the development times, because during exposure also we have discuss. So, this is let us say we have a photoresist layer and you are expose, suppose we have mask over here. So, this is part over each do not want your light to pass you want the lining effect. So, the UV lights it actually penetrating within the photoresist layer. Now, one of the critical things to ensure is that; the light, the exposure profile within the film sort of; goes right in to the or along the depth of the photoresist layer.

In other words there is a possibilities let us say this is another case were we have a photoresist layer and we have the same mask, there is possibility couple of possibilities. Firstly, you might have a profile like this of the light or the expose parts. So, in that case through desired to have a structure like this, we will eventually result in a structure like this. The other possibility is that; this does not penetrate of with the film thickness some of the intensity of the light become three. And so, the; these parts subjected to proper development file over these areas the development is not fully complete.

So, what will happen depending on the when you want to wash in the developer solution the parts which are properly develop will sort of wash away and this parts will not try to this large. So, this might actually lead to a structure which as to fall defect, suppose this is the desire height you want eight zero ideally corresponds to the thickness of the photoresist layer. So, you might have some structure in this particular case, where height might be less than the desired height also you might not see very smooth surface. But here, because part of it might have developed properly part of it might be under developed and things like that.

So, these are this is; so, in addition simultaneously along with development, we also worry about the along with the exposure, we also need to worry about the development process. So, this to sort of work in conjugation or work in random to achieve the desire structure we want. So, an optimum so, desire high fidelity structure like this one, let us say only possible when we have the optimum exposure as well as optimum development. So, this particular slide gives an idea. So, if you have a high dose that is exposure is high and the developer is low weakly improperly develop then you tend to get a structure like this.

So, dose is high and the development is low so, you might actually get a structure like this when we have the both of them are in appropriate proposition are in the optimum proposition, we get the desire structure. And this is, what is known as undercut structure? We what just talk where the exposure are the dose is low and the developer dominant. So, dose is low so, that is why with the depth somehow the light as not been able to sort of follow this inter face shortly and it has sort of become v curve and shade to improper exposure. So, it is important is realize that, the exposure and the development process sort of arcs set of very work, very very complementary fashion.

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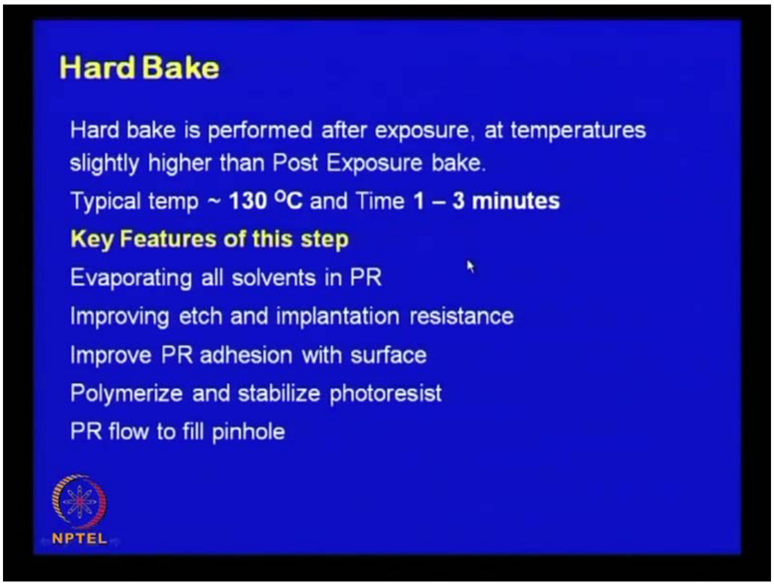

Now, development is followed by; so, that is brief discussion we want to have about development in the lab scale off course you typical go for in immersion development that is routinely what is used. So, the development process which followed by the development process where hard bake is performed the after exposure at temperatures slightly higher than the post exposure bake typical temperatures can carry from 130 to 150 digress centigrade. Time and time one to three minutes key features of this step is evaporating all solvents in photoresist improving the etch and implantation resistance improve photoresist addition with surface polymerize stabilize photoresist and P R flow or the photoresist flow to fill the (( )).

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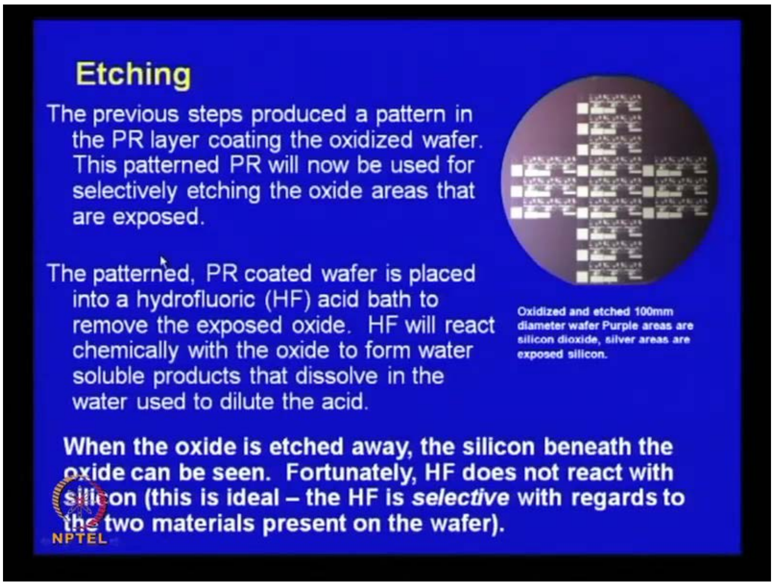

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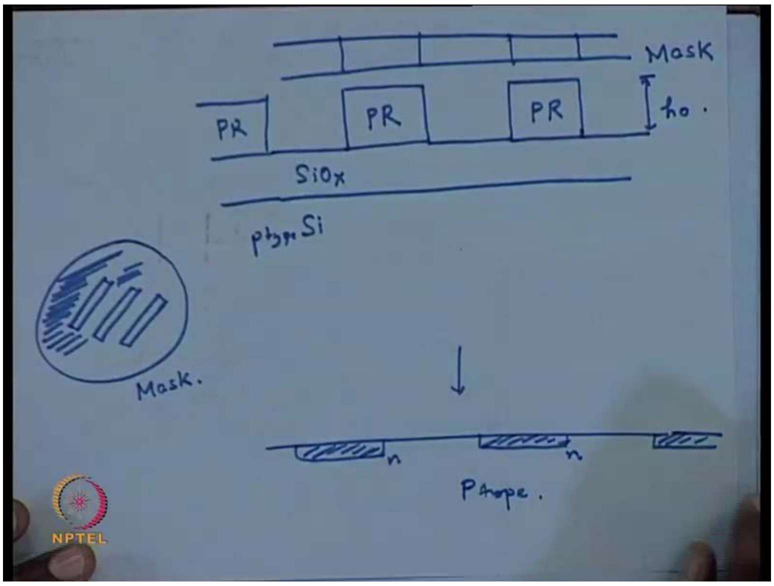

Now, the last stage; so, after we have obtained your structures on the photoresist layer; so, this is post development photoresist structure now, what we want to do now? We our finally, intention is to trance from this photographic structure on the photoresist layer each do not forget is actually a reflection of the structure you had on the mask. So, on the mask you nearly had a chemical structure are sort of you had. If you remember about the mask you had a chrome layer and part of it was split of; it was more of a two d structure there was variation.

So, this parts where covered by the absorbing light let us say over this areas light was allowed to sort of past. And so, the structure on the mask now, we have got it converted on to the photoresist layer and essential idea is that following the same pattern dew finally, so, this is finally. What we would not create could be interesting in creating let us say if it is a p type wafer we will be interested in creating domains of; are n type domains within that p type wafer.

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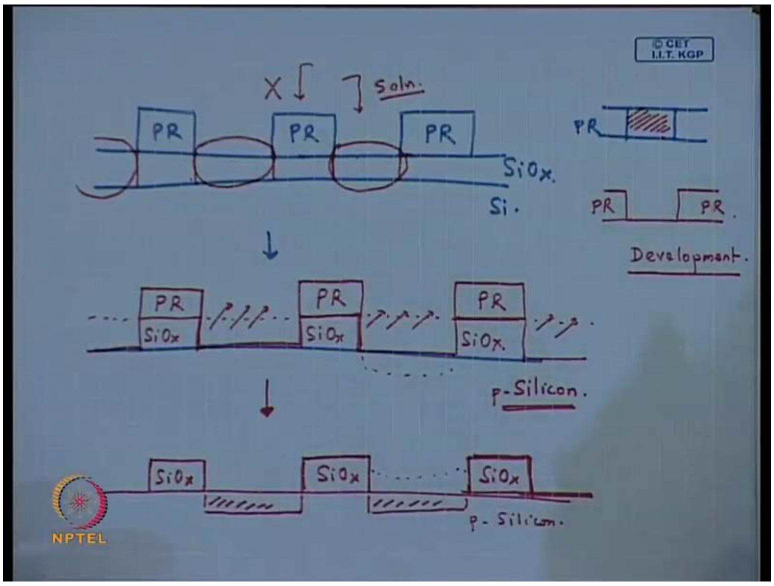

So, in order to have that what are the remaining steps, the remaining is first you need to sort of remove this oxide layer along the photoresist structures. So, your next stage is, I will just draw it again. So, this is your develop wafer, you still have a intact oxide layer on the silicon. Your next desired step will be to remove the oxide layer over these areas.

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And this is achieved by the process of achieve. So, what we have done now? You have actually transform the mask pattern initially to the photoresist layer and then same pattern what you have on the photoresist layer as now, been transferred in to the oxide layer. So, how is it done? Exactly like the stage of development where you had a layer of photoresist having special variation in there chemical composition due to the obtain; due to the sort of special variation in U V light exposure control by the mask. You sort of immerse sheet or applied the developer solution, which preferentially removed parts of the photoresist of the exposed photoresist film depending on its chemical properties. So, this is, what you did as a part of development.

Now, you essentially want to do the same thing, instated of your change in the chemical properties in a; in the developed or in the exposed photoresist film. What you want here? Is that, you want to remove away parts of the oxide layer, which are not covered by the photoresist or the pattern photoresist areas. So, essential idea is that now, again you applied some sort of a solvent, which will remove the parts of the oxide layer which you sort of artificially grew during growth of the barrier layer, where our the solution has axis to the oxide layer. So, if you now immerse this whole structure in a solution, what will happen over these areas?

The solution does not have access to the oxide layer; however, over this; over the areas where is there is no photoresist structure the solution as direct access to the oxide layer and you have to use a material or a solution which then dissolves the oxide layer preferentially. So, eventually the oxide layer below the photoresist structures remain and undisturbed or un part up while the oxide layer which where over the areas above which there was no photoresist coating gets washed away. So, all this gets washed away in the; etch during the process of etching. So, this is what your etching sequence or a etching process does it transforms the photographic structure you have created post development on the photoresist film now, x transfer a preferentially transfer on to the barrier layer or the oxide film.

(Refer Slide Time: 13:56) So, the previous step produces a pattern in the photoresist layer coating the oxidized wafer this patterned photoresist layer will now be used for selectively etching the oxide areas that are exposed, we have all ready tolled. The pattern coated wafer is placed in typically a hydrofluoric acid is used as an etching solution H F bath to remove the exposed oxide. H F will react chemically with the oxide to from water soluble products that dissolve in the water used to dilute the acid. When the oxide is etched away the silicon beneath the oxide layer can be seen H F does not attack the silicon.

So, this remains sort of unpart of and we now, have access to the silicon which let us say has a specific type of doping. And then all you need to do is that you need to again expose this structure thing in to environment where there is a reaction with the; let us say some gas face reactance which react with the p type wafer creating n type domains over this areas, where you do not have a; this photoresist combine photoresist then oxide structures. But the issue is that the doping reactions are pretty harsh. So, the conditions are pretty harsh and. So, if you have the photoresist layer presents during the doping reaction, there are every possible there is every possibility that; the during the doping reaction reactance will also react with the photoresist layer remnant parts of the photoresist structures.

And that will contaminate the doping sequence. So, the next step before doping is perform is to now, wash away or dissolve away the harden photoresist layer itself. This is important and quaky are in a way for important understand that in the process of development. You depending on, off course on the tone of the photoresist we have preferentially remove the areas of the photoresist, which are ether gone which are ether degraded due to U V exposure are the areas, if you are negative photoresist for example, we have remove the area as which remain unvolted by not getting expose to U V.

So, part of the so, the development; so, in other words to the development solution to the developer solution this change in the chemical property within the photoresist layer after exposure was important. So, the developer solution was strong enough to dissolve parts of the photoresist layer that was that is intend remove and it week an after not to effect and not to dissolve parts of the photoresist layer. Which can either be physically crosslink are which has not (( )) either not degraded are has not physically crosslink depending on the tone of the photoresist. So, the developer solution did not affect or dissolve those parts of the photoresist film.

But in this stage, what you want to do? The part of the photoresist layer which sort of could the sustained the developer solution during the process of development itself is now removed away. So, after this particular stage, what we are left? With is the structure barrier layer nothing (( )) to the entire the all the photoresist is now, gone and you are left with the structure barrier silicon oxide or the oxide layer on a exposed silicon.

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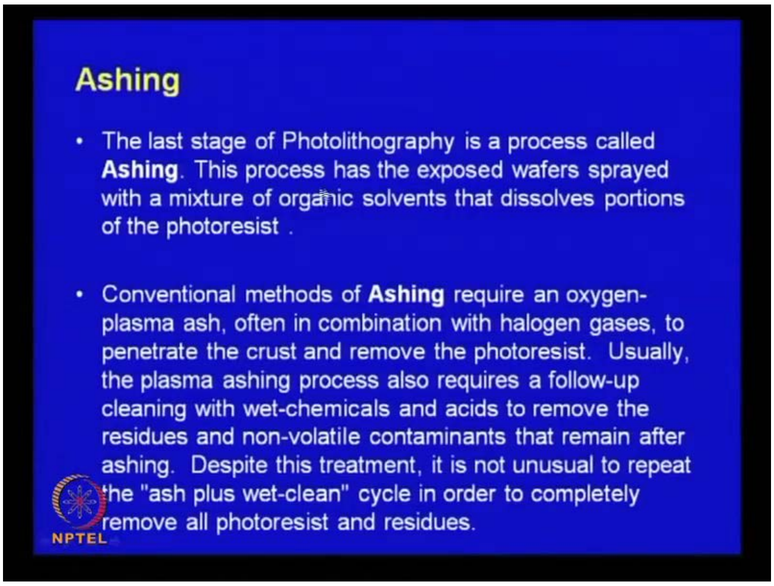

This particular steep of remove this portion of the hard and photoresist structures is known as the method of the process of ashing. It is the last stage of photolithography this process has the expose wafers sprayed with a mixture of organic solvent that dissolve portions of the photoresist. Conventional methods of ashing require an oxygenplasma ash. Often in combination with halogen gases, to penetrate the crust and remove the entire the photoresist, because do not forget this is photoresist sort of chemically stiffened or audient and has non dissolvent in the developer solution.

So, you really need some really storm chemicals remove it on the plasma Ashing process also require a follow up cleaning with wet chemicals and acids to remove the residues and non volatile contaminants that remain after Ashing, because most important is no part of the dissolve photoresist layer should actually go and block this areas. Because then your entire concept or entire objective of the photoresist process the photolithography process gives lost.

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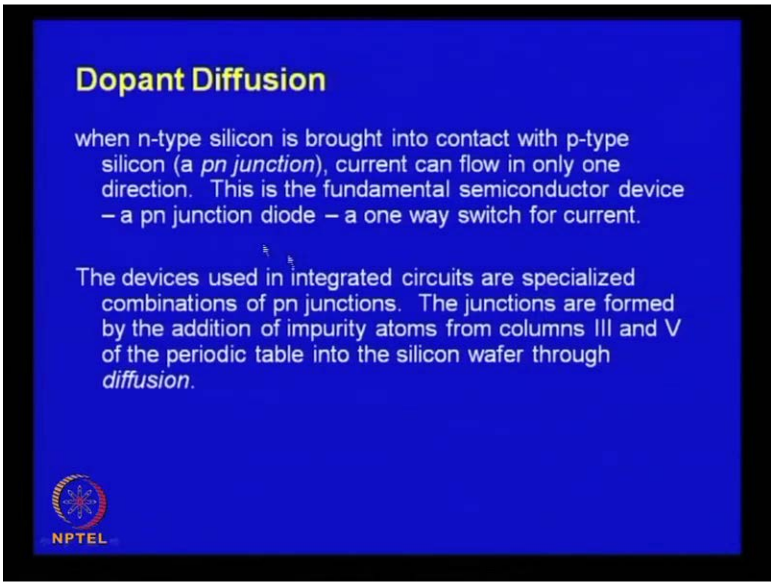

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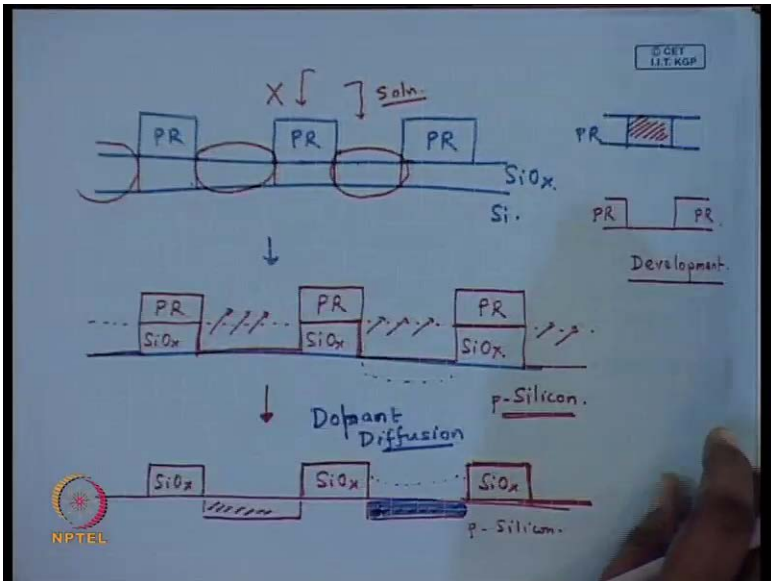

This pied this treatment, it is not unusually to repeat the (( )) plus white clean cycle in order to completely remove all photoresist and residual extremely important that. So, no residual or ruminant photoresist remains at the stage were you finally, have a structured wafer now the structure is only on the oxide layer. And your now, going to subject that to the final reaction which will create domains, let us say n type domains over areas where there is no barrier layer. So, this is the final objective and then that is what is final step is Dopant Diffusion n type silicon wafer is brought into contact with p type silicon current we know this. So, this process this I am not going into the details I am keeping that details final thing final steep will be step of Dopant Diffusion.

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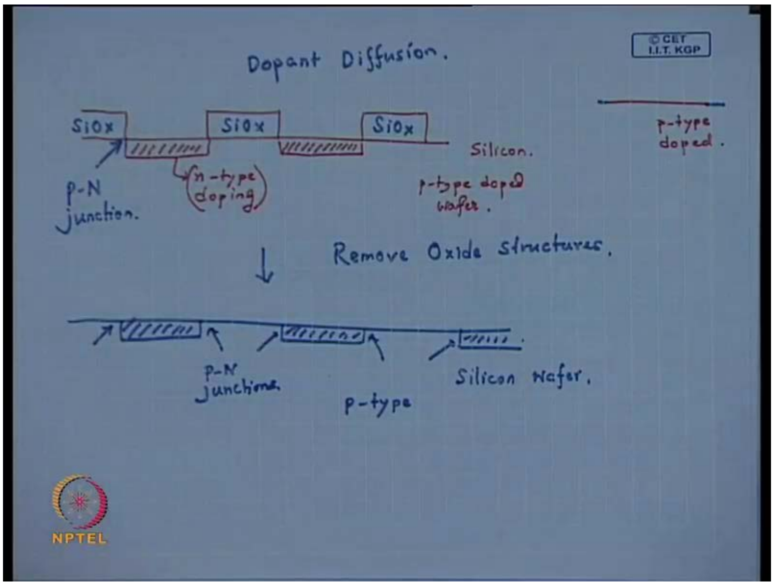

So, that essentially with creates p type, I if you have p type silicon wafer. So, then will some chemical reaction surface reaction here, which will create n type domains here. And once that is accomplice your next so, after the Dopant Diffusion steep you will now, have a silicon which initially you have taken, let us say having only one type of doping after the Dopant Diffusion steep. We know have domains of other type of doping in a let us say wafer matrices. So, our intention as you an initially pointed out each one; now, axes a p n junction

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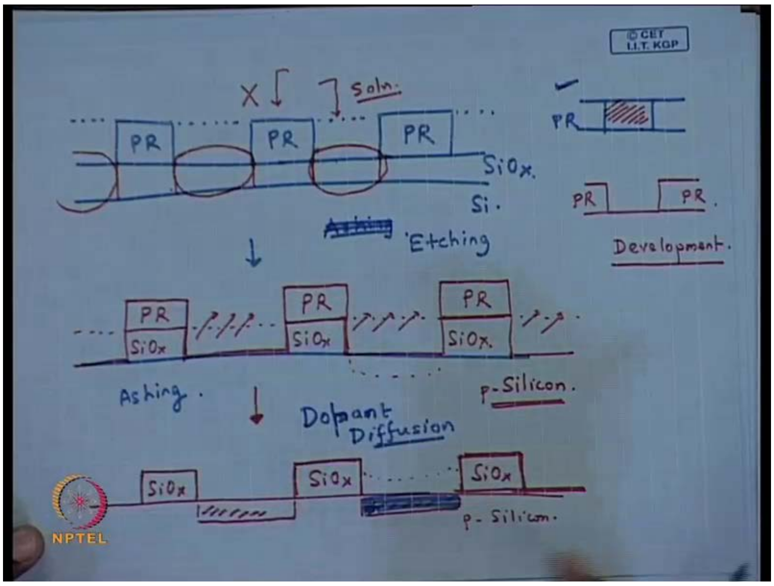

So, this is; I will just technique recap of what we have discussed today. So, you take a mask you then expose it so, you after performing the exposure your here we have a photoresist layer which now as special wearing chemical properties this special variation is sort of in phase with the mask patterns then you develop it you remove part of the photoresist layer and create a structure photoresist film. So, you had a initially had a flat photoresist film and now, part of it has been washed away to have structure photoresist film. Now, from the stand point of microelectronics, what we are saying is all the away important.

So, you sort of get the structure photoresist film then, you with the etching then, you do the Ashing and then you do the sort of the dopant diffusion. However, in various other branches of science for example, if your trained to fabricate some micro fluidic channels or some templates for starting structure and supper hydrophobicity something, we have already talk about in there are can be many many settings in which you go only up to this level. You be happy to have the final structures on your photoresist layer itself, because this we let us say depending on the pattern stricture. You had on the mask we have been successfully able to transfer to that structure on to the photoresist layer.

And you want to sort of make further pattern further experience on this type of structure itself. However, if you talk about full complete photolithography process as it is required in the microelectronic industry. You subsequently go to the stage of etching where you remove the oxide layer following the photoresist structure, what you have? Once the etching over. So, after etching we create like structure like this this you have a pattern you have a pattern present on the silicon wafer. Now, each of the pattern p layer or strip now it is a compose its structure comprising of a photoresist stop and a oxide bottom. The next stage is Ashing, in the Ashing stage you get of the photoresist layers.

So now, again you have a structure surface, but the structures now comprises of only oxide the structure oxide layer or structures are made of silicon oxide which on standing on the silicon. And then you going for the dopant diffusion and then if your taking about microelectronics application you final steep would involve removing the remnant oxide structures all together.

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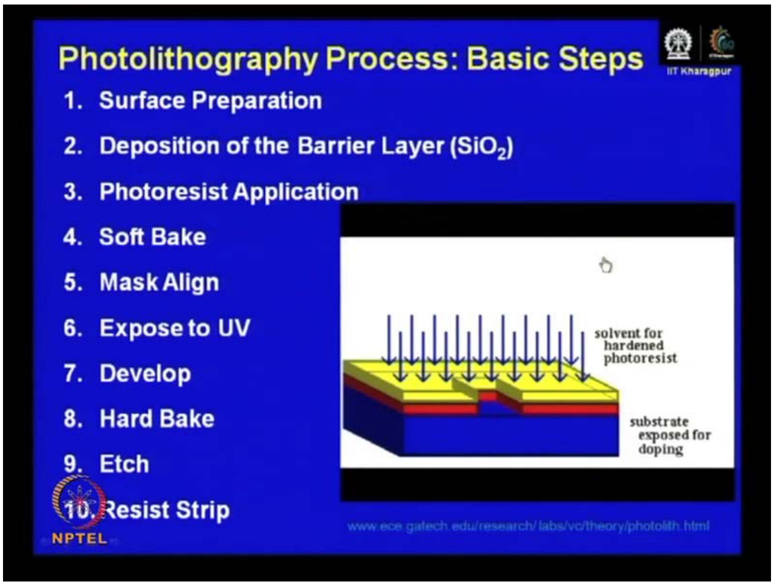

So, finally, we will get back again a flat silicon wafer (No Audio From: 31:22 to 31:30) finally, you get back a flack silicon wafer, but do not forget that you have the started of also with the flack silicon wafer. But only deference you might understand is that you had started off with a entirely p type dope wafer and what you now, have dusting in dope domains. So, each one the junction sort of aces has p n junction. So, this is in a not shall what you wanted do discuss or the concept, I want to give you has a part of this course on photolithography I think if you do little bit of lecture search couple do it then, see this lectures couple of time concept will be clear to you.

We get back to the movie are the movie sequence are the; we had been showing from the beginning so, let us say have a look. Now, whether a understand all the steeps we get started with the p type silicon wafer substrate, which is here as you have talk and then you then subsequently deposit the barrier layer or the oxide layer. You applied the photoresist layer by spine coating you do a soft back to remove the solvent, you make a mask somewhere. And then, align the mask using the exposure mechanisms we have already talk then you expose to U V to achieve the exposer steep when you do the development the hard bake the etch resist strip for the ashing and then dopant diffusion reaction.

So, let us have a look now quickly and I think each steep will now make sense to you. So, you start off with silicon wafer substrate, you grow the oxide layer you applied the photoresist by spin coating, you bring in the mask containing the desire structure. You place the mask depending on what mechanism you want to use expose it to U V depending on the photoresist tone, there will be special variation in the chemical property within the photoresist layer, the mask is lifted off now, you develop. So, part of the photoresist layer is now gone we have unable to successfully transfer the mask pattern on to the photoresist layer, you do the etching. So, that will remove the part of the oxide layer also which will follow the topography of the photoresist layer.

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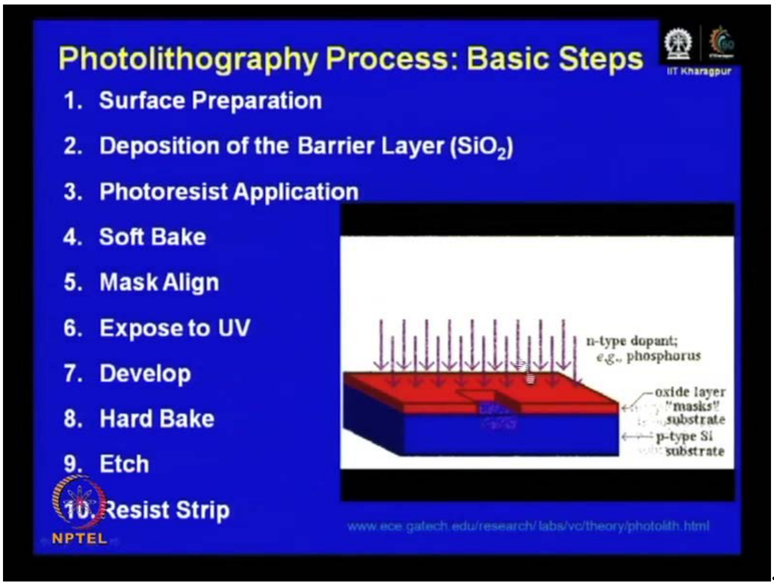

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Then after that this is what we discuss in this particular class. So, between this steep and this steep is essentially, this had a you have a (Refer Slide Time: 28:24) so, the structure on the photoresist layer get transfer on to the oxide layer and the oxide layer is also remove, because of the etching. And after the oxide is remove we talk about the process of ashing which we can see here. So, here now, the photoresist layer gone you are left with the structure on the oxide layer only and then you do the dopant diffusion. So, only the part of the wafer that is not covered by the barrier layer is sort of under goes diffusion or n type domain is created and in the final steep, you also remove the oxide layer and. So, eventually you get to what we had talk about you get back flat silicon wafer, but which contains desisting n type domains as for your structure are the structure you had created on the mask.

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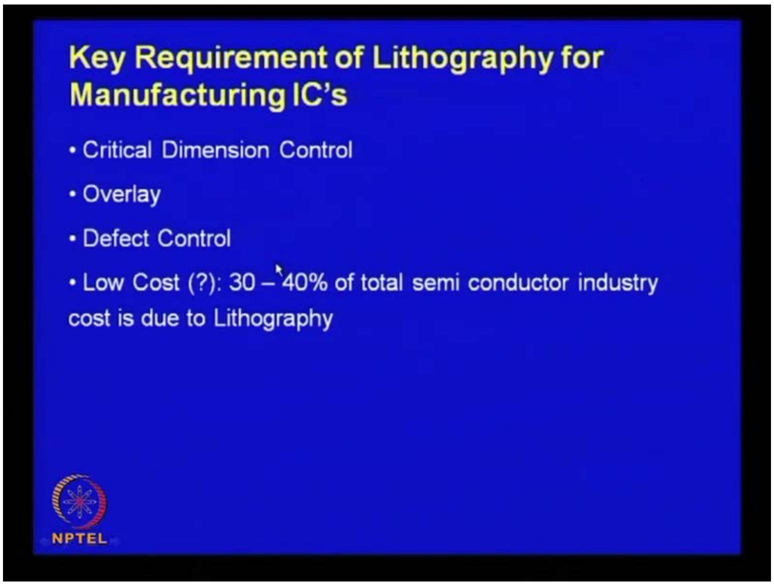

So, this is; this sort of conclude our discuss on the photolithography, what we wanted to discuss? So for, but I will. So, there are some key requirement of lithography for manufacturing integral circuits, critical dimension control, overlay defect control and as much as cost effectively you can making, because 30 to 40 percent of total semi conductor industry cost is due to process of lithography.

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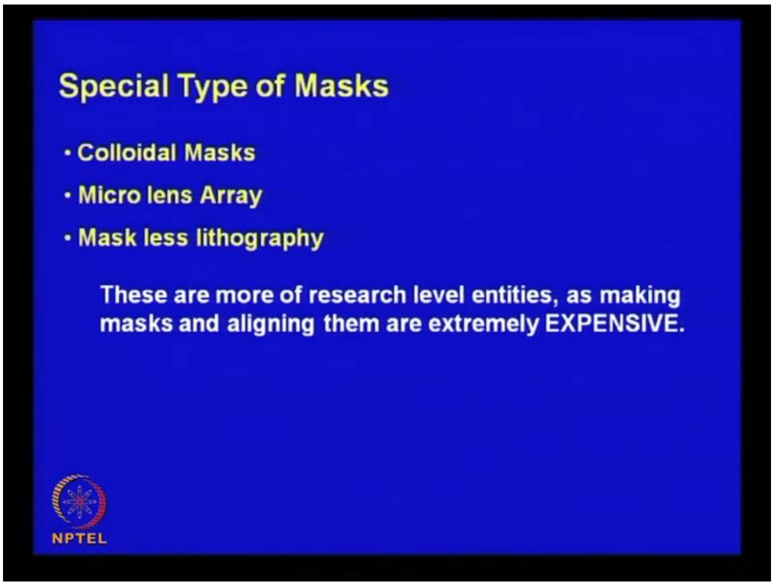

Now, after this we will discuss some novel aspects of photolithography, which are more of associated with created fun. But they hardly are applied presently at the industrially level, but they have some potential and they are research levels. So, let us say have quack look at three have the topics we have what discussion. Firstly, colloidal masks, second is micro lens arrays and thread mask less lithography. Now, by now you also understand alongside critical issues like let us say a mask allayment and things like that. One of the meager difficult thing to obtain or one of the most costly or a meager component of for the successfully completion of photolithography process is to obtain the desire mask.

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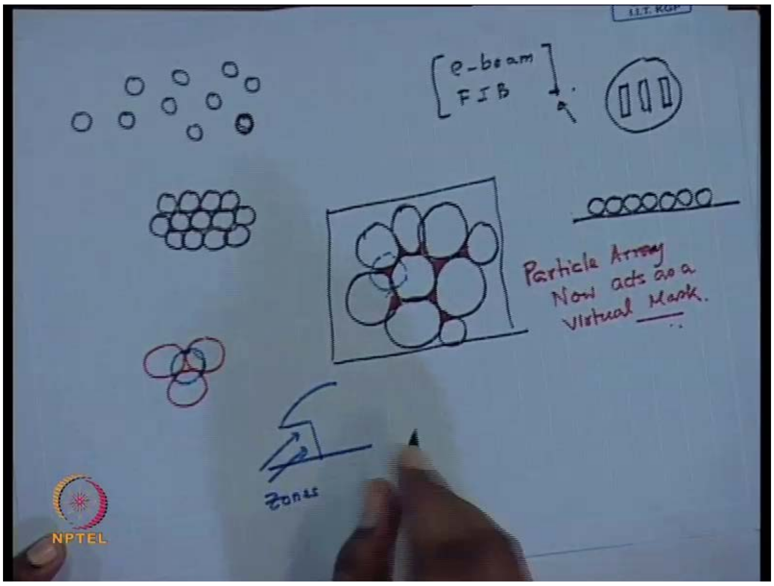

So, which again you take a layer of a quartz class let us say a coated with chromium and then parentally it strep of parts of it. And this as to be done by some direct right method likes electron beam lithography or focused on beam, we can just way literature search this key words which is again in extremely, costly method. And these are direct right methods is a not parallel method in c d l very time consuming slow etcetera, etcetera. So, there has been some focus to sort of; can we create and off course is other thing one we create a specific mask, you cannot change it is deign. If you really want to create a new design, you need to have a new mask. So, there has been thoughts of can we some of make configurable masks and things like that.

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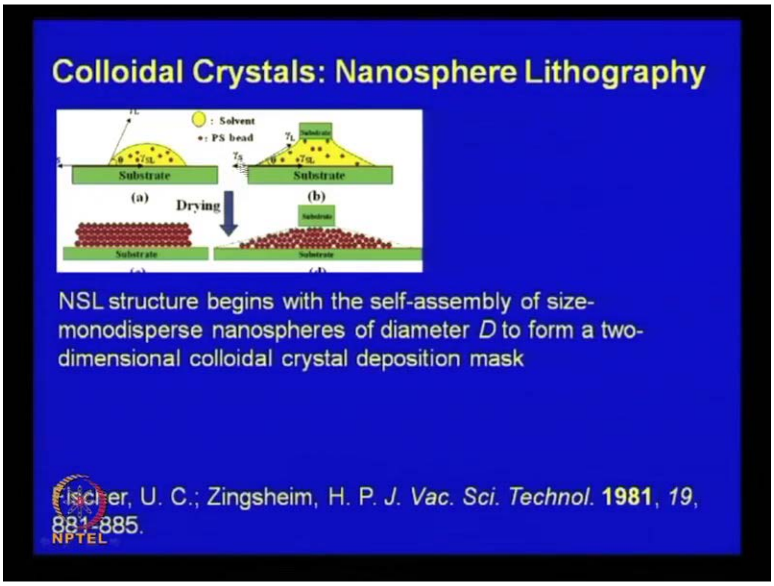

And one of the things that people are working with is the; so, called the concept of colloidal crystals. Now, this also goes by the; an nanosphere lithography this process itself of goes by nanosphere lithography. So, very simple concept, if you have some small special particle, let us say of silica or something colloidal spectacles this verse disperse in a solvent and you apply a drop of that dispersion on a solid surface and sort of do a control evaporation. Under many circumstance, you can actually leave to a layer of this spectacles nicely ordered in the surface with an hexagonal close by structure.

This happens give to the interdiction within the spectacles of the as turns out that; the hexagonal close by structure corresponds to the minimum energy configuration. We might this should latter in this course letters parts of this course, but the timing we have to believe me that if you sort of the allow spectacles to evaporating to spectacles mono disperse that the spectacles have roughly the same size. It is possible to create structures with a hexagonal close by structures. So, it is like this.

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Now, this is sorry for the bad drawing, it is sad then run there in the nanolithography as it is called itself is a meager area of research in has been receiving significant of is attention, but one can. So, I will the skip details is of an achieve as the solvent evaporates capillary forces draw the nanosphere of the spectacles together and the sphere crystallize in a hexagonally close packed pattern on the substrate. There are some little bit of details which one needs to sort of walk out. So, have a single layer cover this happens this hexagonal close structure occurs if you have particulars sort of arranged has a single layer on the solvent surface. Which is difficult to achieve, but it can be done and sacrum specific condition, we are skipping that details for the timing.

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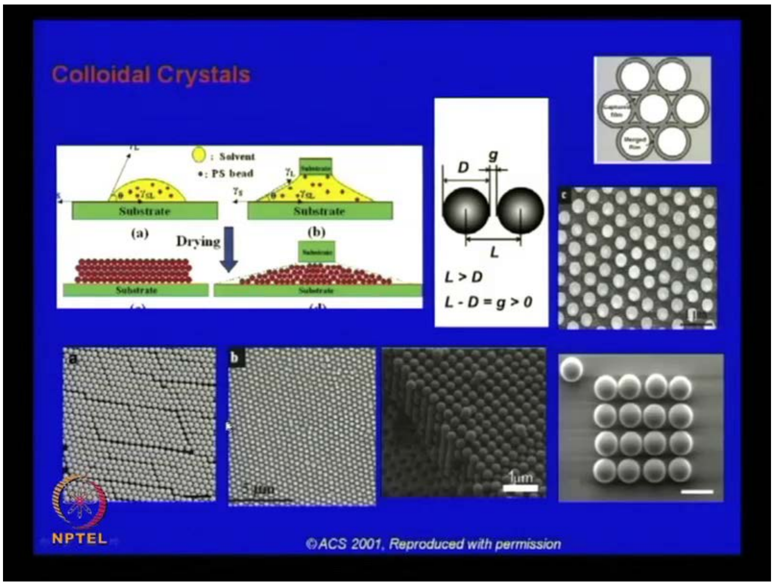

So, here you can see that it become possible to create hexagonal close pate structure like this. They are will be in most experimental cases they are some deficits along this structures, but those again, but can be control. One can also think of working out technique they are technique working on that of making this structures nonclose pates. So, really do not owned the particles to touch each other or the stabilization is taking place due the satiric interdiction. But you can trailer the interdiction by some other mechanism again something probably I will take up at a letter. But for the timing if you regard that it is possible to make hexagonal close by structures like this.

Then, you can see that if you have a structure like this, in between areas of this particulars if you look at this particular figure at the mouse is now, in detail surface below this array of spectacles get is exposed only our this areas and it not exposed other areas. So, now if you have a surface let us say photoresist and on top of that if you have been able to create an array of this type of spectacles. And then, if you expose it to U V light then, what will have happen? Only these parts of the surface will be subjected to U V exposure. And the other parts there will be no U V exposure, because the particles setting over them. So, in other words this particle array now, acts as a virtual mask.

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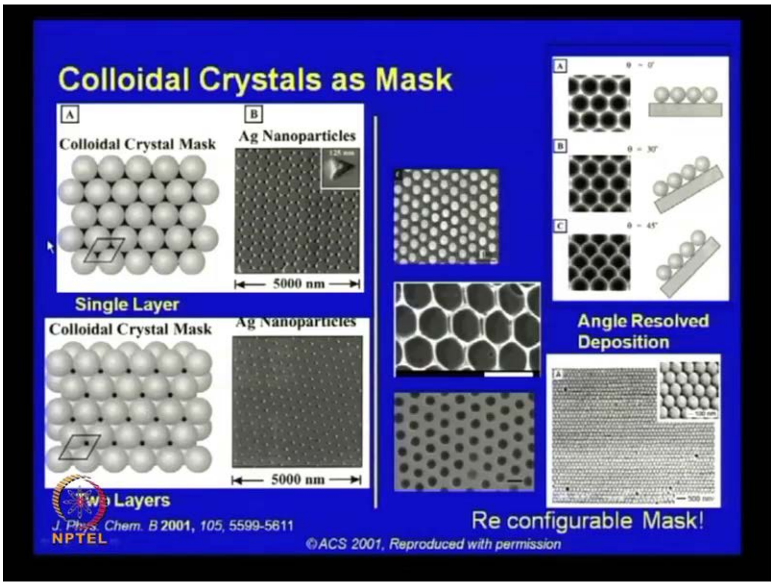

So, this is sample addition parts, if you one layer of particles or one layer of spherical particle, spiracle colloidal particles this access a virtual mask. And if you now expose it you can create structure like this subsequently it as to be followed by the development and things like that.

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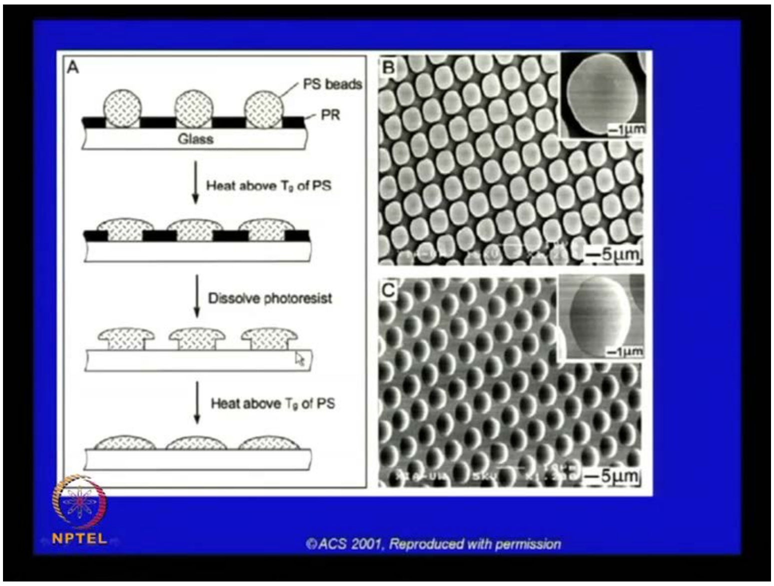

In contrast if you have particular array like this and then you expose it depending on the quality of tone of the photoresist layer you can ether an create structure like this or you can create an structure like this also one can understand very simple very easily if you have a array of spectacles like this can change the angle of spilte and your exposing exposing from that top then also depending that there will be a change in the sort of exposure settings and we can get different type of structure more interesting thing can occur if you if you instated of one particular layer if you can we have two spectacle layer. So, we can immediately understand that if you have a first layer of particular of like this due to the curvature affect of the spectacle on that second layer spectacle will come and sheet over each of the this areas.

But eventually it will create very complicated arrangement it will create and complicated and arrangement and even laser part of the substrate will remain visible to the exposed U V light. And eventually it you can get some nice nano dots like this on subsequent exposure. Verity of colloidal spectacle can be used and it can be sort of use in congestion with other properties of polymer like by heat by it glass transition temperature and one can create nice structure, mushrooms structure with overhang like this are the some of the we will talk in detail.

So, creating this itself is nontrivial. So, here is the idea that you had taken a pattern photoresist layer and we have a take an a pattern layer and then place glass beads are particulars like this. And are poly styrene beats and particulars beads like this and then you head these particulars over glass transition temperature. So, it is spreads it mails spreads over the photoresist layer. And now, if you dissolve the photoresist layer you sort of can get this type of structure, mushrooms structure with over high. Which are very, very difficult to obtain otherwise, because conventional photolithography what over little you have understand, it will be very difficult to create zones like this having over.

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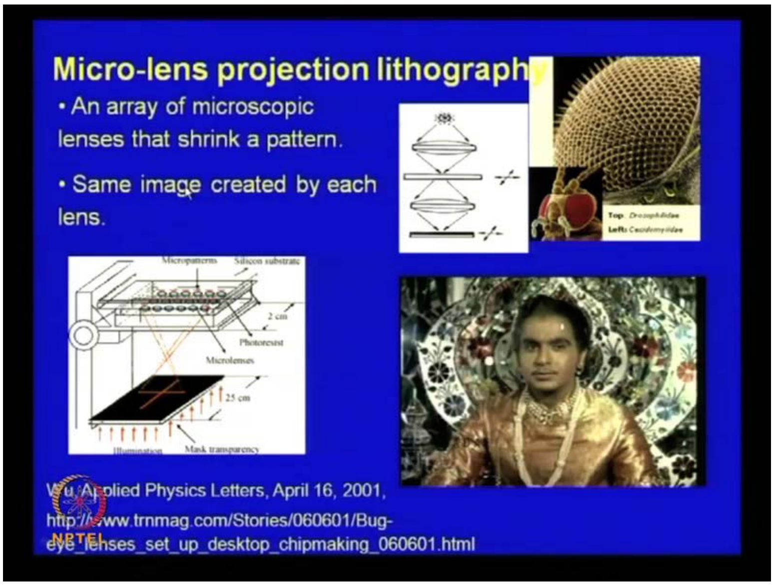

So, lot of activity is going on I will skip some of the details for the timing we now, come to the; another concept which very closely related to particle concept and it also of access the is related to the projection mode of printing. Now, instead of using these particles, each of this particles as a virtual mask.

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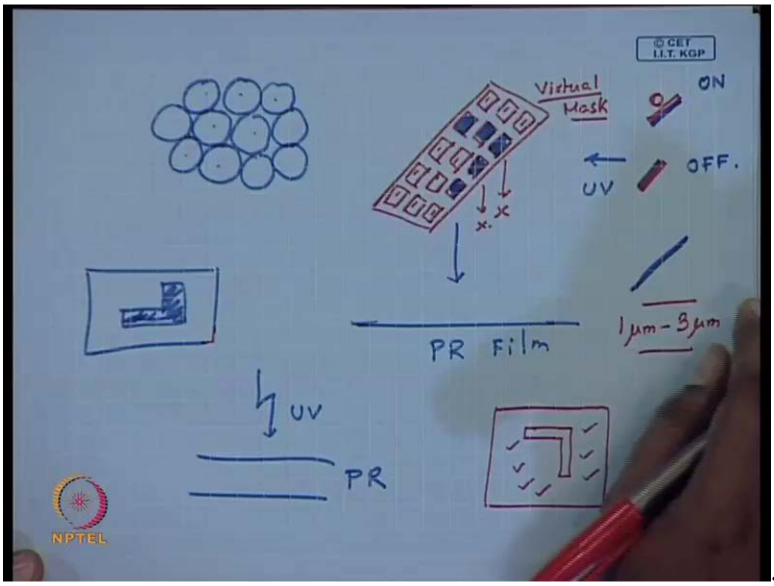

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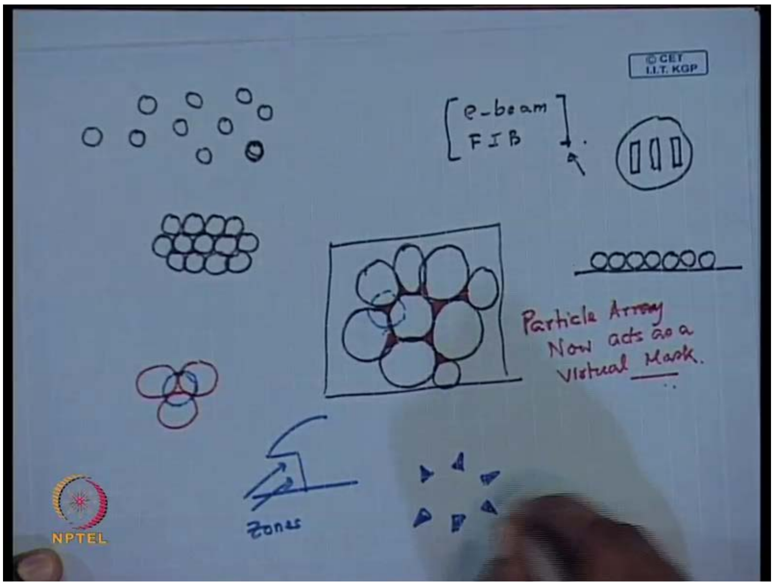

What about you make an away of lances, because in projection mode after all, what you are doing? Your actually using a; you might be wanted DeelipKumar doing here. But we will come to very soon in projection mode ultimate a you are using a condenser lance to sort of create an image of your mask pattern on the photoresist layer. So, instead idea is that instead of using a single lance, if you now have array of this lances. So, you here when we talk, we implicitly assume the; this particulars what we have talking about are not transparent to the U V light. So, there was physically blocking the passage of the light there by transforming the along the parts of the photoresist layer to get it exposed to the U V exposer.

However, instead of using optic particles if you now, use particles which are transparent and each one it is a spiracle particles each one act was a lance. The idea was very, very simple, you have one original mask pattern and you now, an array (Refer Slide Time: 45:27) if you can see in this figure you now have an; a array of this lances. So, what is going to happen is that; so, this is the original mask pattern and each lance at the focal plane is going to create an image. So, we start off with one original pattern and by using instead of using one lance, but using an array of lances micro lances you can sort of create image of the mask pattern at on go. So, you are not reeling on the on the steepen repeat mechanism, when we expose it once then the stepper motor comes in remove it next location and things like that, which we have already discuss just refer to one of our previous lecture.

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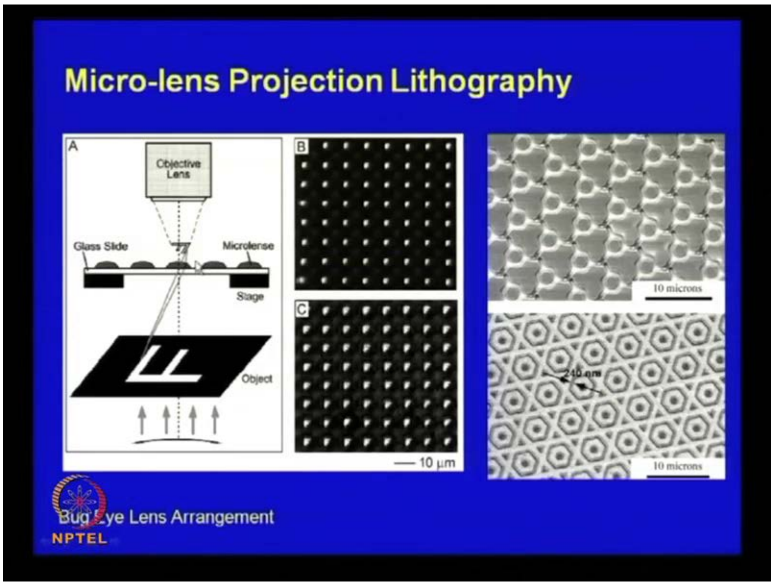

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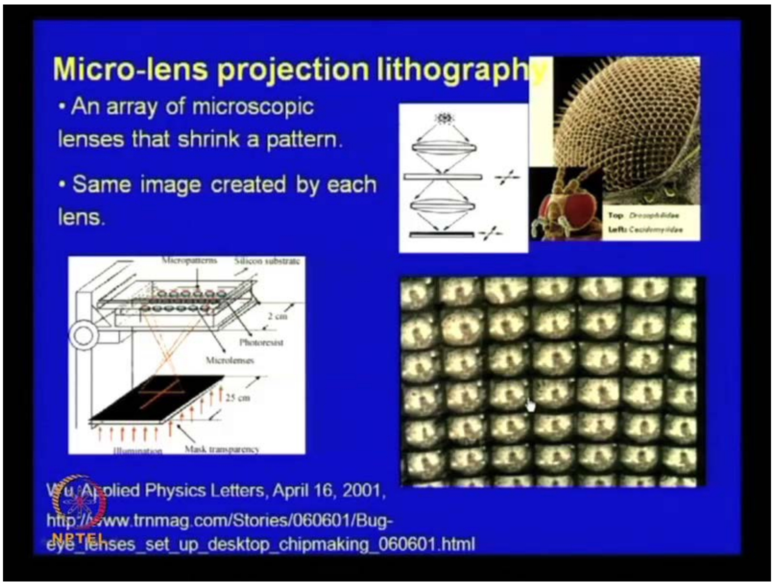

So, here the advantage is that we start off with one mask pattern and each lance sort of creates and image of at on the photoresist surface and then, we can do the exposure and subsequently at one sort of in a parallel sequence can create multiple structures. So, ideal if you want to create an array of this type of structure, I am not sure whether we can see it clear these are small f on this could like to have a mask also like this which is (( )) expensive, which will take lot of time to make etcetera, etcetera. But here this micro lance projection lithography if see on the feed on that you create a mask which as the same structure, but only one much larger, because your projecting.

So, you have the liberty it reduce the size and each of this micro lance sort of art is are produces one image on the photoresist layer, if this idea is not very clear to you just away click look at this clip from Mogaliassam classic movie it is this concept. So, I will repeat it again (No Audio From: 49:22 to 49:31) the differences in this particular sequence each one is sort of Mirer you see multiple images of the; of the dancer Noorjahan. But if you now thing that instated of; so, this are sort of micro mirrors, but if you now thing that instated of mirrors see now have an array of lances.

So, what will do it will produce or condense this image on a in this in this case on the photoresist layer. And so, though we have one lady how is dons we have multiple images in principal exactly like what we have shown here, we can starting from one mask pattern even produce multiple pattern on your photoresist layer. (Refer Slide Time: 47:25) So, this is another very novel development that has taken place in the field of photolithography. This was sort of developed about 6-7 years back that still in the research level, (Refer Slide Time: 49:44) but has lot of potential. This is also often refer to as the baga lay lens arrangement, because you might been knowing that most in set have a complex I, where each of this sort of they have multiple lances unlike our I where you have one lace arrangement they have multiple lance. So, that is sort of gives very wide 360 degree diffusion at time.

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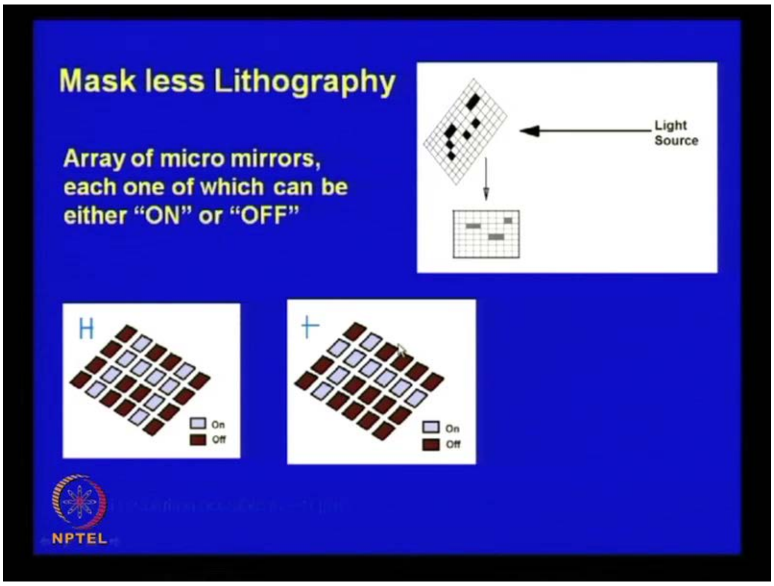

The last thing that again becoming popular, but still at a research level is the concept of a mask less lithography. Now, unlike a array of micro lance mask less lithography uses and array of micro mirrors. So, you have a array of micro mirrors is very decent development company in colophony maxi couple of search instruments are available already in the market. So, you have and array of micro lances of a this array machetes the revaluation of the desk top monitor. And the (( )) each of this micro, I am sorry it is not an array of micro lances it is array of micro mirrors.

So, each of this mirrors let us say now, we are considering in one mirror each of this mirror can sort of this is the lets say the reflecting face, each of this mirror can be tern on or off. And so, let us say a lets a; this is the on position and if you sort of have it in this position it can be simple serial alignment also it is off. So, now imagine that we have created drawing or a structure and your computer monitor, side arrangement we have a U V source hare, you keep your photoresist film here, the light falls in this array of mirror gets reflected I have deservedly drown here 45 degree angle, because that is have it is works . So, lights falls on this mirror gets reflected photoresist layer gets eliminated..

So, the key deference is the un like on other previewers mechanism methods when we have directed exposure of the photoresist layer, here use sort of this 45 digress arrangement with this array of micro mirrors. Now, suppose we have create a design what you want to reproduce photoresist film and somehow following that design you tureen off some of the mirrors, lets a corresponding to this design some of the mirrors tureen. So, what is going to happen? The UV light following on this mirror or a all together, but if get reflected from the mirrors which are turn on.

So, corresponding to this marries so, areas of this mirrors no light is coming to the photoresist layer. So, what happen? If you now look at the photoresist film it is not getting fully exposed by the U V light, but part of it there is no light. So, it gets exposed only over these areas and the mirrors which are turned off corresponding that there is no UV exposer. So, this mirror area the configured mirror array following the pattern you want to create accesses virtual mask and the advantage is that this mirrors reconfigurable reusable. So, every design you want to sort of use the mirror add a can reconfigure its actually computer control very simple depending on the design you want to you automatically changes this mirrors automatically change ether to tureen on and tureen off position.

So, this very novel development still it has shown still at the lab scale. Firstly, it as an shown limitation (( )) revaluation is one micro to three micron, but the biggest advantage of this that this use of this micro mirror array sort of is one of the first meager developments which removes the necessity of the mask. And this array or the micro mirror array control micro mirror array accesses virtual mask which can be sort of configure which configure it is self depending on the design it is a very novel development. And for many, many techniques or process that lab scale where you want we have different structures this can be very, very good development.

So, with that we conclude discussion our photolithography, I hope we have now, have some idea on what is the process of photolithography, we had have some critical discussion on the meager compounds of photolithography of request you to if you consult some text book are look at the Wikipedia along with this lecture notes. And I am sure will have some reasonable amount of understanding of the process of photolithography. What our is necessary in the stand point a parson, how is a non sort of use not high to the hard code I see ship making, but one needs to have some idea of how pattern is achieve. I also talk about how of the recent developments it still at the research level which are augmenting well with photolithography to come of novel concepts like this micro lance are and mask less lithography.