# Sensors and Actuators

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## Lecture - 24
## Crystal Orientation and Si-SiO2 interface

Hi, welcome to this particular module. In the last module, you would remember that we have seen physical wafer deposition techniques. what are physical wafer deposition techniques? Sputtering, (Refer Time: 0:41) operation and thermal evaporation. Now, what you will do once you deposit a metal or an insulator or semiconductor. You have to pattern that metal. the material can be semiconductors like silicon or germanium. It can be metal like gold, chrome, platinum, or titanium. It can be insulated like silicon dioxide, silicon nitride.

Once you reposit it on a substrate, you have to pattern it in the designs that you have been working on and based on the simulation that you have previously done. That means, if I want to design a pressure sensor, then I know that if it is a piezoresistive pressure sensor I have to create interdigitated electrodes. On that, I have to deposit a material that will change its resistance when I apply a pressure correct.

So, first is interdigitated electrodes; how can I create? I have to deposit metal. Now, which metal? I can deposit platinum. Now, if I reposit platinum, platinum will be everywhere on the substrate. I have to pattern that (Refer Time: 1:56) and that patterning can be done using a process called photolithography. Then over that, if I reposit a piezoresistive material again piezoresistive material will cover the entire substrate I have to pattern it that it only covers the inter resistive electrodes and other areas we have to (Ref Time 2:20) the piezoresistive material.

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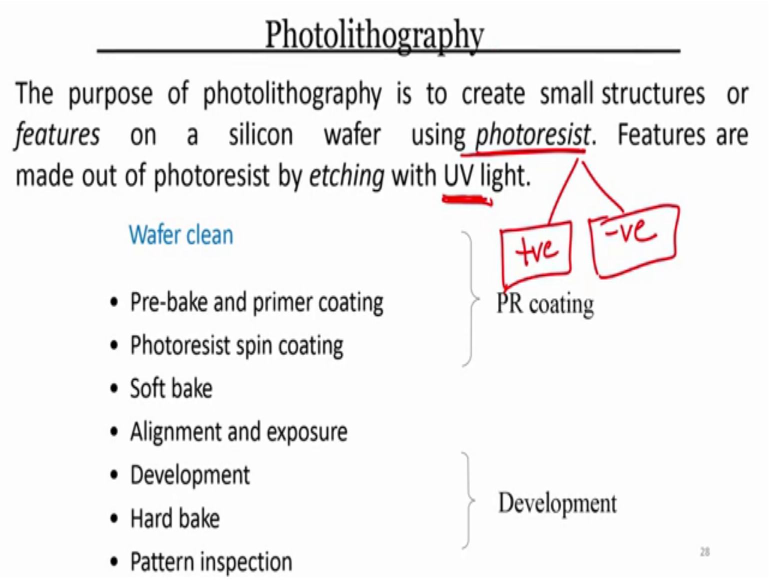


What do I mean by it? I will take an example so that you understand in a better way, but. Now, let us see the slide and the slide says that the purpose of photolithography if you see the slide the purpose of photolithography is to create small structures or features on a silicon wafer using photoresist.

We have seen that what is photoresist photosensitive resist? if I say photoresist; photoresist are of two types positive photoresist and negative photoresist correct and features are made out of photoresist by etching with the help of UV light. based on the exposure to positive and negative photoresist some areas will be stronger some areas will be weaker. This weaker area can be developed in a photoresist developer and thus it says that etching with the help of UV light. Because we are using UV light in the photolithography is also called UV lithography. UV stands for ultraviolet.

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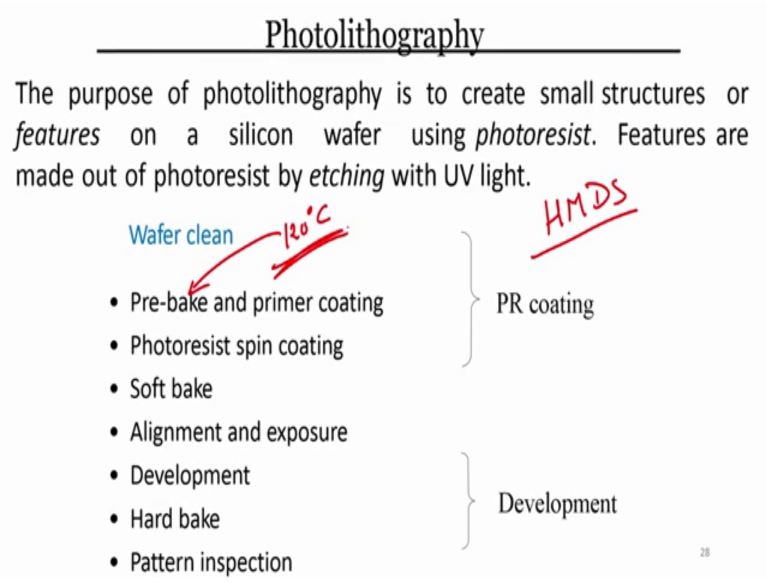


So, what is the procedure? The procedure is you have to start with the cleaning of your substrate. If it is the silicon wafer, you have to clean the wafer and then you have to pre-bake and primer coating. Your primer is HMDS. First is pre-baked; pre-baked is done at $120^0$ C on a hot plate. a pre-baked will help to remove any moisture from the wafer, from the substrate. Then primer coating we do we coat with HMDS and then are followed by photoresist spin coating.

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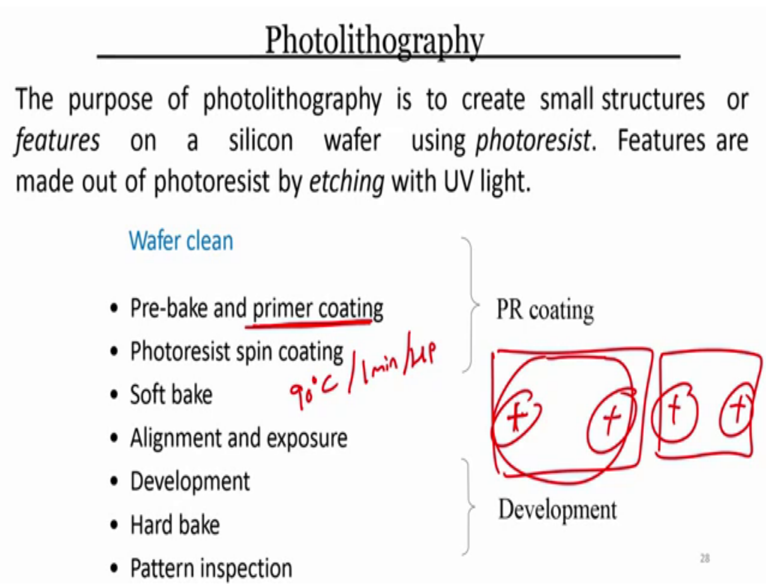

So, why we had to go for primer coating? Because the primer coating will improve the adhesion of photoresist onto the substrate. now after primer coating, you will go for photoresist spin coating. When you coat the wafer or subset with photoresist, the next step would be soft bake. Soft bake is done at $90^0$ C for 1 minute if we are using a hot plate correctly.

After this step, the next step would be alignment and exposure. You have to align some masks with your wafer. Suppose this is an alignment mark on the mask like this, this alignment on the wafer, you have to align these marks with the marks on the wafer. alignment once it is aligned correctly then you will see that this is overlapping. You can expose the wafer to UV light. alignment and exposure are done with the help of a mask.

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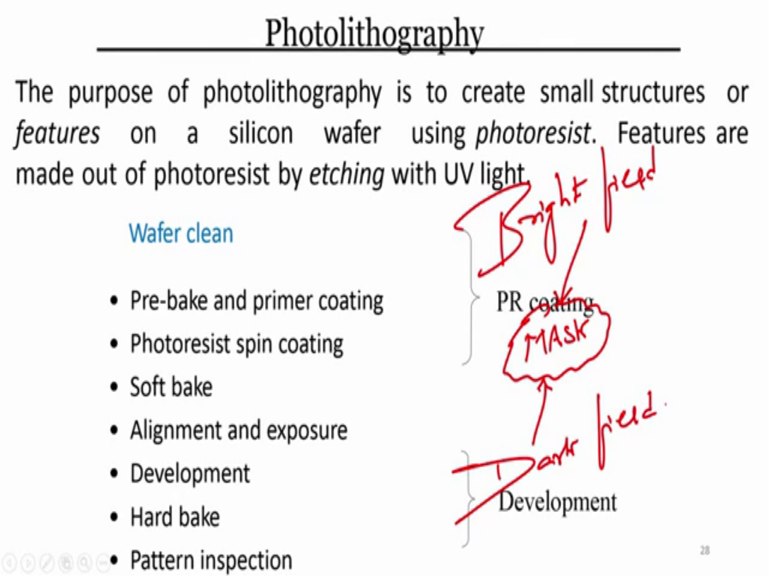

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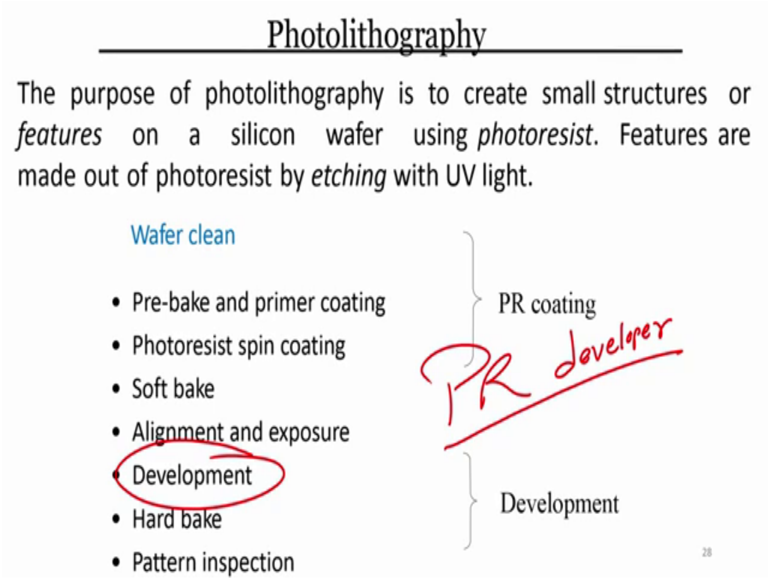


Masks are two types; bright field and dark field mask. this is about your alignment and exposure. After that, you have to develop the wafer. Developing a wafer can be done with the help of a photoresist developer, photoresist developer.

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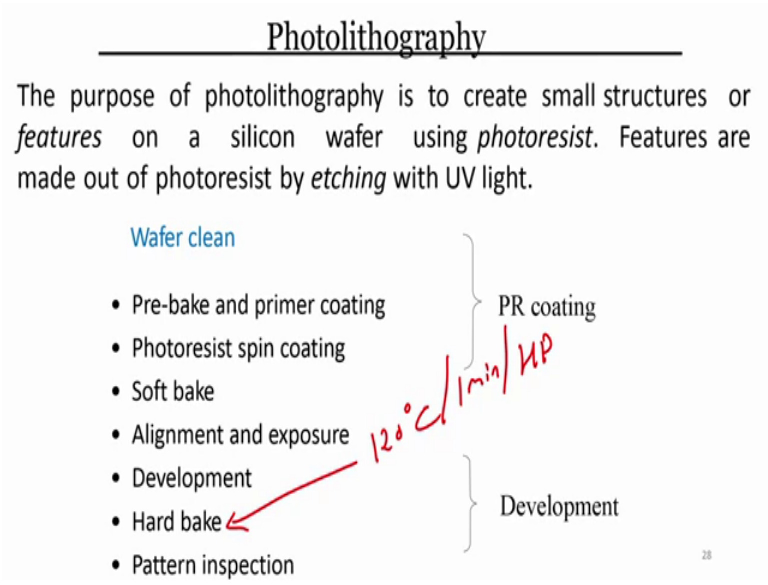

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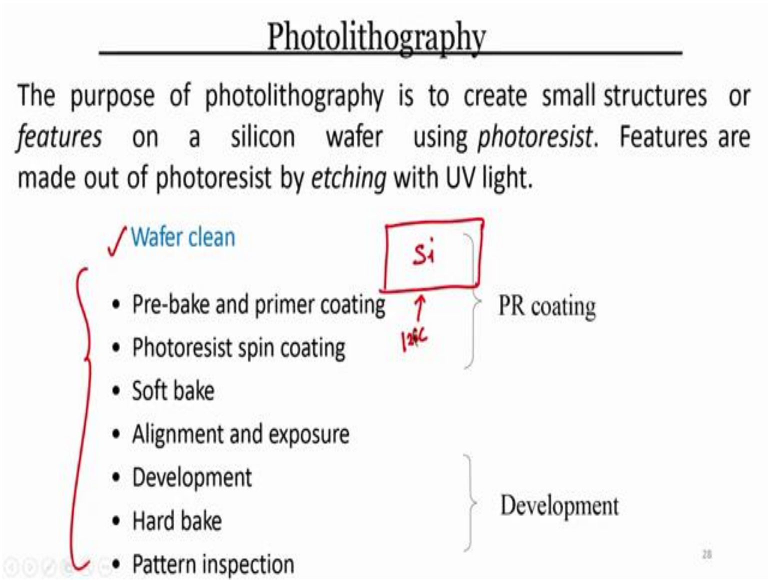


After you develop photoresist the next step is hard to bake and hard bake is done at this is hard bake is done at $120^0$ C for 1 minute on a hot plate. After you perform hard bake you will form, look at the pattern inspection. let us understand how the process flows. did you understand what exactly we mean by each step, the first step is you take the wafer. I will take a wafer I am drawing a cross-section of it let us say it is a silicon wafer. Then I clean the wafer after a free cleaning I will heat the wafer or pre-bake the wafer at $120^0$ C and then I will coat primer.

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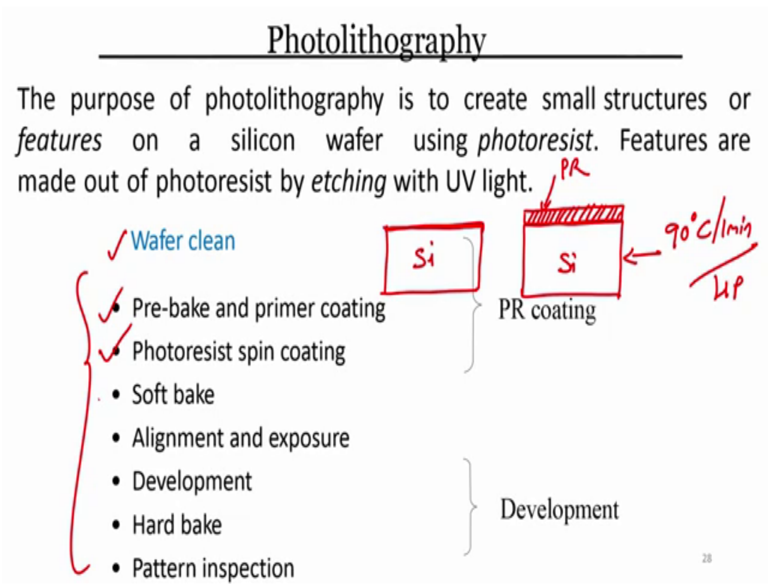

So, this is a like a primer coating, a thin layer of primer is coated onto this wafer. This will improve the adhesion of photoresist. After the primer coating, the next step is the primer coating next step is photoresist spin coating. let us say this is a photoresist; this pattern that I am drawing is your photoresist all. prebake is done primer coating is done, then photoresist spin coating is done, what is the next step? The next step is I will heat this wafer which is called soft bake at $90^0$ C for 1 minute on the hot plate all. the soft bake is done.

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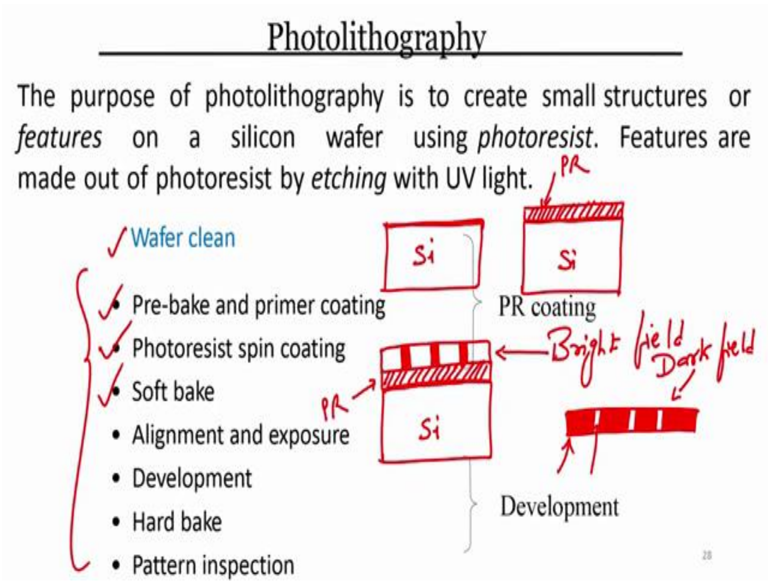


The next one is I add to align and expose. I will take my wafer, load into a photoresist UV lithography system or it is called mask aligner system. There are several mask alignment systems and then I will load the mask. this is my silicon, this is my photoresist and this is my mask. Now, the red bold area is the red this one blocks in this design are some pattern onto the mask some pattern area onto the mask.

So, what is this one? This is my bright field mask. I will show it to you once again what bright field is and what dark field mask is. Where the field is bright and the pattern is dark is called bright-field mask. If the pattern is lighter or transparent and other areas are dark then it is called a dark-field mask. For example, this is my dark-field mask, the one that I am drawing now.

You will see that wherever we want to pattern something I have to get it transparent and other areas are covered with some material and that some material is your chrome and that is why this is also called as chrome mask; chrome mask. this is my dark-field mask dark field.

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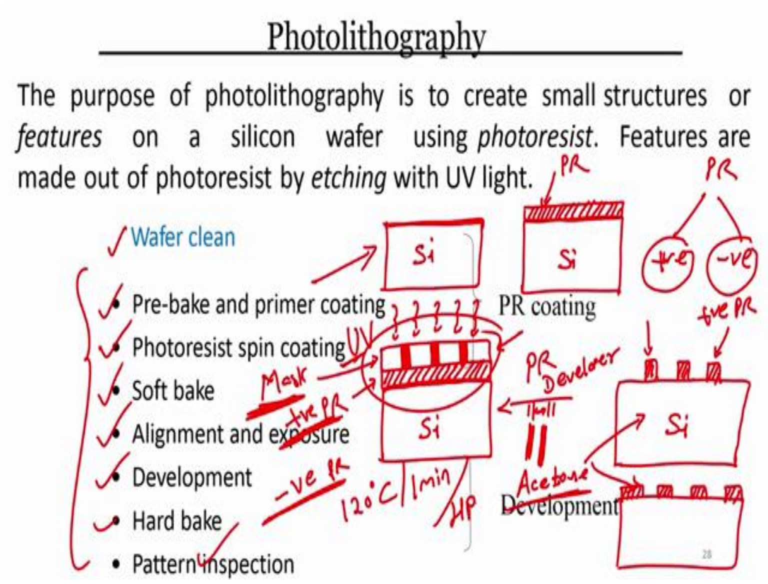


Now, let us see the next step. After I load the mask an align the mask with the wafer I have to expose it. I will expose this to UV light. After I expose it, I will unload the mask and dip this wafer in a photoresist developer. When I do that what will happen; that if it is a positive photoresist if a positive photoresist I told you, photoresist are two types positive and negative positive, photoresist will have the same pattern that is on the mask, negative photoresist will have opposite pattern.

That means, that if I use positive photoresist if I expose this my mask looks like this. When I develop it what will happen is that on my silicon substrate I will be able to replicate whatever pattern was there on the mask. You see here the bread blocks are the area that is not exposed to UV and the area which is not exposed becomes stronger and you can see that the photoresist is not developed where the area was not exposed by UV light.

In another term we are replicating the same pattern of the mask if I use positive photoresist, but in case if I have to use negative photoresist if I have instead of using positive photoresist if I use negative photoresist with the same bright field mask; what will happen you know the pattern that you will be able to see will be like this. Opposite of whatever is there on the mask. If I use negative photoresist, I will get the opposite of or reverse of whatever there is there on the mask. If I use positive photoresist I can have similar features that are there on the mask all.

The next step is to perform hard bake, after development hard bake. for hard bake we are using $120^0$ C temperature, we are heating for 1 minute on a hot plate. After I perform a hard bake, the next step would be pattern inspection. Pattern inspection is to look at the patterns are correctly patterned on the wafers or not.

What does that mean? If I have a width of 10 microns and spacing between two lines is also 10 microns, is it 10 microns it is more it is less that depends on the exposure time, developer time and if the patterns are not correct what we can do is to dip this wafer in acetone. What would happen? Acetone is a stripper for photoresist either a positive or negative does not matter positive or negative photoresist you can dip the wafer in acetone. If you dip the wafer in acetone you will get silicon wafer back photoresist will be stripped off. for stripping of the photoresist we use acetone.

Thus if the patterns are not replicated or the photoresist is not exposed or developed correctly you always have a chance of dipping the wafer in acetone and restart the process. But if the recipe is correct; that means, the time of the exposure and your developer time is correct then you do not have to worry, because in the pattern inspection you will get the feature size whatever the feature size is there and the gap is for the mask all. this is the photolithography step.

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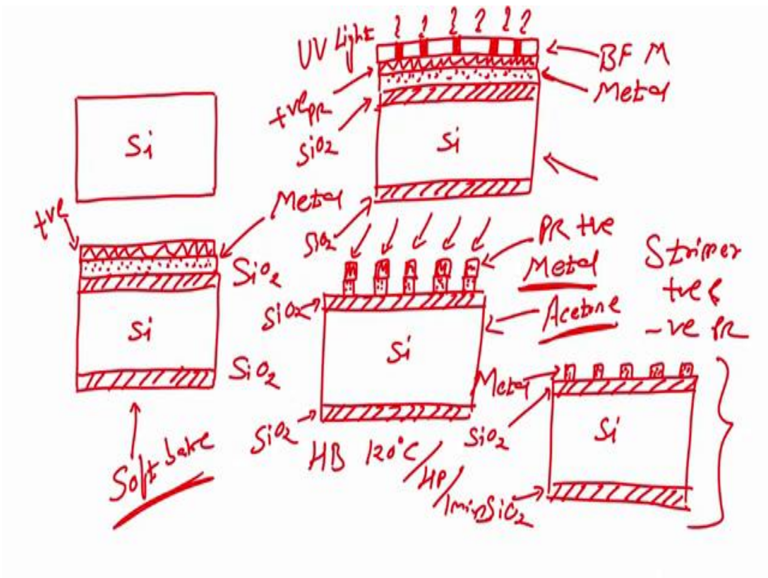


Now, this is where you are only worried about the photoresist because you are only developing photoresist. But if I take another example you will understand appreciate the photolithography technique much more. Another example is that if I want to pattern metal all let us take an example. I have silicon substrate I want to deposit metal. if I want to deposit metal I will have an insulating layer because silicon is a semiconductor.

So, I will grow let us say silicon dioxide; SiO2, SiO2 this is front and back, The next step is I will deposit a metal. the dotted pattern is of metal. Now I want to pattern this metal such that I can form and interdigitated electrodes as shown on the screen all. this is my metal silicon dioxide. On this metal, I am coating primer and then I am a spin coating photoresist. photoresist this is positive photoresist, the photoresist that we are a spin coating on this silicon dioxide or oxidize silicon substrate with metal deposited using physical wafer deposition is my positive photoresist.

The next step is a soft bake. The next step is to load the mask, you have the wafer, silicon dioxide is on the backside, silicon dioxide is on the front side and then you have your metal. Over that, you have your photoresist, over that you are loading now a mask and this mask is a bright field mask. Positive photoresist bright field mask and then you have here we have metal silicon dioxide on top, silicon dioxide on the bottom, silicon as a substrate. After you load the mask you have to do lithography. you are exposing to UV light. Soft bake, load the mask expose the wafer using UV light.

The next step would be to develop this wafer. If I develop this wafer what will happen? Since I have used for positive photoresist, I will get a pattern as shown in this schematic, what you can see is that the unexposed area became stronger, the unexposed area is stronger. The next step would be a hard bake.

So, after I perform a hard bake at $120^0$ C on the hot plate for 1 minute, I will dip this wafer in a metal etchant. When I dip the wafer in metal etchant what will happen, that the area which is not protected by photoresist metal will get etched. You can see in the figure, the area that was not protected by photoresist you will get etched in the metal etchant.

The next step is I will dip this wafer in acetone. If I dip this wafer in acetone, acetone is a stripper for positive and negative photoresists. you acetone will strip off positive negative photoresist and what will I have? I will have a substrate which is oxidized silicon wafer with the metal pattern. Now before I dip this wafer in metal etchant I can always do the inspection of the photoresist patterning. this is a photolithography a technique, I had given one example where you can create an interdigitated electrodes with the help of photolithography.

So, if you have any questions feel free to ask me in the forum. If you have any doubts you know always feel free to ask do not hesitate because this is not so easy to understand and at the same time it is extremely important. I do not want you to miss anything out of this particular module, but at the same time, it is not that difficult also if you really focus. Till then you take care I will see you in the next class bye.