Electronic Packaging and Manufacturing
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Lecture – 18
2nd Level Packaging: PCB- III

Hello, welcome back. We will continue with our discussion on 2nd Level Packaging as part of our Electronic Packaging and Manufacturing course. In the last two lectures, we had started talking about motherboards ok. And in the last lecture, we were looking at motherboard materials, where we said that if you take a typical motherboard or circuit board, printed circuit board, printed wiring board. These are all being used interchangeably synonymously right.

So, there typically the two major components or constituents of a circuit board is number-1, a glass woven cloth in a polymer binding matrix. And number-2 copper ok, because this copper that is the main ingredient for having these wiring traces that go through the different layers in a circuit board ok. So, today we will continue with our discussions on circuit board materials. And today, we will take off from we were if you recall we were discussing the laminate materials before right. And we talked about the different types of motherboards, the nomenclature of the laminate materials, the nomenclature of laminate materials f r 4, f r 5 and so on and so forth.

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So, today we will focus on the we will start with focus on the copper part ok, which is the 2nd major ingredient ok, so that is what we see here the concepts that are going to be covered today is circuit board materials, which is and we are going to focus on copper. And then we are going to go to this fabrication part, where we will see that how the different layers of these circuit boards are fabricated, and then assembled on top of each other ok.

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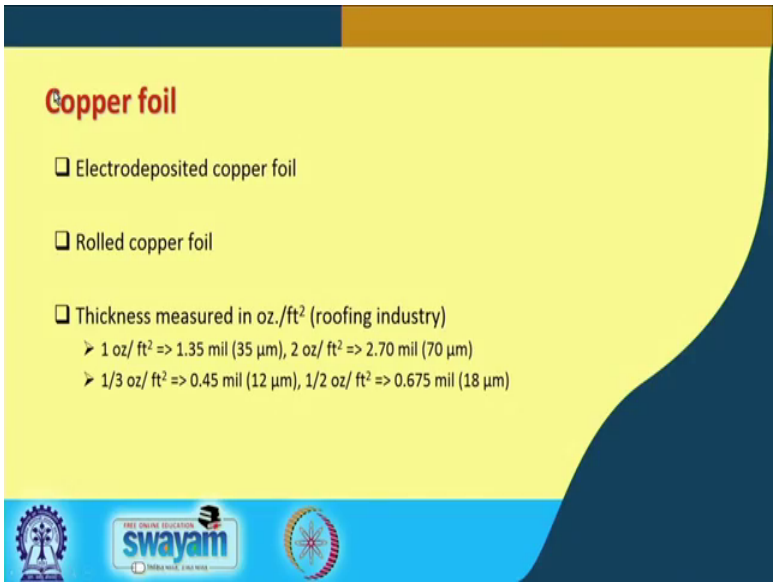

So, let us go over here, what is the copper that is being used in a circuit board. So, the copper that we need should be in the form of a foil, because if you look at the wiring traces that go inside a circuit board, these are really very very thin, if you talk about I mean they go anywhere in the range of let us say 15 microns to about 75 microns and so on. So, really thin copper ok, so where are we going to get these traces from, we will get these from a foil, which is of that thickness ok, so that is what we are looking at.

The copper foil can come in the in two forms, and we are going to look at that. The 1st one is called an electro deposited copper foil, where you will see that this foil is deposited in the form because of an electrolytic process. And the 2nd one is by rolling ok, and we will see both of these. But, before going to that process, let us also look at a certain you know certain standard nomenclature in the electronics industry, and which is actually borrowed from the roofing industry.

The thickness of the copper foil is measured in ounce per feet squared, so it is ounce per feet squared all right. So, one ounce per feet squared corresponds to 1.35 mils, mil is milli inch, and therefore it is about 35 microns right, so that is what is used. So, if somebody tells you, that you know the copper that was used the copper foil that was used for fabrication of this four layer motherboard was 2 ounce per feet squared. So, then if you look over here 2 ounce per feet square actually means, the thickness of the foil was 70 microns ok.

Similarly, one-third ounce per feet square 0.33 ounce per feet squared that is 12 microns 0.45 milli inches. One mil is 25 microns just because 1 inch is 25 mm, therefore 1 milli inch will be 25 microns that is the way to remember all right. And so I am showing here that this the denominator in terms of copper thickness or nomenclature for copper thickness is in terms of ounce per feet squared, and corresponding thicknesses both in mils and microns are shown on this slide ok, so with that let us move on to the next slide.

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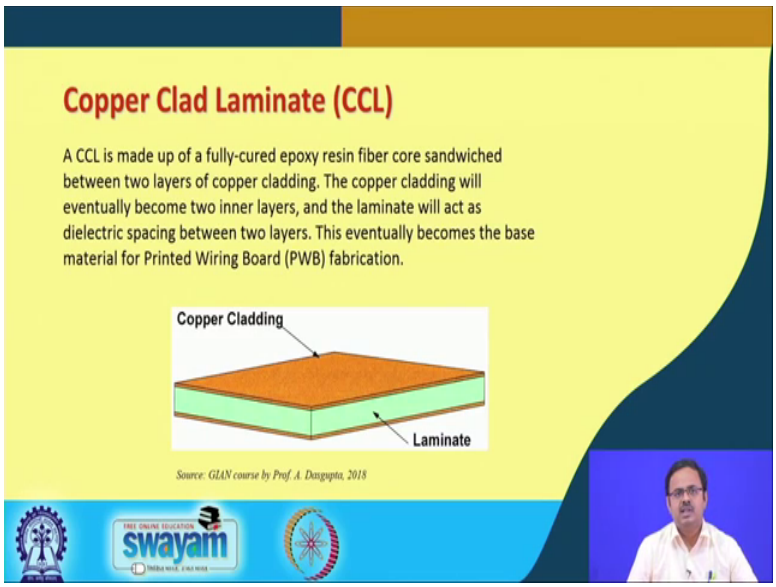

Now, this one is a very basic unit that goes to make a motherboard ok, so this is called a copper clad laminate. So, we talked about the laminate in the last lecture, what is your laminate? That is this glass you know glass, fibers or glass cloth inside this polymer matrix right criss-crossed and that is the laminate. And then, we talked about copper in the last slide.

So, right now a copper clad laminate is what that is as shown in the picture, it is a laminate with a copper sheet on either side. So, copper clad laminate or CCL you can look at. It is made up of a fully-cured epoxy resin fiber core ok, so that is a laminate we talked about sandwiched between two layers of copper cladding ok. The copper cladding will eventually become two inner layers, and the laminate will act as a dielectric spacing in between the two layers ok. So, eventually this copper cladding is going to become an inner layer.

So, now it is continuous copper, then what we will do is we will remove the copper, where it is not needed, and retain only the copper which will correspond to now these wiring traces ok. So, therefore a printed wiring board fabrication if you look at it, this CCL becomes one of the building blocks, it is a base material a base assembly on which we are going to build layer by layer ok. So, once again CCL or copper clad laminate is a laminate layer with two copper layers or two sheets of copper onto the other two sides that is CCL all right.

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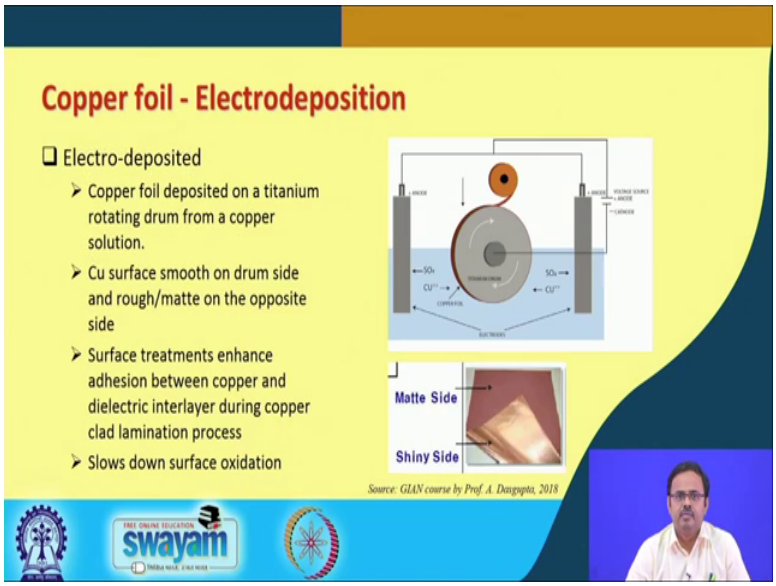

So, we are talking about copper foil. And we said that there are two different ways by which this copper foil can be made. The 1st is called electro-deposition, which is shown over here. So, what is this in electro-deposition, if the copper is electro-deposited, the copper foil is then first you have what is it is a rotating drum made of titanium ok, which is dipped in an electrolyte and then there are two electrodes ok. So, what happens is the

copper foil is first deposited on this rotating drum ok. And then what happens is then you have a spindle, and then the sheet is as is shown here. From the drum on which it is deposited it comes out, and then it is rolled in the in this form ok. So, now what happens is how is this copper deposited because of the electrolytic process ok.

Now, therefore what happens is as it gets deposited on the drum, then the side that gets deposited on the drum surface is a smooth side ok. And the side that is exposed to this electrolyte is becomes slightly rough. So, if you look at the surface finish, one will be a shiny smooth finish, the other will be a little rough or matte finish ok a nd the matte finish actually helps also later in terms of addition ok.

But, the surface treatments enhances addition between the copper and the dielectric interlayer during copper clad lamination process. So, if you go back over here, then this copper sheet that we saw in this electro depositors, this copper sheet that is or copper foil that is resulting from this electro deposition process is the one that sorry is the one that goes to form these layers on the two sides of the laminate, and gives you the CCL or the copper clad laminate ok.

So, we also do surface some surface treatment not just for addition, but also to prevent or at least slow down if not prevent, at least to minimize the surface oxidation ok. So, in the bottom side you see a picture, where one can see the copper foil. And you see that the bottom side is very shiny, whereas the top side is matte, because the bottom side the shiny side was actually attached to the to the rotating titanium drum, whereas the other side which is the matte side was exposed to the electrolyte all right. So, this was one process of getting a copper foil.

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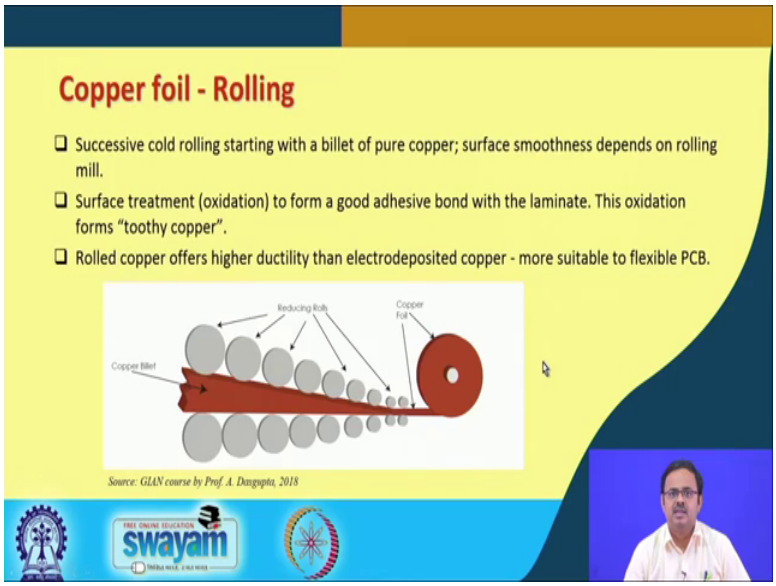

What is the other one this was an electro-deposition process, the other one is a mechanical process of the rolling ok. So, what we do is you take a thicker sheet of copper, and successively cold roll the copper. So, in the rolling mill you see, these are these rotating rolls as you see. And as a copper billet as it is called or a slab, as it goes through these rolls it is kind of thinned down.

So, if you go to a mechanical rolling mill any steel industry and all, you will be able to see rolling mill is a very is one of the very important shops, where from the rolling mill it the metal comes out in the form of sheets. So, in this case here as you can see that this one as it is rolled, it finally gives you the very thin sheet or foil in this case ok. So, the surface smoothness or surface roughness depends really on the rolling mill on the rolls that is present. So, this is not going to be a heavy-duty rolling mill that you see in a steel plant let us say ok. This will be more delicate and more sophisticated.

The surface treatment to form a good adhesive bond with the laminate ok. So, the again like before, we will do a surface treatment most to prevent oxidation as well as to form a good adhesive bond ok. And finally, the rolled copper offers high ductility rolled a rolled couple offers a higher ductility compared to electro deposited copper. And therefore, you see this more flexible PCB's these days you know, you have these bands where you need you need flexible mother ports, it is not rigid anymore ok, so that is a different type

different kind. But, there if you have these wiring traces that, copper you need it to be more ductile, and that is what it is ok.

So, therefore in such scenarios or such applications, it is the rolled copper foil that is used clear all right. So, we talked about two methods of getting this copper foil. The one is through electro-deposition and the other is through cold rolling as we see here. And then once we have the laminate, and we have the copper foil, we can have the copper clad laminate a picture of which we saw two slides back, and which we said was a base material for the fabrication of the motherboard or for the fabrication of the circuit board ok.

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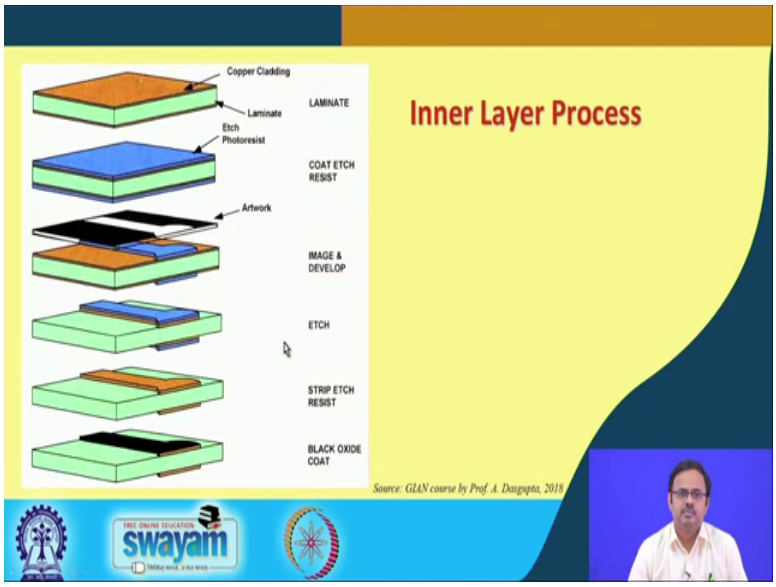

So, remember when we saw this first one this CCL copper clad laminate, what did we say, we said that these copper foils that is deposited on either side will eventually become or will eventually be the basis for having these wiring traces. We said that from this copper, we are going to retain we are going to retain that part, which is used for having these wiring traces and remove the rest ok.

So, how are we going to do that that is the next question? So, here we are going to spend a few minutes on this slide, and then again recap what we call the photo the lithography process ok. So, what is the 1st step, the 1st step is the first building block is the copper clad laminate, we saw that it is one laminate and then two copper foils on both sides.

Next thing what we do is we will put a photoresist on both sides of the copper, so both on the top. So, we will cover the copper foil with this photoresist ok.

Then what we will do is we will have this is what is called the mask ok. So, the mask what is it, it is going to have cutouts for you know for those areas or portions, where we want to have the wiring trace and it will and the rest of it will be covered ok, so that is the mask. The mask will expose only that part when or mask when put on this photoresist is going to expose only those parts, which are eventually going to become wiring traces ok.

So, then what we do is once this for this mask is put, then we go through the photolithography process as a result of which what happens is we are able to remove the you know we are only able to retain the photoresist at the place, where we are going to have the wiring trace and remove the rest of it ok, and that is what we are showing here. So, once this is done, then what we are going to do is we are going to etch this remaining copper away.

So, look at this 4th-figure from the top. And what we are left with is now, the laminate and then some portions of this copper foil, which was initially or the copper cladding, which was initially attached to the laminate ok, the rest of the copper has been removed by etching. We are going to talk about the etching process later ok, actually both of these processes ok. Next what have we have what happens, we will remove this photoresist. And what are we left with; we are left with the laminate. And a portion of the copper, which is actually a wiring trace ok.

So, we started with the figure-1 the topmost figure, and we ended up after a photolithography and etching process, we ended up in the emitter configuration, which is shown in the 5th figure from the top all right. And then what we do is we will do a black oxide coating on this for protection and all clear.

So, this is how you can see this now eventually from this now forms a inner layer, so you have a laminate and you have copper traces ok, if this was just a two layer motherboard that is it. If it is a four layer motherboard, then we have to bring two more outer layers on top of it. If it is a six layer, there will be more inner layers and then outer layer and so on and so forth ok, but this is the inner layer process clear.

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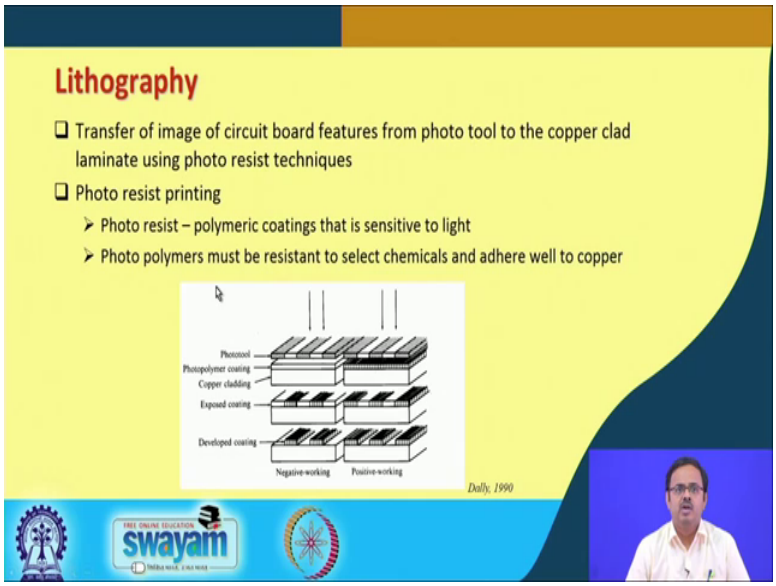

So, now what did we see, we saw that there was this photolithography process ok. So, we are going to recap the photolithography process once more we saw. We briefly saw that earlier, when we were talking about you know when we when we made a diode right in the in the beginning of the course, we talked about photolithography process. We are going to look at this again now, but with focus on motherboard. So, what is lithography, it is the transfer image of circuit board features from a photo tool to the copper clad laminate using photoresist techniques clear. So, earlier we were using we were removing something else, but now it is about removal of the copper from the copper clad laminate all right.

So, photoresist printing, the photoresist is polymeric coating that is sensitive to light. So, depending on whether it is a positive photoresist or negative photoresist depending on that when exposed to light, and typically it is UV light. We are going to either harden the expose portion or which will be helpful for removal later or we are going to sorry we are going to soften the exposed portion, which is going to be easy for removal later or we are going to the opposite, where we are going to soften or we are going to harden the expose position expose portion, which therefore will be retain and the rest of it can be removed ok, so that is what is shown here negative working, positive working all right.

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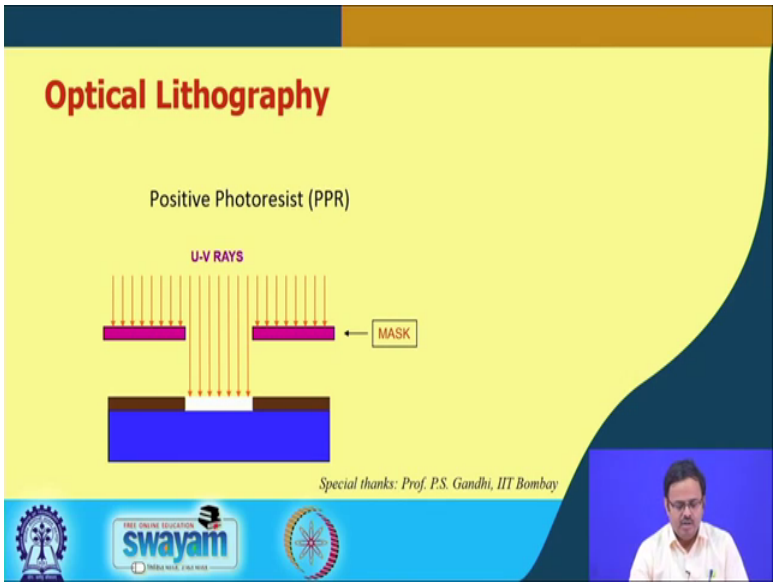

So, let us again have a recap of what we did, before when we talked about optical photo lithography. So, positive photoresist, this is my substrate. And then we have this photoresist layer, it can be PDMS for example. Then this is the mask, this is a cross section. So, as we can see the mask a lot of it is covered, and then a part of it is exposed, this is like a cutout in the mask ok. Just like your face mask, we have cut-out for eyes and nose and mouth, this is a cutout.

Next, when we shine UV rays through, then what happens? The UV rays is going to go through the etch the cutout, and therefore fall on the photoresist ok, but the portions where it is covered with this mask, it is not exposed to the UV light. So, next what happens is it is it affects some change probability, it changes the property of the photoresist, which was subject to UV light, and which can be removed easily or sorry it changes the properties ok, which can be removed easily or not we will see. So, in positive photoresist, we remove that ok, and the remaining part is retained clear.

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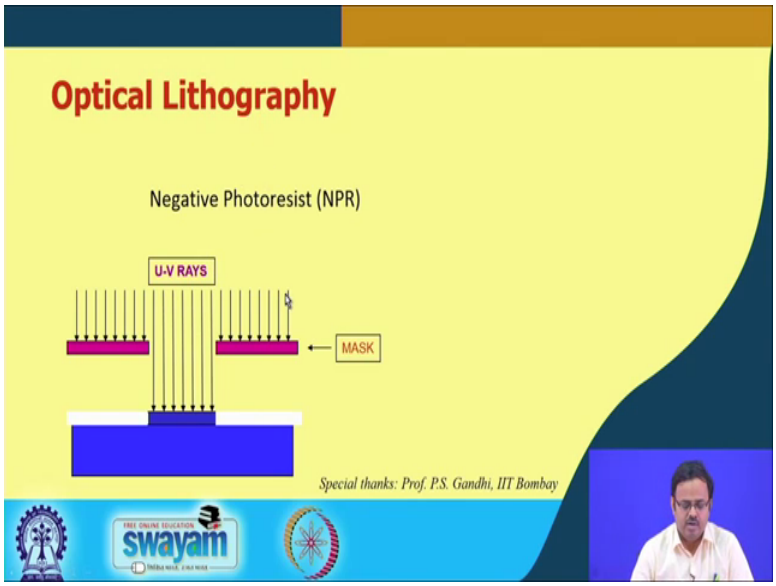

In the negative photoresist, what happens is again the same thing you have the photoresist on top that is the PDMS. Then you bring in the mask, you expose UV light and the property of the photoresist, when exposed to UV light changes, this part is till this part is the same. But, next what happens is you have some process by which the portion that part of the photoresist, which was not exposed to UV light can be removed while retaining that portion, which was exposed to UV light ok.

And this is what we saw if you go back to slides here, this is what we saw the portion which was exposed to the light was retained and the rest of it was removed agree. Here also you see that in negative the portion that is exposed is retained the rest is removed. In positive, the portion that is exposed to UV light is removed, the rest is retained ok.

So, depending on what you want to do this is the lithography technique, but at least for motherboard, which we saw before in the previous slide what is used is negative photoresist negative photo lithography process clear all right ok. I take it back I think I just my slip of tongue in both positive and negative, I said the photoresist, for example PDMS well no and PDMS cannot be both positive and negative photoresist, it has to be some other material ok. So, optical photo lithography, optical lithography or photo lithography is done.

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But, next remember what we said is the remaining copper is etched away. So, chemical process chemical etching, it is a process that strips the copper cladding away from unprotected regions that is used that is how I am going to remove, retain only the circuit traces or the or the wiring traces and remove the remaining copper from the copper cladding ok, so that is what the 2nd point says the copper that remains after etching defines the board features such as circuit traces solid solder pads will come later etcetera. So, now what are these etching processes there are two methods of etching. One is a photoresist coating, the other is a solder plate coating ok. So, this is for your information.

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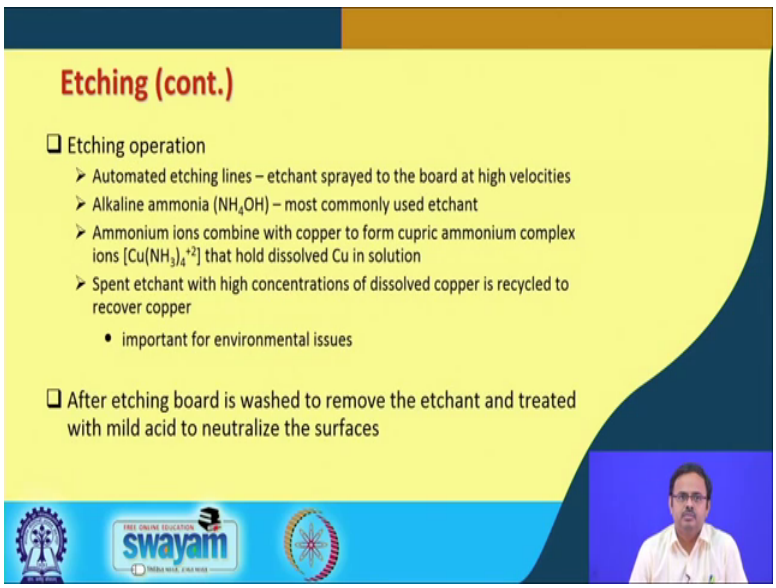

So, the etching operation if you look at it, what happens in a you know in a circuit board manufacturing plant or manufacturing equipment is that there are automated etching lines well, where the circuit board is going the etchant is sprayed to the board sprayed on the board rather at high velocities ok. Now, what is the etchant material? The most common is ammonium hydroxide NH 4 OH is an alkaline, it is an alkali, so alkaline ammonia it is called some but is it chemical named ammonium hydroxide NH 4 OH ok.

So, what happens, when you etch it? The ammonium ions combine with copper to form cupric ammonium complex ions, so Cu NH 3 4 that whole dissolved copper in solution ok, so that is how the copper is remove the copper reacts with an ammonium hydroxide and is removed. Now, the spent etchant, what is spent etchant? Spent etchant is the etchant once it is sprayed, and it has combined with copper. Then and what comes out is a product of this chemical reaction of this chemical etching process that is the spent etchant that is already used up, now what do we do with this ok.

Now, see copper is expensive and copper is precious, and you have a lot of copper that you have removed, we started with a complete sheet. And finally, what we retain are some of these traces majority of it probably is move removed correct, I cannot just waste it. So, therefore both in terms of material conservation as well as from environmental issues the spent etchant is re used is or rather is the copper that is in the spent etchant is recycled to recover the copper, which can be further used again ok.

And after the etching process, the circuit board is washed to remove the etchant and then treated with mild acid to neutralize the surfaces, remember the etchant is ammonium hydroxide it is an alkali ok. So, mild acid is used for washing, first of all the agent has to be removed. And then to neutralize the surfaces the mild etch and the mild acid is being used all right.

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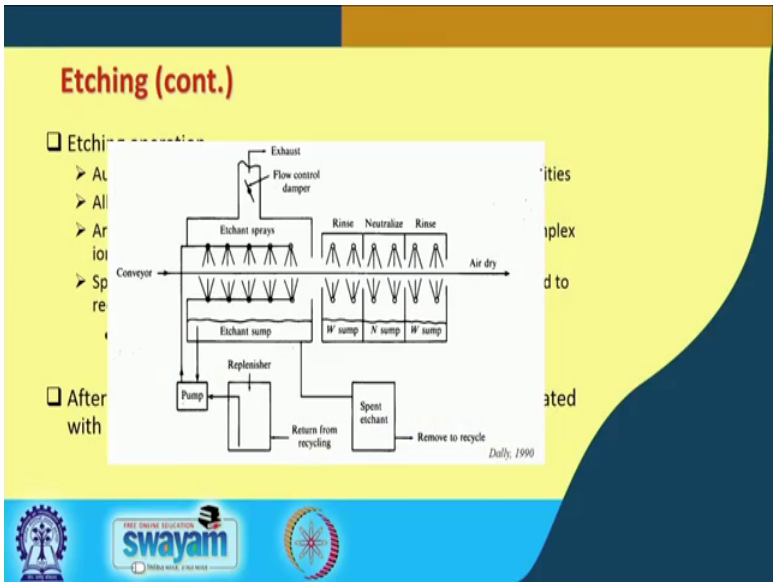

So, this is a diagram as you can see, it is a conveyor belt there is an etchant sump. So, what happens is the motherboard goes on the conveyor belt, then this is the etchant is sprayed from the etchant sump on both sides. And thence it is rinsed, it is neutralized again it is rinsed, and then dried, and the board comes out. And the spent etchant as you can see is removed for recycling ok and getting the copper back ok. And from the recycling plant again it is replenished here, and remove the remaining etchant is replenished over here, and again in pumped and sprayed down and so on and so forth ok.

So, with that what we will do is we will complete today's lecture or this lecture, where what we did here is we looked at first of all the copper cladding that goes into a motherboard, then we started with this elementary block of CCL-copper clad laminate, and from there we looked at the process as to how the rest of the copper is removed, and the circuit traces are retained, the wiring traces are retained right. And that and while going through that process, we saw that two major fabrication techniques that are used is lithography and etch followed by etching.

So, we went through a revision of these processes, what is lithography, what is etching, and also what is the etching process, when you are having these motherboards manufactured ok. So, we saw this conveyor belt, how the etchant is sprayed, and how the copper is removed, and what is done with the spent etchant so on and so forth all right. So, thank you very much, I hope after this lecture, we have a fair idea at least as to what

goes into fabrication of a motherboard ok. So, when we come back, we will again continue from where we left off or where we are leaving now, and to continue with the topic of motherboard fabrication.

Thank you very much.