Integrated Circuits, MOSFETs, OP-Amps and their Applications

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Lecture – 09
Introduction to fabrication technology Contd

Welcome to this particular module, and here we will understand a very important step that is used in fabricating, lot of devices all right. So, what is that particular step, or process the process is called photolithography. Now until now what we have seen, is how can we select a substrate, and if we select silicon as a substrate, then how can we grow oxide and once we grow oxide then how can we deposit metal, or insulator, or semiconductor. Now if I want to pattern with this semiconductor, or insulator, or metal I have to understand what is photolithography? Now your question should be that where I will use photolithography. So, when you design a MOSFET, you have to design source and drain right.

So, you want to diffuse the n type dopant or p type dopant, only in the area where you want to have your source and drain. Then you have to grow oxide only below the gate that is a thin gate oxide, right then finally you have metals so, you have to deposit the metal and pattern this metals.

So, require creating a window for diffusion, creating a thin layer of oxide and patterning it, creating a polysilicon gate, or a metal gate and creating a contact pads with metal, this all requires photolithography. All right so, if you understand photography, then we can understand lot of steps lot of devices not only MOSFET, but also the whole circuit design and also lot of other engineering devices, this which can be sensors, which can be actuators, these are all micro engineer devices all right.

So, let us understand in this particular module, what is photolithography?

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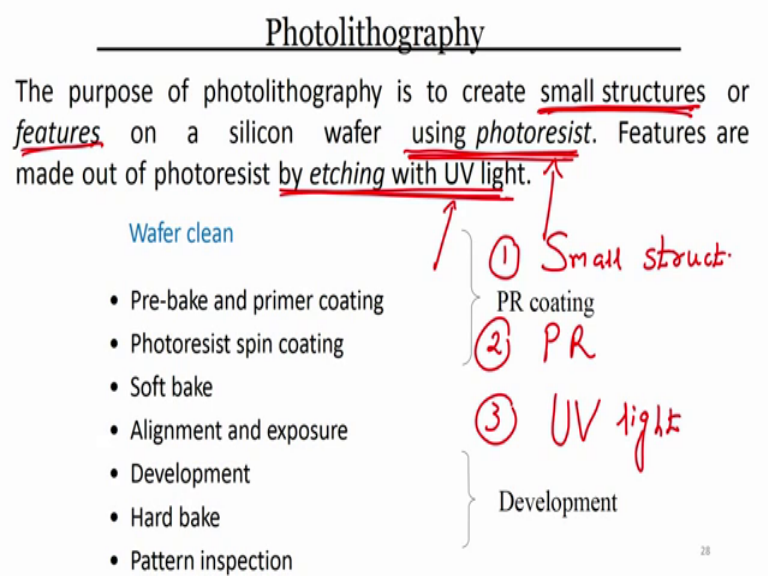

So, if you come on the screen, this will be our class 7, and when I talk about photolithography right, the word itself has 3 different, sub group photo or 3 different words, photo, litho and graphy all right. So, this litho graph is again we have seen in the class 1, that it comes from a word lithos, lies and graphic; that means, that we are carving a single stone, or we are craving a stone right the monolithic single stone, but litho is carving graphic. So, using photons. So, photolithography all right, now nothing but purpose of photolithography is to create, small structures or features, on a sing on a silicon wafer, using photoresist.

So, we should understand what is photoresist? Right features made out of photoresist, by etching uv with uv light. So, understand, how we can expose the wafer with uv light? So, 2 things we understand is, one is you can create small structures, second is you have to use photoresist, third is you have to expose or etch this photoresist with the help of uv light, you have to pattern this photoresist to the help of uv light, 3 things we understand.

So, what are the steps in photolithography? Right what are the steps in photolithography? The first step is the first step is you have to clean your wafer, that is the first step always when we start fabricating a device the first step is you have to clean your wafer, second is you have to coat the wafer, coat the wafer with what, photoresist coat the with what photoresist, that is called photoresist coating all right.

So, for photoresist coating what are the steps, first step is you have to pre-bake and primer coating.

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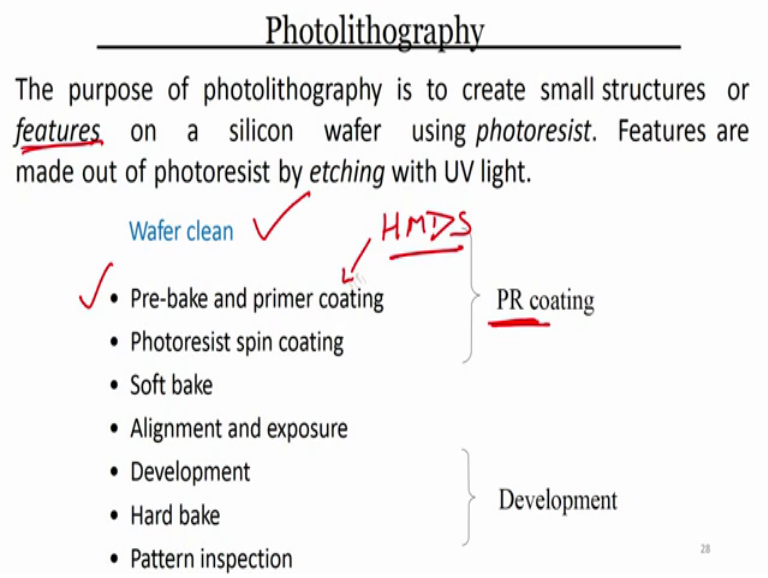

All right; that means you have to coat the photoresist, so, before photoresist the primer coating, is sometimes you will see a word called HMDS. HMDS this is your primer, all right so, for improving the adhesion of photoresist onto the oxidize silicon substrate, or onto the metal over the oxidized silicon substrate, sometimes we use a primer called HMDS all right. So, first step is your pre-bake and primer coating, second is photoresist spinning. So, this first step this is second step.

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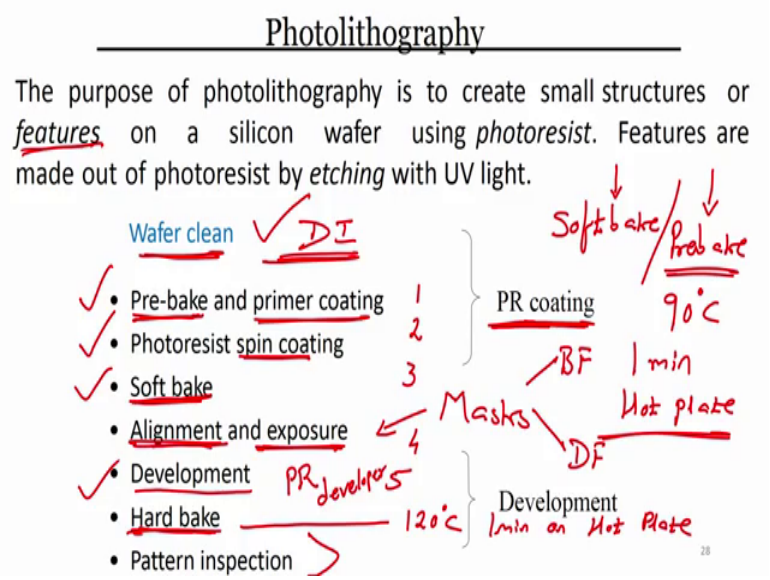

Third step is soft bake now, you should know this things we have already discussed right one is spin coating, after spin coating you have to do soft bake or pre bake, remember this word pre bake, the pre bake was done at 90 degree centigrade for 1 minute, using hot plate this we have discussed, when we were looking at the fabrication of inter digitated electrodes in su 8 well, remember this word pre bake, right pre bake is also called soft bake, all right. So, first is your first thing is you have to, pre-bake the wafer pre-bake the wafer because, you have cleaned the wafer using chemicals, and then finally your rinse the wafer using di deionized water, and that is why you have to dry the wafer you have to dehydrate the wafer, that you can do with pre-baking, and then you have to do primer coating.

So, then from now we will use to distinguish the pre-baking, that is pre-baking is used for, removing any water content right on any moisture content pre-baking we will use, and we will use soft bake when it comes to photoresist. So, it is easy for us to identify or delineate between 2. All right so, we will use soft bake when it comes to photoresist, we use pre-bake whenever it comes to removing the moisture from the surface of the wafer.

Now so, the step for PR coating would be, first step pre-bake and primer coating second step photoresist spin coating, third step soft bake. Then you if you remember I have shown you masks, what are kind of mask, bright field masks and dark field masks. Using the mask, we have to align the wafer, and expose the wafer, which is already spin coated

with photoresist, and has been soft baked that wafer we had to align it and we had to expose it, aligning will be done using the mask, are 2 types one is bright field second one is dark field.

Right and then exposure is done using uv, uv is your ultraviolet light easy. So, first thing is wafer cleaning, second thing is primer coating, before primer coating pre-bake then primer coating I have primary coating p e r, p e r coating is photoresist coating, after that you have to do soft bake, soft bake is done at 90 degree centigrade for 1 minute if you keep the wafer on the hot plate, if you keep the wafer inside the oven then the time would be higher.

So, after soft bake is done, you have to expose the wafer, but you can do exposure with the help of a mask and uv light, you have to keep the mask on the wafer which is coated, with the help of the photoresist. Right that alignment is done with the mask, and then it is exposed using uv light. We have seen this if you remember, if you do not remember again look at the video where I have taught, how to pattern inter digitated electrodes inside the su 8 well, or how to fabricate a gas sensor using micro fabrication techniques, and you will understand that how we are using the photoresist. So, I will also show you one time again in this particular lecture, how we can use photoresist? How the exposure is done? How the alignment is done? All right ah.

So, we come back to the screen and what we see is, the next step after alignment and exposure would be development, development of what, development of photoresist. So, next step would be so, this is your 4th step, 5th step would be developing photoresist, for developing photoresist you have photoresist developer all right after you develop the photoresist, you have to perform a process called hard bake. Right one is soft bake, one is hard bake. Hard bake is carried out at you remember right 120 degree centigrade for 1 minute on hot plate, after hard baking you have to inspect the wafer, inspect the wafer for what whether the photoresist has been properly patterned or not, this is very important all right.

So, for performing that for performing this hard bake, and to understand whether the photoresist is properly patterned or not, what we will do, we will see what are the steps, and what do you mean by wafer inspection. So, let us see on the screen, if you see on the screen, what do you see, a black screen. Now let us take an example, let us take an

example, whatever we have seen what we have seen, we have seen the following steps. So, what I want to show is what do you mean by pattern inspection, and how can you inspect a pattern. So, let us see.

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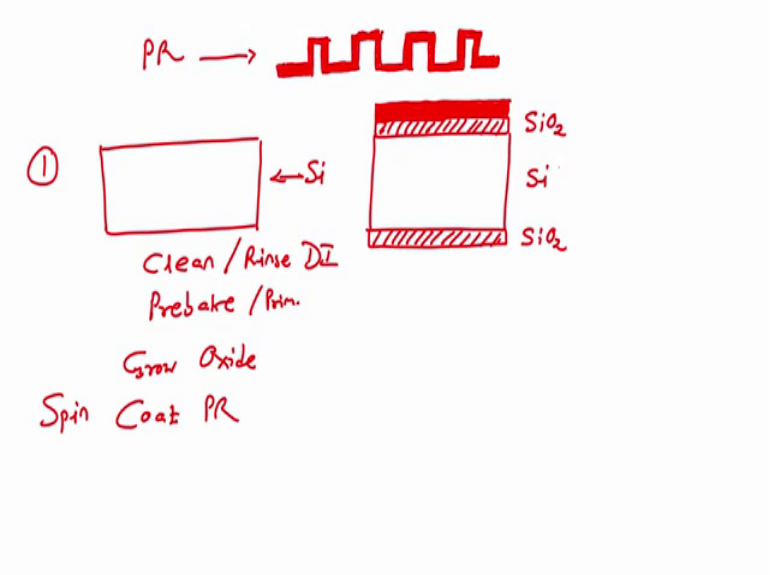

So, let us let us assume like this, that we want to pattern, a metal with this particular shape, and this shape is your meander shape. Like this all right so, what do you want to do, you have want to have a pattern, we of metal which will look on this when we look on the substrate it looks like this. So, what is this material, material is a photoresist. So, I want to see whether I can pattern this photoresist, on the silicon substrate and whether it looks like this or not, whether it looks like this and how can I obtain this pattern, that is another question right.

So, we will obtain this pattern with the process that we have just now seen, process called your lithography process called photolithography. Photolithography because we are using uv light, right so, let us see what is the first step, first step would be we take a silicon wafer, once you take your silicon wafer then what you do, you have to a grow oxide because, this pattern we want on the oxidized silicon wafer, we want this pattern on the oxidized silicon wafer, all right it is very easy all right I want to see this pattern. A little bit thick and maybe one more layer, my pen is not working properly, right that is why you see that there is a lot of error, amazing anyway does not matter, point is that we draw it correctly just. So now, I want this pattern all right. So, what will I do first I will,

you see on the screen, first I will take a silicon wafer next I will grow a oxide, now all of you know how to grow a oxide using thermal oxidation. So, I am growing Sio2 this is my silicon this is my Sio2. Now I want to have a pattern of photoresist, which looks like this right.

So, what will be next step, next step would be I will deposit or I will spin coat the photoresist, I will spin coat the photoresist on the oxidized silicon, right that will be my third step. First step is I take a silicon wafer then of course, when I do not say that we are cleaning it, we have to assume it we have cleaned. You take the silicon wafer then you clean it, it rinse it with a DI then you pre-bake it, then you apply a primer, then you grow oxide, then you coat, spin coat photoresist. All right this process we have done that is why we have from here we have obtained, which is wafer shown here. All right what is our next step? Next step is, if you remember right next step will be our soft bake right.

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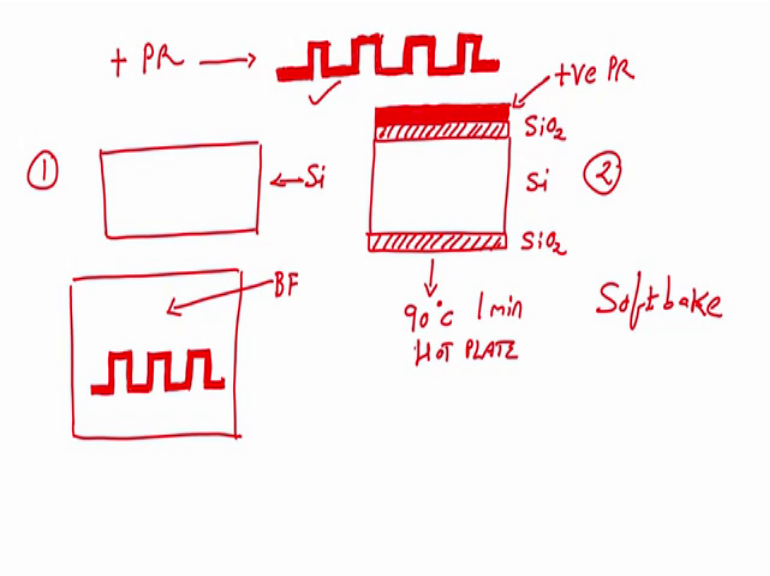

If you go back, see we have done this, now we have to do next which is soft bake. So, we will keep this wafer on a hot plate at 90 degree centigrade for 1 minute, and this is a positive photoresist, that we will discuss we have discussed we will again discuss this is photoresist and is a positive photoresist. So, we will put this wafer on a hot plate, at 90 degree centigrade for 1 minute. All right that is our soft bake, what is the next step we require a mask. So, we will have a mask that will have a pattern, which we want which is

shown here, all right I am just showing this represented diagram. So, it is look similar to it.

So, do not say that there are 4 square waves and I can only see 3 here it is not correct, is a representative diagram. So, you have a mask with this particular pattern, and we have discussed that this mask, where the pattern is dark and the field is bright, is called bright field mask. Right this is called see the bri field is bright this all the area here is bright. So, it is a bright field mask right, now once have you, once you have this mask once you have this mask what is the next step, next step is we load this mask.

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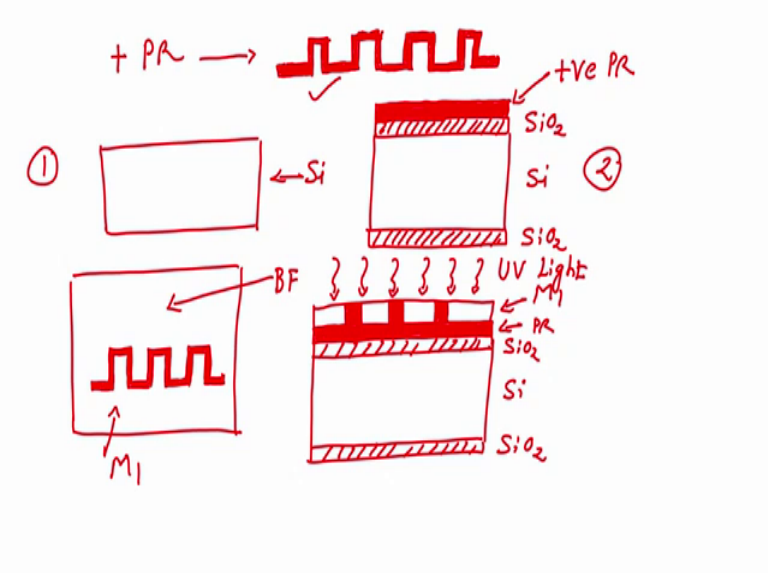

So, next step would be we will load this mask. So, I will draw the wafer once again, then we have oxide, then we have photoresist, right and then we will we have done soft baking already, we have completed soft baking. So, what is the next step next step is we have to load the mask, load the mask where, load the mask on this wafer.

That means I load the mask, which has pattern this is a cross section right you see this this mask, I am loading this mask let us say M1 this is my photoresist, this is my silicon dioxide, this is silicon, this is silicon dioxide, and this is my cross section of the mask, right. So, if I take a cross section on side view of the mask shown, on the bottom left of the screen then it will looks something similar to what I am drawing here, on the wafer. So now, I have loaded the mask, now I have loaded the bright film mask on the oxidized silicon dioxide, what is next step you had to aligned it. So, I have aligned it, next step

here to expose it, expose using what you know expose using uv light, what is uv? Ultra violet light right.

So, go let us go back. So, we have done pre-bake, primer coating yes, I said let us consider the primer coating is done, next is photoresist spin coating done, soft bake done, alignment and exposure done, next is development, development of what, development of photoresist.

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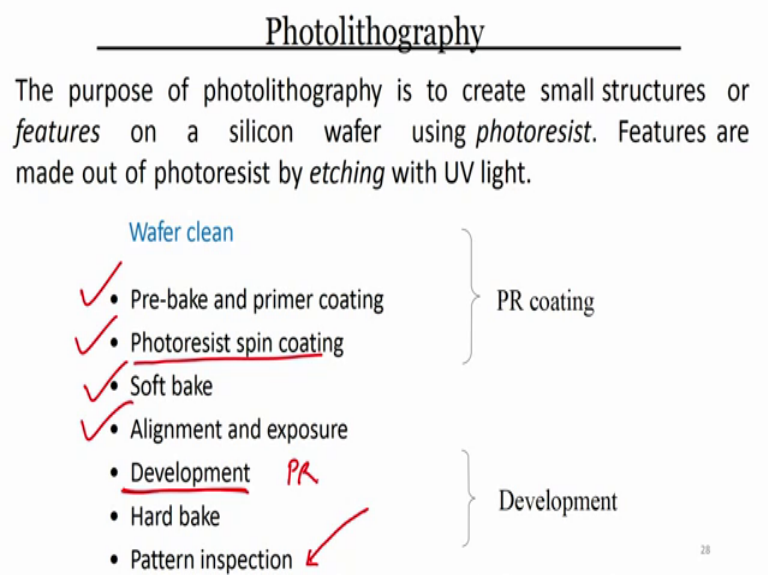

So, for developing photoresist, the first step would be that, you have to take out the mask, you have to unload the mask, you have to unloads after this step next step would be to unload the mask, from the photoresist and dip this wafer, dip the above wafer in photoresist developer.

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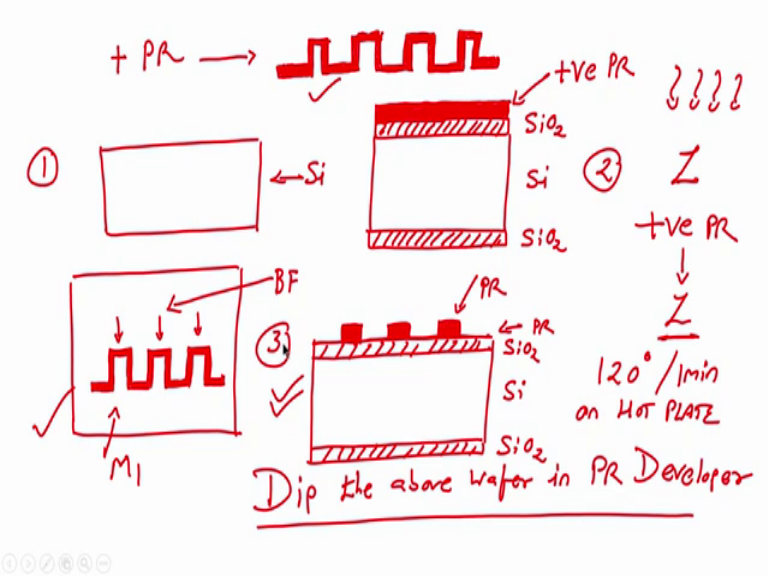

When you do that right now, you understand very important we have used positive photoresist. So, whatever the pattern, suppose this is the pattern then we will have or let us say let us put a symbol so, it is easy let us say, this is the pattern z all right then if I use positive photoresist I will get z, same pattern; that means, whatever area is not exposed, you see if I expose this right then the area which is z that area is not exposed, the area which is not exposed that area becomes stronger.

The area which is exposed then becomes weaker. So, in this particular case the area which was not exposed, the area under this pattern what was not exposed and what we say characteristics of positive photoresist, the area which is not exposed gets stronger. So, when I dip the above wafer in the photoresist developer what will happen this will happen, what will happen this thing will happen you see here.

This is my photoresist right. So, this thing will happen, when I dip the above wafer the this particular wafer in the photoresist developer. All right guys and then I had to see whether my photoresist is completely developed or not, is perfectly develop or not that is called wafer inspection. So, if you go back I have done, what I have done I have now aligned an exposure pre baked, pre bake and primer coating photoresist spin coating we have done, we have done soft bake, then we have done alignment and exposure, right then we have developed the photoresist, and then we have done hard bake right so, we

have to I next topic next step, is after developing the photoresist we have to put the photoresist, put the wafer at 120 degree for 1 minute on hot plate right.

That is your post bake, or hard bake, finally you have to inspect the wafer, you have to inspect the pattern. So, what is the pattern, pattern is this particular pattern in our case we will inspect once this is done, this is what it means when we are talking about photolithography steps, which are shown right over here. All right easy extremely easy I will take an example another example so, you get it. So, you have to understand when you have to develop or you had to pattern something, these are the steps that you have to follow.

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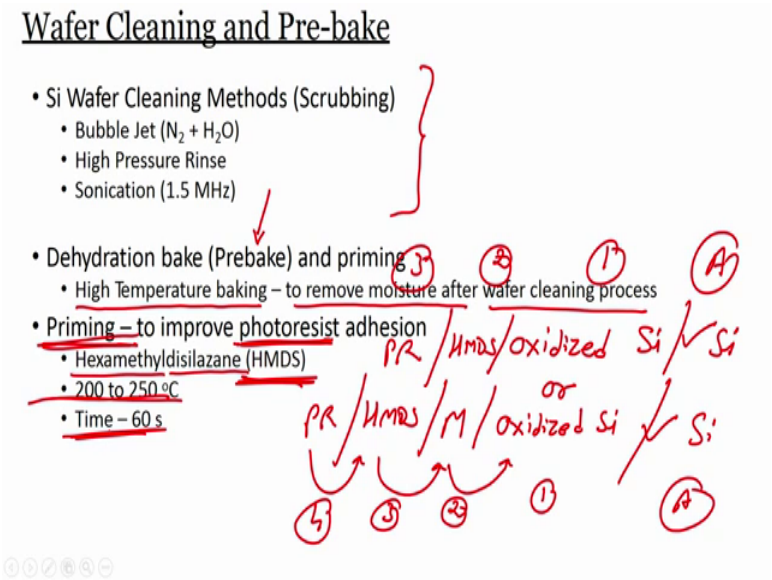

So, after this let us see, how the wafer is clean and how the pre-bake is done right. So, the wafer can be clean that is the silicon wafer can be cleaned by several techniques, one is bubble jet where you have to use nitrogen plus ha plus water right in a jet formation and you can use bubbler so, you can clean the wafer second is with high pressure you can rinse the wafer, third is you can use a sonicator and clean the wafer. Sonicator is used at 1.5 megahertz, and these are the cleaning techniques for silicon wafer.

Now, there can be moisture on the wafer after you perform these steps. Right so, how to remove or how to dehydrate the wafer for that we have to do high temperature baking, also called pre-baking to remove moisture, after wafer cleaning process, easy very easy. Next to improve the adhesion I have told you to improve the adhesion, of photoresist

onto the oxidized silicon, or any material on oxidized silicon, you have to improve the adhesion of photoresist on any materials that is deposited on the oxidized silicon, or you want to improve the photoresist on oxidized silicon.

You have to first you have to first do the priming step that is done by HMDS, HMDS and that is your hexa methyl disilazane, right disilazane. So, hexamethyldisilazane is used for improving the adhesion of photoresist onto the substrate; that means that up before I want to coat photoresist, I will first coat HMDS, and then I will coat photoresist if I want to coat photoresist on metal which is deposit on oxidized silicon, I will first coat HMDS on that I will coat photoresist.

So, it goes like this oxidized silicon substrate is a first one, second step is metal, third step is HMDS, 4 step is photoresist. In this case oxidized silicon substrate first, HMDS second, photoresist third, of course, you want to add for the step then A would be silicon, right easy and this is, then you have to put it at 200 to 250 degree centigrade for about 60 seconds, there are various way of improving the of adjusting or optimizing this temperature and time.

There are various techniques to improve the various ways, to improve the op optimize the time and the temperature, but that is we are not discussing, what we are discussing is that if you are given a wafer, can you clean the wafer if yes after cleaning, can you pre-bake the wafer if yes, after that can you coat HMDS on.

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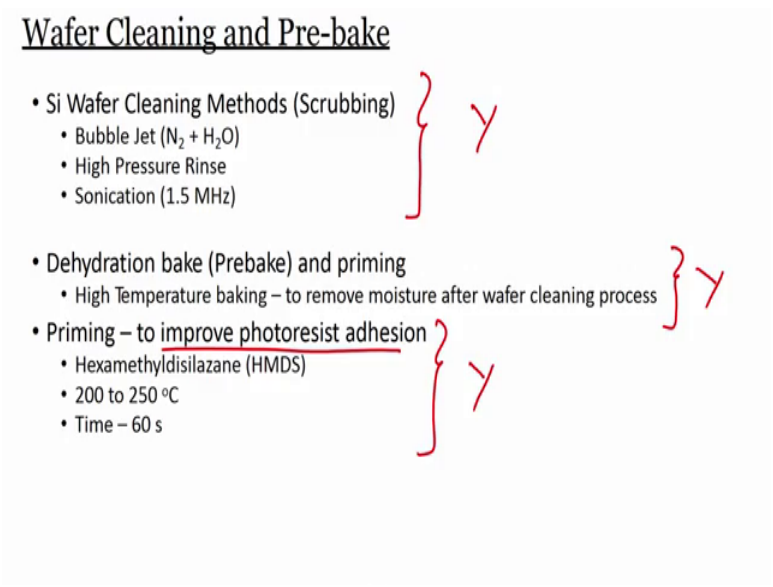

The wafer to improve the photoresist adhesion, then it say yes everything is yes, we can do this, yes, we can do this, yes, we can do this, right so, this is your wafer cleaning and pre-bake technique, all right easy very easy correct.

So, if I let us go to the next topic, next topic would be photoresist. So, what are the photoresist all right we will see the photoresist in the next module and ah. So, that you have some break in between modules, right now what we have seen we have seen, how you can clean the wafer and how you can do the lithography step, for performing the lithography step we have seen certain steps right from wafer cleaning, then we have to do pre baking and primer coating, then you do photoresist spin coating, then you have to do soft baking, then you have to align the mask, expose the wafer.

Then you have to do hard bake developing, then you have to do hard baking, then you have to do pattern inspection, then you follow with example here, and then we have seen the before cleaning, and the priming and drive dehydration steps. Now the next step would be how what are the photoresist, and what are the kind of photoresist, and how can we use photoresist for fabricating, a or for using a as of for patterning several metals, or materials onto the oxidize silicon substrate, right that will be the next step.

So, we will I will see you in the next class, and till then you take again a look on the things that we have discussed, and let us continue the next class how the photoresist or kind of photoresist are there, and how we can pattern, how can use for obtaining a pattern of our desire. Alright, I will see you in the next class till then you take care. Bye.