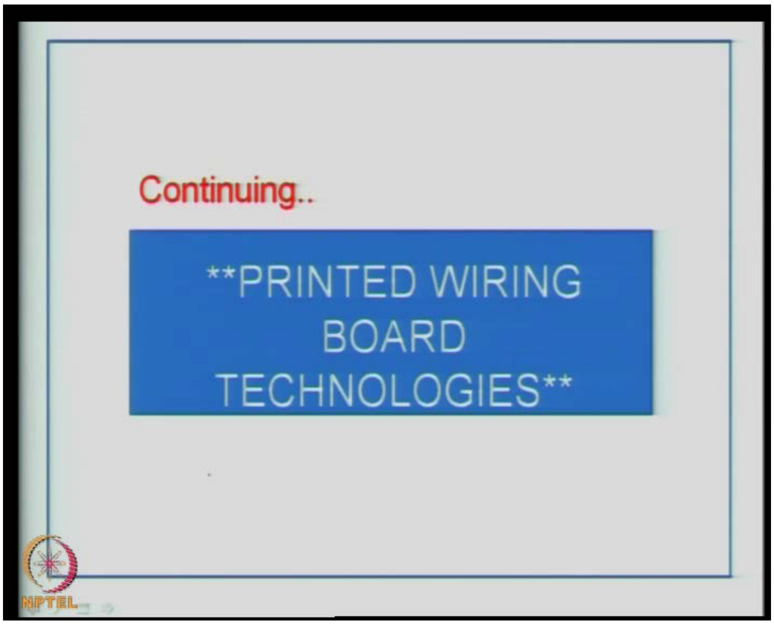
An Introduction to Electronics System Packaging

Prof. G. V. Mahesh
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

Module No. # 06
Lecture No. # 26
Photoresist and application methods
UV exposure and developing
Printing technologies for PWBs

We will continue with this chapter on printed wiring board technologies; this is a very important part of this course.

(Refer Slide Time: 00.15)

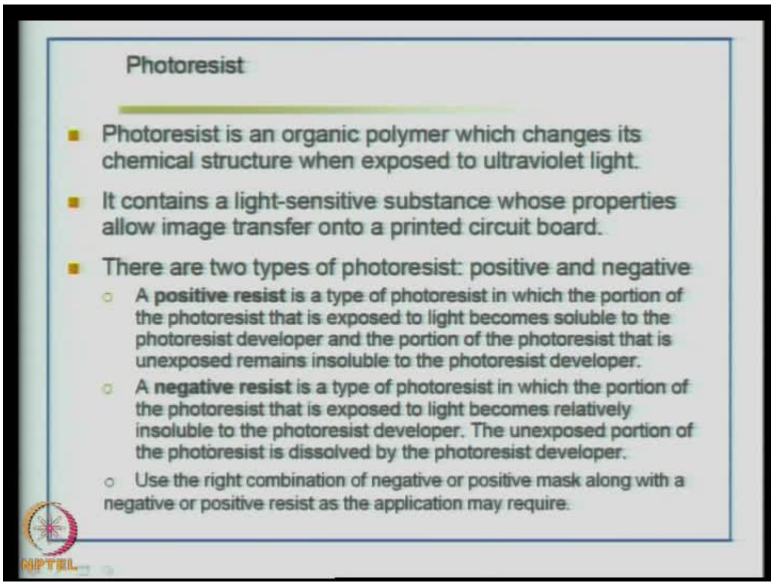


We are trying to assess and understand and also look at the highlights of the various processes that lead to the complete buildup of a printed wiring board. Remember, some of the important terms that I have used - this is system level printed wiring board that we are ultimately thinking of.

Nevertheless, we are looking at the basic building blocks of how to fabricate printed wiring board that will lead to understanding how a high density interconnect for a system level printed wiring board for high performance applications could be finally managed. In the earlier classes we have seen more about the photo plotter, we are seen how a photo plot works, what is the output from a photo plotter. So basically, you will get a mask - the mask or the photo tool is the starting point for your design translation to the printed wiring board.

Then on the other side of the fabrication, at the beginning you select a laminate, right. As I said earlier, a designer must be the person who will decide on what type of laminate is required and therefore, we have seen the various types of laminates that are available. We have also looked into the imaging part of translating your image from the mask to the surface of the copper on the copper clad laminate; so, we will continue from that point onwards.

(Refer Slide Time: 02:10)



We are now basically looking at photolithography; as part of it, we now understand the photoresist: the photoresist is a material; it is as an organic polymer which changes its chemical structure when exposed to UV light. It is also true that some other physical properties also will change, when photoresist material is exposed UV light. Therefore, it contains a light sensitive substance because the properties are changed when it is subjected to white light or UV light whose properties allow image transfer on to a printed circuit board.

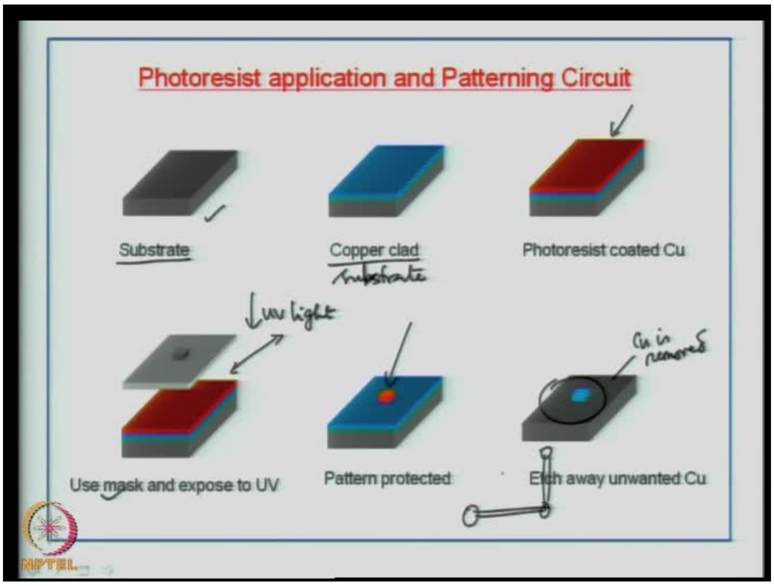
So, you must appreciate this point: that a photoresist is key material, more research is going on into bringing different types of photoresist materials that can aid us in creating very fine lines on the printed circuit board. On the one side, if you recollect, in the semiconductor industry also we are using photoresist material, right now. Their line widths are much smaller. Today, in the circuit board industry also we are moving towards 2 mil lines; currently 4 mil lines is a very good leading in standard and imagine we are going to work on 2 mil lines. Even for a 4 mil line, you require an excellent photoresist - that can have repeatability that can be applied on to this printed circuit board copper surface at very low thicknesses; so that you can have very good aspect ratio on the board because as a fine line demand is more in the industry. You have to do it in high volume especially the photo litho graphic process has to be very fast.

There are two types of photoresist material: positive and negative photoresist. Recollect that there are two types of photo tools also - you have a negative mask or a negative photo tool and a positive mask or a positive photo tool. Similarly you have in the resist - a negative and positive photo resist; so let us see, how these work. A positive photoresist material is a type of photoresist in which the portion of the photoresist that is applied on to the board surface and that which is exposed to light becomes soluble in the developer.

So one thing is very clear, if you use a photo resist you have to develop this image that has been formed - a kind of latent image - that has been formed by exposure to white light or UV light. How do you see that? You use a developing process, you use a chemical that is called developer and in this particular case, that is a positive photoresist: the portion of the resist that is expose to white light or UV light becomes soluble in the developer, it is removed away from the surface of the copper and the portion of the resist that is unexposed right remains insoluble to the photoresist developer. So, when you apply a photoresist there has to be again, if this process as to be explained further, there will be a sort of a curing process. So that is how the photoresist material becomes insoluble in the photoresist developer in those areas which is unexposed to white light.

On the other hand, a negative photoresist: It is a material in which, the portion of the resist that is expose to light becomes relatively insoluble in the photoresist developer chemical; the unexposed portion will now be washed away or dissolved by the developer. So, you have to clearly distinguish between the developer action on the photoresist material which is a positive and on the negative photoresist material. So use the right combination of negative or positive mask along with negative or positive resist as the application may require. You have now, two materials positive and negative resist and you have two photo tools positive and negative photo mask; so how do you use these and when for what kind of application?

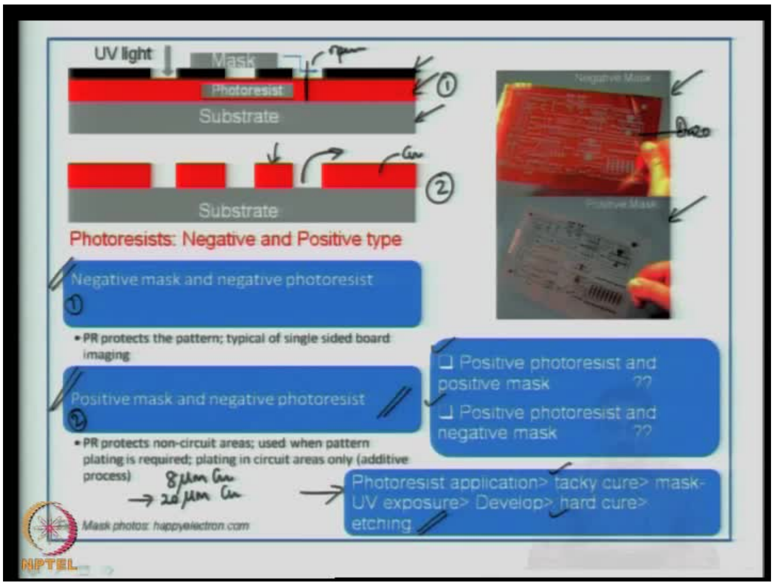
(Refer Slide Time: 07:12)



Before that, a photoresist application and pattering circuits in terms of illustration is given here. So, you start with a substrate. Now this can be an organic substrate, this is copper clad on the substrate, now you coated with a photoresist you can see here the photoresist material coated on the copper, here you use a mask or a photo tool and then without any air gap in this area between the mask and the photo resist material with the photo mask in place you apply UV light so those areas which are expose light will be affected by the UV light (Refer Slide time: 08:00).

In this way the pattern is protected you can see here, after the developing process is over, you can see a small area of the photoresist on the copper surface; that means, that area the circuit is protected, this is typically what we see in the PCB imaging step. Finally, you want to remove the copper, you can see here copper is removed and copper is present only on those areas where the photoresist had protected the circuit; so this is the image that is finally required. So, essentially in a PCB you will have pads and the tracks being generated numerous of them and feature size being very small, in some cases fairly large and all of these have to have fairly good resolution and repeatability. So, this is in short a nutshell the pattering process.

(Refer Slide Time: 09:11)



Let us look that in much more detail. If you look at the top figure, here in the left, you see there is a substrate, there is a photoresist that is applied and then you have the mask. This is the mask then, there are areas which are open; now UV light is subjected through the mask and is applied or expose to the photoresist. The photoresist gets exposed; here, the timing is very important depending upon the thickness of the photoresist and these are again recommended by the manufacturer.

So, if you look at the next figure, you see the exposure is over the mask is removed and you can see after the developing process is over some of the photoresist material is removed; so you get sort of a pattern. Let us assume that, these are the copper areas; accordingly you have to choose a mask. If you take as the black areas that represented blocking of UV light was actually this area, typically this will be a negative photoresist or a positive photoresist can also be used in the PCB process.

You can see here, those areas in this particular diagram; specifically those areas which were exposed to UV light, that is the photoresist in these areas which is exposed to UV light has been washed away. So those areas which were masked and protected and by the UV light has still been found on the substrate without any areas getting affected.

Typically this will be a positive photoresist working, because if you look at the developing process exposed areas have become soluble. Similarly, you can do it for a negative photoresist in which the exposed areas will be in intact on the substrate and the unexposed areas will be washed away by the developer. Here you can see, this is a negative mask and this is a positive mask; in the positive mask you see the copper areas the circuit areas are denoted by the black silver material (Refer Slide time: 12:00) and here this is a diazole film and in this you see that this is a negative, the circuit areas are opened. So, typically a negative mask with a negative photoresist can be used for making a single sided printed circuit board.

So we will see the options now. The first option is you have a negative mask and negative photoresist - here the photoresist will protect the pattern, typical of single sided board process imaging. Then, you have a positive mask and a negative photoresist - so there this is same; you change the mask what happens? The photoresist will protect the non-circuit areas used when the pattern plating is required; that means, you want to use additive process. We have seen what is an additive process is and what is a subtractive process. Typically an additive process implies copper being added, copper is added only on specific circuit areas. So, this combination can be used when you want to you use plating on circuit areas; that means, typically you might start with a 8 micron copper and then you can plate and then improve it up to say 20 micron of copper. So, specifically you are adding copper to the circuit areas.

Now, I think you will be able to understand when to use negative mask and a negative photo resist or contrarily if you have only a negative photoresist with you and if you do not have a positive photoresist, when can you use a negative mask and when can you use a positive mask should be very clear from these two points. The photoresist application typically starts with applying the photoresist using certain methodologies, certain equipments; then it is tacky cured, then the mask is exposed to UV light. Here, you can see in this particular figure, then it is developed, then a hard cure is done before finally it goes for etching.

The reason for curing process that is, the tacky cure and the hard cure is that the material - host material that is the photoresist should not lose its dimension should not be attacked by the etchant, chemical that is going to be used finally. As the name indicates, the photoresist should resist the etchant in some sense; so that is why these process steps become very important.

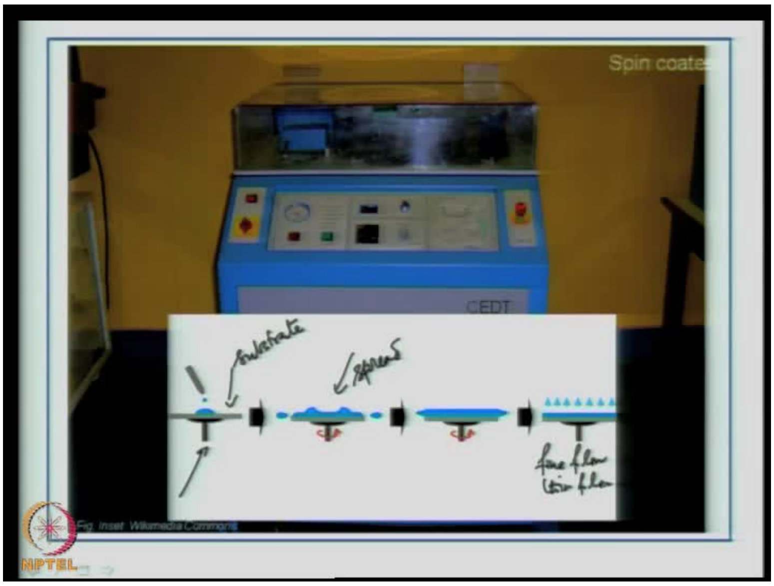
On the other hand, we have discussed negative photoresist exhaustively. Now if you want use a positive photoresist, you also have two options - a positive photoresist with a positive mask and the positive photoresist with a negative mask. If you use a positive photoresist with a positive mask similarly, you can apply this tool for a single sided board process, but the key issue here is positive photoresist are currently expensive and a positive photoresist with a negative mask can be used for additive process. So depending upon what resistive you have, you can change your photo tool and apply to the board process sequence.

(Refer Slide Time: 15:42)

Now, this is a picture of spin coater equipment, spin coating is one of the methods that are used to apply a photoresist material on to the surface of a board. Obviously, the material has to be wet, it has to be liquid or a thick viscous liquid can also be coated using a spin coating equipment. Typically, as you can see in this particular equipment, which is present in CEDT this is fairly small equipment and spin coating obviously is used for small area surfaces, low area boards. Spin coating is not a process that anybody would apply for high volume manufacturing. There are other methods for applying a photoresist material for large volume manufacturing.

Spin coating can also be used for applying not only photoresist; it can be used for applying any dielectric material, any liquid dielectric material to on to any surface - it could be a silicon wafer, it could be a ceramics substrate, organic substrates, any metal surface, any other liquid. The only thing that you need to know is what are the properties of the liquid? That is physical properties especially in terms of flow, the viscosity, the thickness and so on. Obviously, these are very sensitive materials so typically this is handled in the yellow room area.

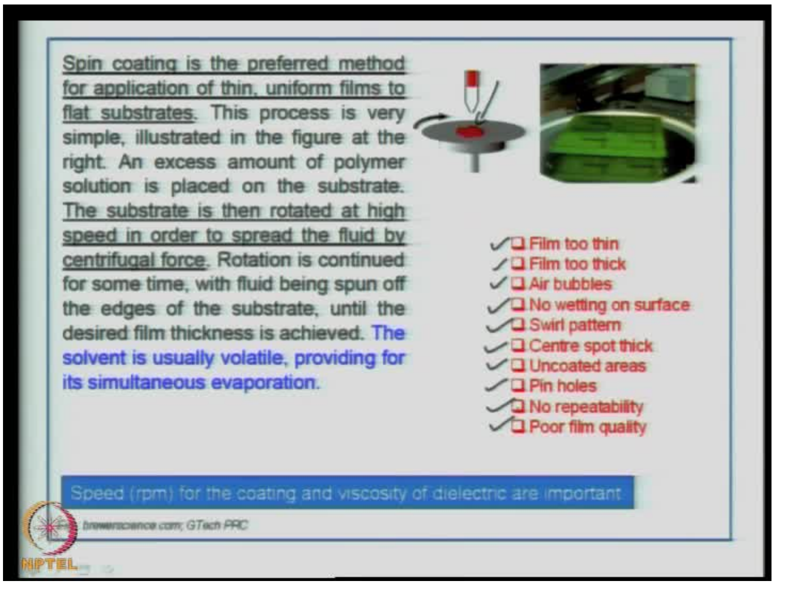
(Refer Slide Time: 17:23)



A small illustration here will give you an idea what a spin coating process will look like. Here you can see, there is a holder which holds your surface. This is the substrate, then calculated amounts of liquid dielectric materials are poured at the center of the substrate and then the substrate is rotated. Now in spin coating equipment, normally you said the RPM revolutions per minute is based on the area of the substrate, the thickness that is ultimately required; that means, the volume is calculated, the viscosity should be known, you must also know or have an idea about the solvents that are used because during this process there can be evaporation of the solvent. So, in some cases you might have to dilute if it is thick starting material before you start the process and so on.

Now, coming back to the process the liquid dielectric material or the photoresist material if now spread over the entire area for a particular time that you have set and the speed ultimate or maximum speed that you can achieve, you can hold it for a long time to improve the thickness or to reduce the thickness. Then finally, obviously there will be some wastage of material that it flows out of the substrate area. During this process the solvent can evaporate that will aid in also reducing the thickness; so you will get a fine film, thin film, of the dielectric material that you require.

(Refer Slide Time: 19:31)



So, this picture briefly gives you the process steps. Spin coating is the preferred method for application of thin uniform films to flat substrates. The important property is the substrate should be flat, no warpage and so on. The process is very simple; it is illustrated in the figure at the right; as you can see and which I have explained in the previous slide also. An excess amount of the polymeric material, the dielectric material, it can be photoresist as I said or it can be any liquid dielectric that you intend to apply on to the substrate.

These material are usually polymeric, the substrate is then rotated at high speed in order to spread the fluid by centrifugal force. Rotation is continued for some time with the fluid being spun off at the edges of the substrate; you are to make sure that there is complete coverage from the center of the substrate to the edge. The substrate can be circular, in the case of wafer or it can be rectangular in the case of a PCB. In the case of a PCB, because of the shape there is still much more control required for the material to spread along the entire area. Ultimately, you want uniform thickness in the entire substrate area, which is a very difficult thing unless you are very experienced, unless you know the dielectric material very thoroughly about its properties and obviously you can do this for small area substrates, typically 10 inches by 10 inches maximum is what you can use with spin coating; larger areas pose problems. The solvent is usually volatile providing for simultaneous evaporation.

What are the difficulties or what are the defects that you can see in spin coating; now speed for the coating process and the viscosity as I said are the key issues. In spite of that, you can see difficulties like film being too thin; that means, you have added more diluents and film too thick that it is more viscous it is not spreading, your dilution is not proper. In some cases, there may be two solvents the proportions may not be okay or one might evaporated much faster than the other. Air bubbles in some cases, you might have two components - component a and component b being mixed together just at the point of spin coating. So, when you do this mixing process by hand or by machine, assisted mixing you might end up some air bubbles. So you have to essentially, leave that material for some time until all the air bubbles are removed only then you can start the spin coating process, because air bubbles can cause problems during the spin coating and finally, it might end up with different thicknesses in those areas which eventually will lead to poor imaging.

Then we have seen these properties - no wetting on surface; that means, the board surface is not cleaned properly; this whole pattern, it should not leave any marks or uneven thicknesses in-between specific board areas. So again, this is the property of material and the speed; center spot should not be thick that means, if you pour the material at the center, this center spot obviously should not have different thickness, larger thickness, compare to the edges.

So, again this is a property of the wetting of the material they should be no uncoated areas. Pin holes are a problem because of external contamination; then you are preparing the dielectric material which will result in spots on the board. So, you have to work in a clean room, work in a area where there is dust control, where there is laminated air flow and the material has to be mixed in an environment: where the mixture, the equipment’s that are used and the vessels that are used, to use this particular material you have to be fairly clean enough.

If you have no repeatability in continuous spin coating process, then there is some problem with the speed or the viscosity of the material. Poor film quality is again reflection of the process control. So, we will now see a typical dielectric being now coated on an organic substrate. In this video we are going to explain in spin coating of a photo image able dielectric on inorganic substrate.

Here you can see, basically dielectric is selected which is photo imageable typically we want about 30 to 50 microns thickness of the dielectric for imaging. Now, in this particular case of a demonstration there are two materials a and b which are weighed separately and now they are mixed. So, the proportion by weight of the different materials including the solvent is very important. If you fail to observe this first important thing of mixing the various components in the respective weight ratios then you are going to have problems in imaging.

The equipment is now prepared for this spin coating process, you can see here; it has protective lid, then there is a cover which is protecting the all important spin coating area, there you can see a check at the center which will hold the substrate. Now, this equipment has provision for vacuum hold of the substrate, so currently the vacuum is released. The substrate is well prepared that means, the surface has to be very clean in order to avoid d wetting, there should be very good wetting. Now, you can see this substrate is very clean; it is a very small area substrate. It is held on the surface by this vacuum hold that is there in this particular equipment; all equipment’s have this vacuum hold.

Now, we are ready to apply this dielectric material normally you will see that the material will be poured of the center, if it is a thin liquid. In this particular case of demonstration, this is a fairly thick material - it is a photo imaginable solder mask, this is a dielectric material. We are showing you how you can manage to spread this, even if it is take on this area the printed circuit board by making some adjustments. What is that you do? You assume that you are doing some kind of a screen printing process where you are apply the entire dielectric material on one edge of the substrate.

Now, after some experience, the technician will know how much material is required for this area of the substrate. If you take too much of material it is going to be spun out and you will end up with wastage. So, with experience the technicians will able to understand to minimize wastage of the dielectric material, because in some cases the dielectric materials are very expensive. So, the substrate is held by vacuum. Now, you can use a blade, a doctor blade, and then you can spread the material as for as possible manually throughout the copper surface. This is a thick material, so instead of having the entire material put at the center of the substrate and allowing the spin coating for longer time will not result in even distribution.

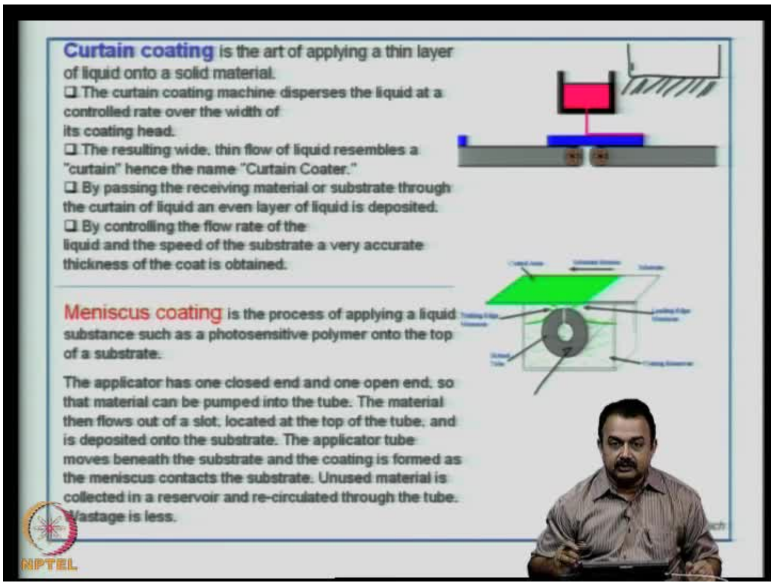
So, what we trying do is spread the material as much as possible to the entire area of the substrate. We are basically assisting the spin coater now, after that is done, the spin coating equipment is now ready to start you have now set the rpm here and you have set the time. This is again based on a lot of trails that you do; so for different materials you have do some kind of a trail run before you work on the final process, parameters, the lids are closed and finally, it is now time to start the spin coating.

Now, there will be a slow ramp up of the speed till it reaches the maximum set rpm for this particular process. Finally, you can see now it is a 1500rpm 17, 19 and 2000rpm this is the final set value, the timer is also set and the material is now expected to spread all round the substrate and you can see here, a view of the spin coating. The excess material is now spun off outside the board area into the tray, here stainless steel tray. So thorough cleaning this is also required; so the maintenance of this equipment is also clean because if you are going to use different material for example, then they should be no cross contamination of the materials from this spin coater.

(Refer Slide Time: 30:24)

Now you can see, a fairly decent a spread of the material has taken place. Even then this is not 100 percent because the viscosity of this particular material is very high. So you will have a chance to work with different types of materials, during this spin coating process and the key is to obtain uniform thickness, plus or minus 3 microns around the entire area of the substrate. You can see a finished spin coated board, here again, you can see at the center that it is slightly thicker than the other areas; so you need to gain expertise in spin coating for different materials.

(Refer Slide Time: 31:07)



Then there is another coating process called curtain coating. Curtain coating is the art of applying again thin layer of the d coat dielectric on to solid material. Now, spin coating as I said is typically not viable for large area manufacturing so, we go for curtain coating. What does it do? The curtain coating basically provides a curtain of the liquid as you can see here. In this particular figure, you can see that there is curtain of the liquid dielectric material being available and the substrate is passing through the curtain on a conveyer belt and as it passes through the curtain it is getting coated.

So, using a horizontal conveyer zed motion and having a curtain of the liquid, here again the important the parameters are that the curtain flow should be constant, there should be no air gap, there should be no intermitted flow of the material, and it should be very continuous. The curtain coating machine disperses the liquid at the controlled rate; you need control the rate together require thickness over a certain width of the substrate, the resulting wide thin flow of liquid resembles a curtain, hence the name Curtain Coating. Typically the curtain width can be very large, it can be more than a feet or it can be up to a meter. So, the entire PCB can pass through this curtain and then get coated with definitive thickness; the thickness is dependent on the flow of material from the curtain head to the surface of the substrate.

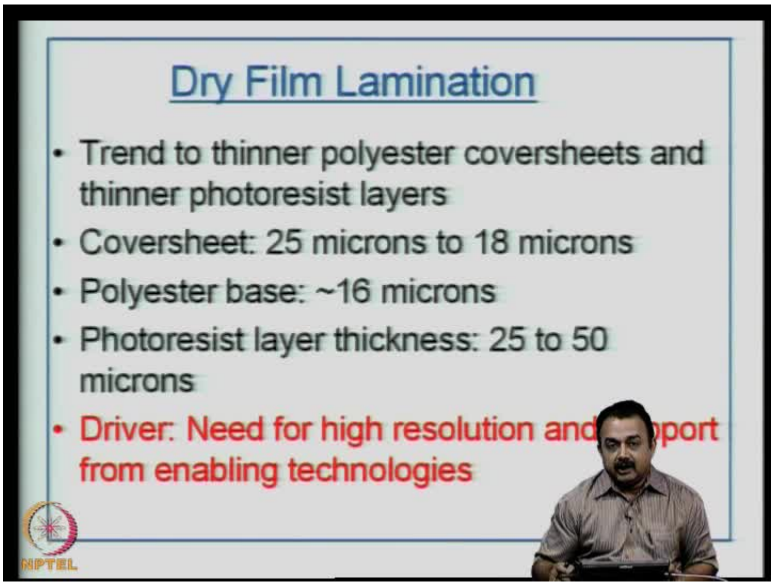
Now, by passing the resulting material or substrate through this curtain of liquid and even layer of the liquid is positive; controlling the flow rate is very important, the speed of the substrate over the conveyer that is also very important. So, all of these combinations, just like we have seen various combinations of parameters in this spin coater; here again, you require to monitor the speed of the conveyer, the flow of liquid from the curtain head or the vessel to the surface of the substrate, all of these become very important to get a uniform thickness.

But, the first hand information that I can give is curtain coating will definitely give you much better thickness control, you can get thicknesses even up to 15 to 20 microns, which gives you an idea of how we can utilize this technology for high density interconnect applications.

The other process is Meniscus coating were you have a liquid such as photosensitive polymer or dielectric which needs to be coated again were you have vessel and then you have a slotted tube like what you see here, then there is opening at this slotted tube at the top. The liquid dielectric material is now pumped through the tube and it comes out of the slot as a meniscus, it flows like a cascade from both sides and this meniscus, this flow at the top will have definite thickness.

It will be a very small pump; the flow is very important here, it as to be very slow, there should be no air bubbles and you can use some kind of a small stepper motor to pump out the liquid and the important thing is the that slot should be very clean, the flow should be even. Now, you move the substrate and you move that in such a way that it touches the top of the meniscus at this area, at this particular area, so that the bottom of the substrate gets coated. In this case, it is the bottom of the substrate that gets coated, where as in curtain coating it is the top of the substrate that is coated with the liquid material.

(Refer Slide Time: 36:35)



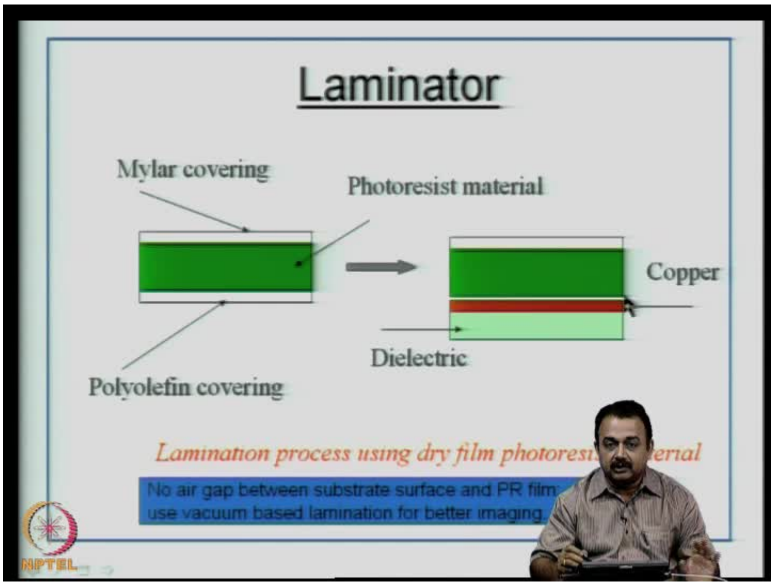
Now, meniscus coating in comparison with the curtain coating and spin coating will have very less wastage less than 5 percent because you are using less volume, the meniscus is very small, the height or the separation between the substrate and the liquid is very small. So, only the required amount of liquid dielectric is coated; very useful for coating something like 1 to 5 microns of the dielectric material on to any substrate: you can use it for glass, ceramic, organic substrates and so on. So, these are the various coating methods that we have: so the spin coating, the curtain coating and meniscus coating are typically used for wet photoresist material or liquid dielectrics.

We will talk about dry film methods, which mean the photoresist is available in a dry format; so you cannot use the earlier methods that I have used, so we will use a process called lamination to apply this dry film photoresist on to the PCB surface. The trend to thinner polyester coversheets and thinner photoresist layers are in vogue now, because the ultimate aim is to reduce the photoresist thickness. In the dry film format, you have this limitation of producing very low thicknesses of the dielectric; typically, you can get from about 20 microns to about 40 microns depending on the manufacturer and depending upon whether it is a positive photoresist or a negative photoresist.

But in a liquid, you can control the thickness using the equipment whereas, in a dry film whatever is available as a definite thickness in a particular role - a film that you buy you will get guarantee thickness in entire role - that is a major advantage of using dry film. So, depending upon your final requirement of thickness you can either choose a dry film or a wet film photoresist.

Now, the dry film will have protective sheets: cover sheet, which is about 25 micron to 18 microns, there is a polyester base which is holds the dry films which is about 16 to 20 microns and the photoresist layer thickness in itself is about 25 to 50 microns. It is very difficult to get a dry film which is less than 25 microns and if it is, it is going to be expensive. So, the need for using dry films is that we require high resolution, we require good control on the thickness throughout the entire process from one edge of the PCB to the other edge of the PCB and it should support enabling technologies like here high density interconnect.

(Refer Slide Time: 39:00)



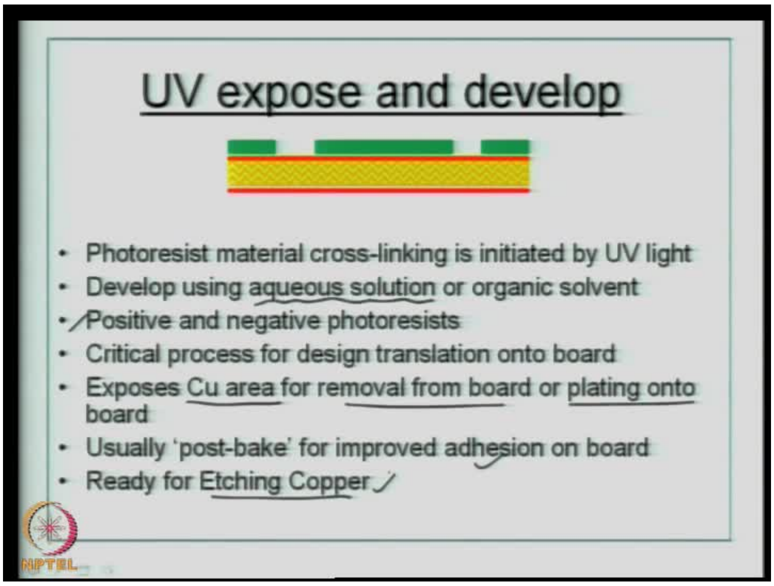
How does a laminator for dry film work? Here, you have the mylar protective covering this green area here, that you see is the dry film photoresist material and at the bottom you can see there is a polyolefin covering. The polyolefin covering and the mylar covering have different thicknesses, the thickness of this photoresist material is well defined, it could be 25 to 50 microns depending on that particular batch of the material; the thickness is going to be guaranteed the same. So there is one of the key advantages of using a dry film, which in wet film may not be reproducible all the time.

Now this is a cross section, what you are seeing is a cross section; if you can remove the bottom polyolefin covering your board gets introduced in to the dry film cross section. So, you can see this is the copper, this is the organic dielectric, now there is an adhesive in the photoresist material, it bonds with a copper on the PCB and that is how you get laminate, and this is the lamination process that we are talking about. Lamination process uses dry film photoresist material and the key thing is when you do this lamination process here, there should be no air gap between the photoresist and the copper surface. If there is an air gap here, then your imaging is in problem, because you will get varied contrast during UV exposure and which will result in diffraction because of air and you will get very poor resolution.

(Refer Slide Time: 40:51)

So, what you seeing here in this picture is a dry film laminator at the CEDT department here in ISE. It is typically a volume production machine and the width you can see here comes in different flavors it could be 12 inches, 15 inches, 18 inches or above. So, depending upon the requirement this equipment can be modified; it can be used for different dry films roles that come in 12, 15, 18 inches width and typically the total length will be around 100 feet or so.

(Refer Slide Time: 42:01)



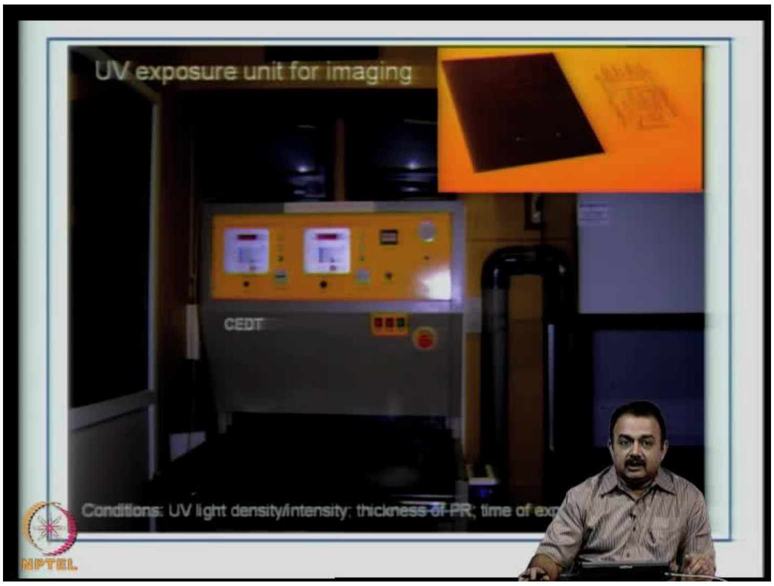
So shelf-life of this material is fairly small, it is about six months and you can see here dry film in this protected with black cover layer, because it is sensitive to white light, but nevertheless the equipment housed in a yellow room. Now, in order to avoid the air gap between photoresist and the copper we use vacuum lamination. So what is this UV expose and develop process? How is it part of photolithography? Now we can see here, the photoresist material that we are using whether it is a dry film or a wet film, there is a cross linking when it is initiated by UV light that is, what happens when we expose to UV light and next step is developing using aqueous solution or organic solvent.

But today we are definitely moving out of organic solvents; we would recommend using aqueous based developing solutions. Then we are seen we have positive and negative photoresist, in the dry film also we have positive and negative. It is a critical process for design translation on to the board, exposes the copper area for removal from board or plating on to the board; this is what we are finally achieving.

Usually you do a post-bake to improve adhesion of the dry film or the wet film on to the copper surface. Remember you also done some micro etch on the copper for this simple purpose to improve the adhesion; after the exposure and developing process is over the board is now ready for getting etched to remove unwanted copper.

Now, you will see a demo of photoresist application. We are going to talk about the dry film vacuum laminator - the clean boards here as you can see are picked from the oven and as I said the boards are made sure it is dry, 80 to 100 degrees for 10 minutes will remove all the moisture after cleaning. We are now going to see vacuum lamination of the dry film: power is on, the various controls are on. What are the various controls? There are rollers in which your boards going to be fed, the gap has to be decided, the rollers speed has to be decided, there are heaters on the roller which will have to be set to a particular temperature because the board is now activated, the dry film is now also activated, and the adhesive at the temperature will enable bonding or lamination to your substrate. We can see this dry film is now pulled one end that is one of the layers is already removed; so the dry film is now exposed. The exposed area I mean expose to the board surface, it is now attached to the board surface through a lamination process at a particular temperature and pressure because of the set temperature and pressure it is pressed between the rollers and then out comes the board with the adhesive playing a great part in laminating the surface of the board with the dry film. So, this is a completed lamination done for a clean surface.

(Refer Slide Time: 45:20)



Now, the next step after you have done a dry film lamination or a wet film application the next step is to use your mask and apply it for UV exposure for imaging purposes. What are the conditions? First you must have a mask, it can be negative mask or it can be a positive mask; so depending upon your process flow you can select what you want, it can be a subtractive process or it can be an additive process. The conditions of the UV light exposure stage is that you must know the light intensity that needs to be set for a particular photoresist material of a definite thickness and the mask thicknesses is also important and time of exposure because the time of activating the photoresist is a key to good contrast and developing process of the image that you finally intend to have on the board.

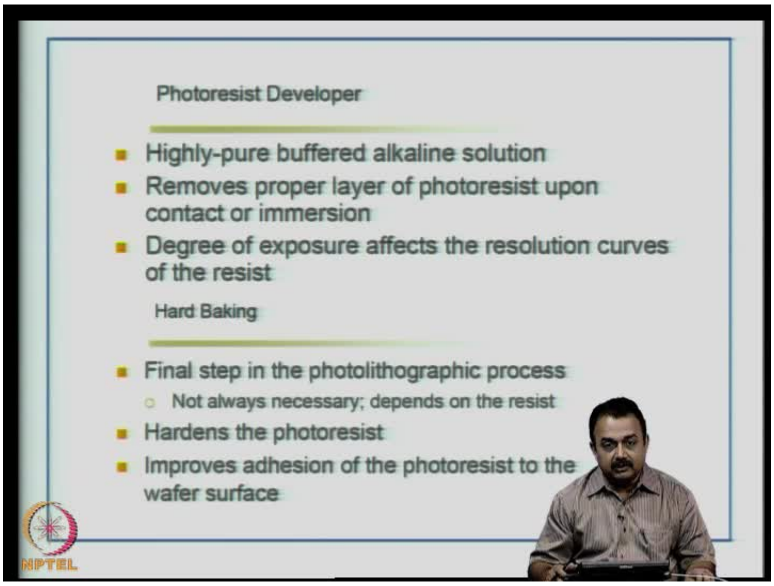
So, the final step after exposure will be the developing process, because that ultimately will give you the exact one is to one replica of your board that you designed in your CAD system. That will, as the name indicates it will resist the next step that is the etching process.

We are going to see how UV exposure equipment works; this is again equipment at CEDT Indian Institute of Science, here we are talking about mask. You see here, there is a mask a negative or a positive mask as the case may be, it should be clean any defects have to be rectified or a new photo tool has to be made. Once you select the photo tool, this the board that you have dry film laminated and now you are going to align based on the holes that you have drilled with the mask. This is a simple example to show how manual alignment can be done but, in the industry I want emphasis here, you normally do not do manual alignment there will be a fixtures for photo tools and boards which are marked by CAD x y coordinates and it is very easy to get perfect alignment, but here we are talking about a simple manual alignment using tapes, but you can do some bit of a perfect alignment for course boards.

Now, this is the equipment that house of the UV light it is called the UV exposure machine; at the control units there are the UV light sources. The number of light sources in a particular machine will depend on what capacity you are working with the light intensity that you are required. So you have to keep the lights ready for the exposure, the time for exposure again is determined by understanding the thickness of your photoresist material and the light intensity that you can generate with one bulb, two bulbs, and three bulbs and so on. Now, typically in a machine you will have two rows of lights top and the bottom so that you can do simultaneous exposure of both sides but, here you will see only one side exposure is done. Now the board is loaded, the mask is applied and then drawer is closed, a vacuum is applied so that, there is no air gap between the board and the mask.

Now, the light source is switched on once the drawer is spread inside or closed inside, you can see now the vacuum is played its part, once the required the value is obtained the drawer is pushed inside, the light is switched on, and you can see the exposure is completely less than 10 seconds. Now the drawer is open, the light source are switched off, the vacuum is closed, now if you can remove the board you will see that an image as been translated; if you remove the mask you can see that the image has been transferred through the mask by the UV exposure light to the surface of the board.

(Refer Slide Time: 50:50)



Next process here will be developing to realize this image. So here, in this particular section, the UV light intensity, the time for exposure, the thickness of the photoresist, cleanliness levels, the mask cleanliness and mask thickness everything plays a great part in getting an excellent one is to one translation if you desire. Now, you can imagine for PCB if you are working with 4 mill lines or 2 mill lines, you have great control, quality control and nevertheless for me say, that much more regress treatment you can expect in the semiconductor industry.

Next step is the developing process. Here, you use a highly pure buffered alkaline solution that means it is aqueous solution that you are using. So typically, you can use 1 to 2 percent of sodium carbonate as a developer, it can be easily prepared in the lab, and it removes the proper layer of photoresist upon contact or immersion. Degree of exposure affects the resolution curves of the resist which as I just mentioned; after the developing process is over, you can do another round of baking it is known as hard baking, before the exposure process actually you can do a soft baking. Now, you do a hard baking to make sure that the addition of the photoresist to the copper surface is improved.

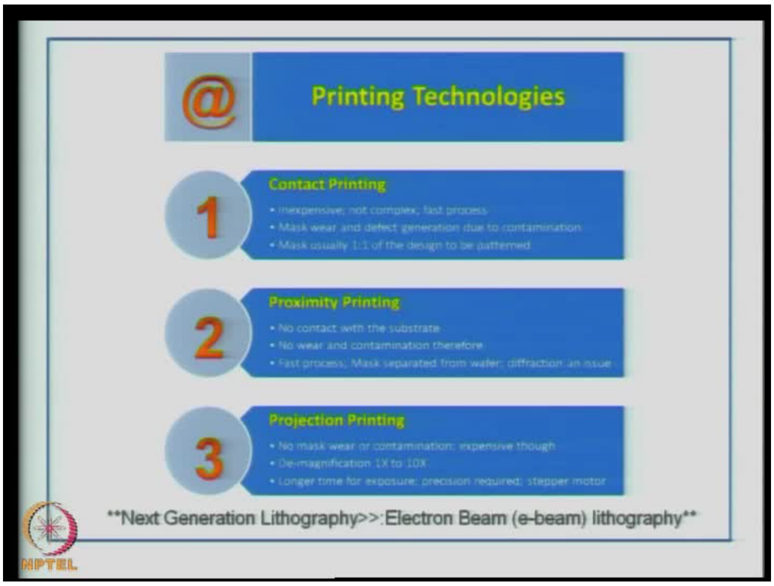
The hard baking is the final step in the photographic process or the photolithography process; it is not always recommended, but by practice people have tempt move towards this process in order to achieve better etching results. It hardens the photoresist physically but, you can always trip this photoresist later in case there are imaging problems, but the key issue here is to improve the addition.

We will now look at the demo of the developing process, in the context of fine line imaging using aqueous developers. Here what we are trying to show you is, remember in a dry film there are two layers protecting your photoresist. Now, the first layer was removed when you did the lamination, at the vacuum lamination equipment. Now there is a top layer, which as protect the dry film until now. Now this layer can be removed before the developing process, it has to be removed, because if you introduce the developer it will not react with the photoresist material.

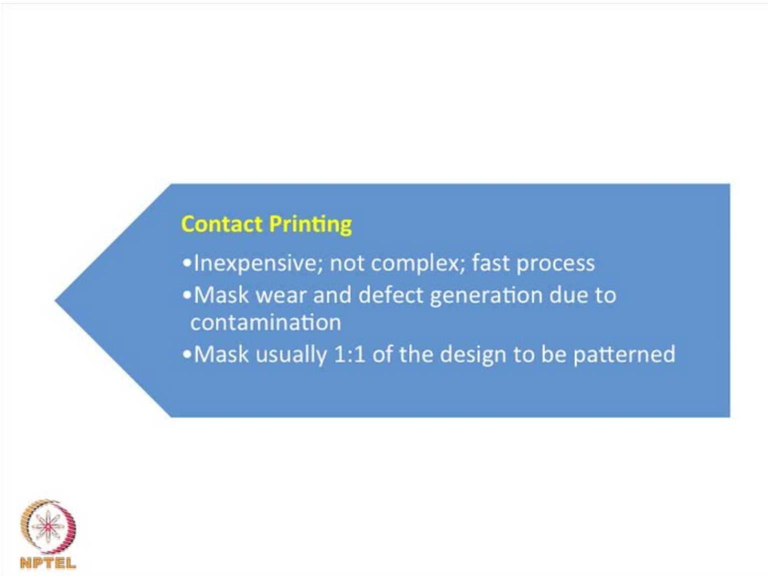
So the second protective layer, which again I am emphasizing a very key ratio; if you want compare dry film with wet film which I explained in last class, that this is one of the important advantages of a dry film over a wet film. Now you see here, the technician is now removing the protective cover layer from the board surface, what you are now seeing is a nice image that has been created on the photoresist surface. Now you have to improve this further, by introducing it in to the aqueous developer. It is a conveyrised dry film developing unit, which houses the aqueous 1 to 2 percent sodium carbonate solution the controls are - the mains switched on, the pump is started, there is a mother tank which pumps the liquid to the spray nozzles at the top, then the conveyer is also set for its correct speed and then the heater: typically it maintained around 40 degree centigrade to 45 and now the board is introduced through the rollers in to the conveyrised machines.

Now depending upon the areas where UV light exposed photoresist, they will remain intact. This is the negative photoresist and a negative mask that has been used. Now you can see very clearly this is the row of spray nozzles, you can see the spray nozzles here - that spray the liquid - you can see the liquid is sprayed on to the surface. So essentially you can use this equipment for double sided developing at a time; if it is desirable, you can also have nozzles from the bottom. You can see that the board is now sprayed with the developer; the photoresist material is now removed in those areas where the UV light has not touched the material, because it is a negative photoresist and outcomes, the board after it is cleaned with deionized water. So, one end of the conveyrised machine will have cleaning section, using the deionized water and you can see the board is not complete with the developing process.

(Refer Slide Time: 55:38)

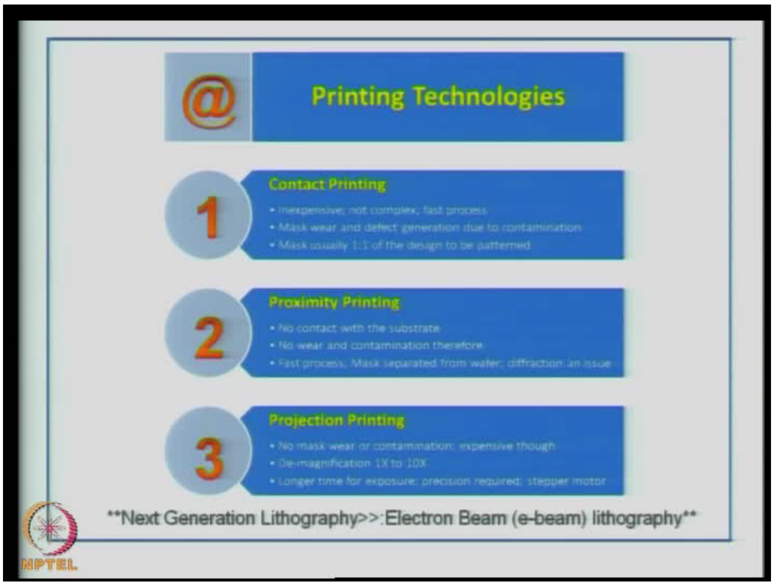


(Refer Slide Time: 55:56)



Now, board can be sent to the oven for a quick removal of moisture or it can directly go to the etching process, because etching is again a wet process. Another point I want to mention here about printing or photolithography is that the printing technology have improved day by day. The first thing is contact printing that means you have a film, you had another film on top of it and take the image that is known as contact printing. It means you can make a negative from a positive or positive from a negative by just having two films in contact; that means, if I have a photo mask here which is a positive I take another unexposed film, keep on top and expose UV light or depending upon the light source you can get a print of the original film, so this is known as contact printing. What you see here basically between the photoresist and the mask in the exposure unit is a contact printing process; the mask is touching the wet or the dry film.

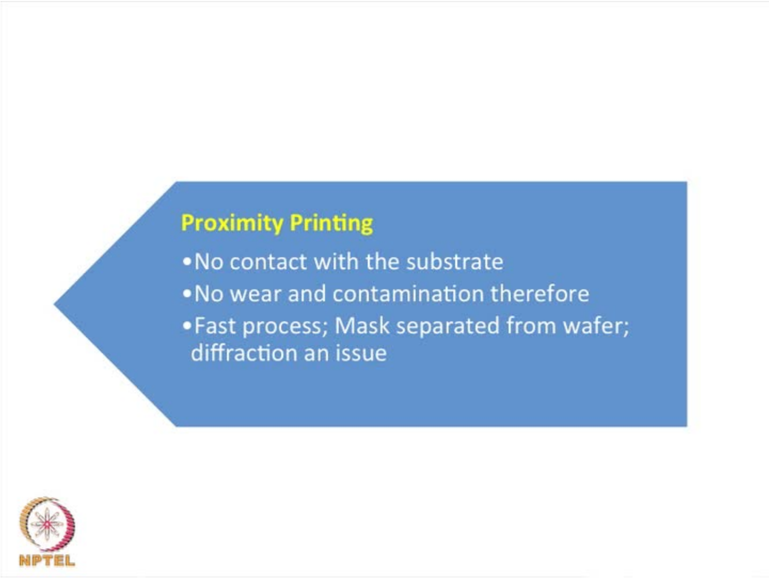
(Refer Slide Time: 56:07)



It is an inexpensive process, not complex, it is a fast process, the mask will undergo wear and tear because of contact printing, and defect generation will be due to contamination because it is touching the surface and in contact printing usually you take one is to one size. For example, if you look at sample here, this is the laminate; assume if it coated with the photoresist material now, what you see here is a photoresist coated substrate. Now you keep your mask, the mask is actually in contact when it is exposed UV light.

Because of continuous exposure and contact with the surface, the mask can undergo wear and tear. So, you have to change the mask very often; let say typically after 1000 to 2000 exposures and because of heat in the UV exposure unit that mask is subjected to - there can be dimensional stability. So during the quality check, you will be noticing slight variation in the dimension. Contact printing is currently in work but, there are some problems with contact printing.

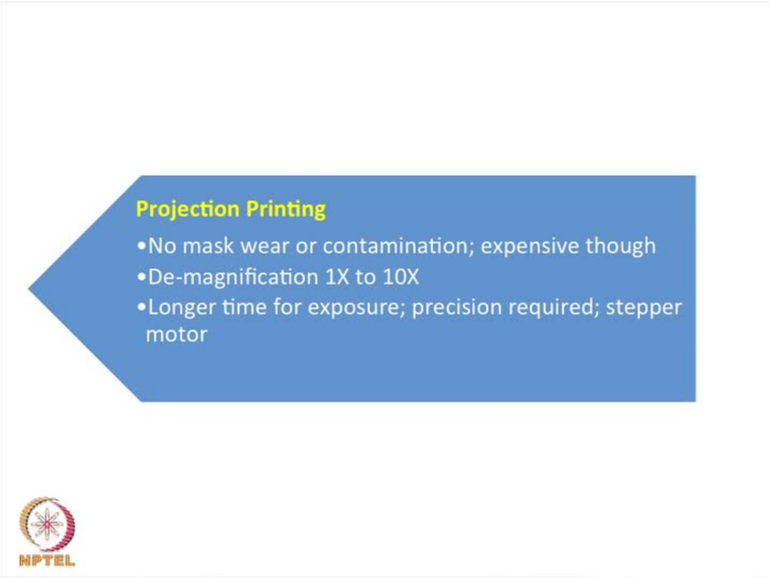
(Refer Slide Time: 58:14)



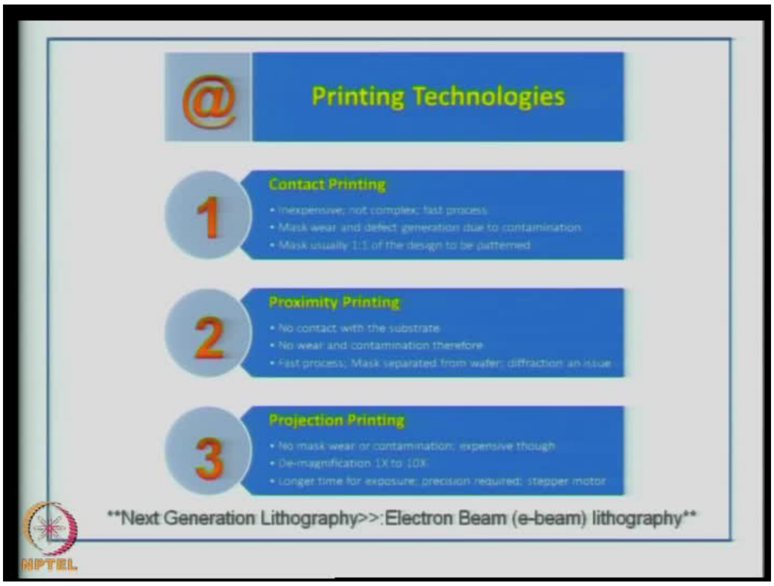
Proximity printing on the other hand, the next point that you see here, which is typically not used in the PCB industry today, but used in semiconductor industry were the mask will not touch the surface of the substrate. There will be a small gap, a very small gap typically about 15 microns to 20 microns gap between the mask and the substrate.

Now, because of that the wear and tear on the mask will not be there. It is also fast process but, you have to make sure whether that 15 micron is going to affect the quality of your imaging process. If it is, then you have still to reduce the gap between the mask and the substrate. These are two ends contact and proximity printing each as own advantages.

(Refer Slide Time: 59:09)



(Refer Slide Time: 59:34)



The third one is the projection printing, where the gap between the substrate and the mask is fairly large and you are going to do the imaging by using de-magnification or projection. So basically, you are going to project the image through optics, various set of lenses and you can de-magnify your image from a larger image to a smaller image, one is to one, on the surface by using set of lenses and you can do it from one x to ten x de-magnification; but, this requires excellent equipment where you have expensive stepper motors which will not allow to any kind of dimensional variation. Precision is required from the equipment side, longer time for exposure because for every substrate or batch or sample you have to do the checked projection.

So, all though the point number 2 and point number 3 proximity printing and projection printing are not very common in printed circuit boards, contact printing is very common. Because of the demand for fine lines we might be seeing these kinds of printing processes coming into this industry as well but, the next generation lithography in the semiconductor industry especially is to use electron beam lithography, because we are moving towards fine lines. So, this is some of the various processes - starting from cleaning of the board to developing an image - now the board is ready for etching. In next class, we look at what etching is and how we can remove copper or unwanted copper or non-circuit areas copper from the board.