Sensors and Actuators
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Lecture – 29
Photolithography- Part 1

Hi, welcome to this particular module. In the last module, if you remember what we have seen, we have seen physical vapour deposition techniques. what are physical vapour deposition techniques? Sputtering, Ebeam evaporation, thermal evaporation . Now, what you will do, once you deposit a metal or insulator or semiconductor? You have to pattern those metal know the pattern the material . The material can be semiconductor like silicon germanium, it can be metal like gold, chrome, platinum, titanium, and it can be insulated like silicon dioxide, silicon nitride . But once you deposit it on a substrate, you have to pattern it in the designs that you have been working on right 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 which will change its resistance when I apply a pressure correct. First is an interdigitated electrode. How can I create? I have to deposit a metal, now which metal I can deposit platinum. Now, if I deposit platinum, platinum will be everywhere on the substrate. I have to pattern that and it can be done using a process called Photolithography.

Then over that, if I deposit a piezoresistive material, again piezoresistive material will cover entire substrate I have to pattern it so that it is only it only covers the interdigitated electrodes and other areas we have to etch the piezoresistive material. What I mean by it, we will discuss and you will understand. I will take an example, so that you understand in a better way.

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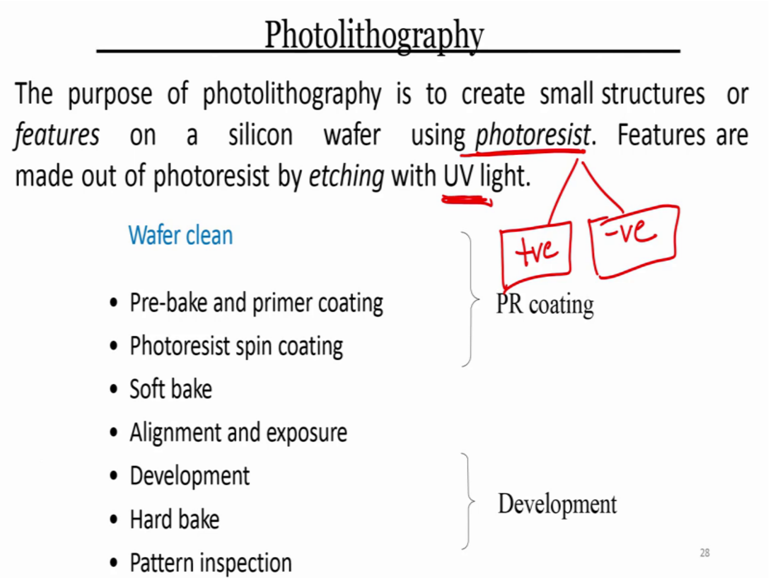

But right now let us see the slide and the slide says that the purpose of photolithography. If you see the slide, the purpose of photolithography is to create small structures or features on a silicon wafer using photoresist, we have seen that . What is photoresist? Photosensitive resist. if I say photoresist, a photoresist is 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 area will be stronger, some area 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, it is also called UV lithography. UV stands for ultraviolet. what is the procedure? The procedure is you had to start with the cleaning of your substrate. If it is a silicon wafer, you have to clean the wafer, and then you have to pre-bake and primer coating. Your primer is HMDS.

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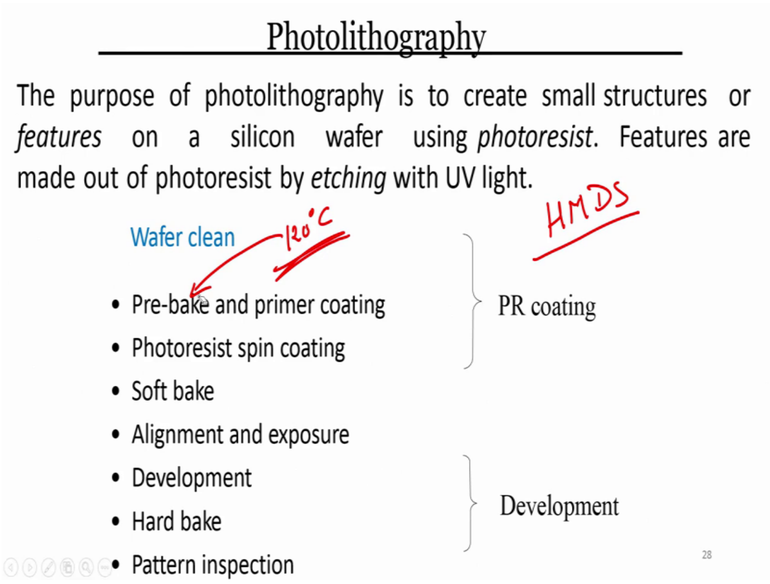

First is pre-bake; pre-bake is done at 120^0 C on hot plate. pre-bake will help to remove any moisture from the wafer from the substrate. Then primer coating we do we coat with HMDS, and then are followed by photoresist spin coating. why we had to go for primer coating? Because primer coating will improve the addition of photoresist with 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 the next 90^0 C for 1 minute if we are using hot plate correctly.

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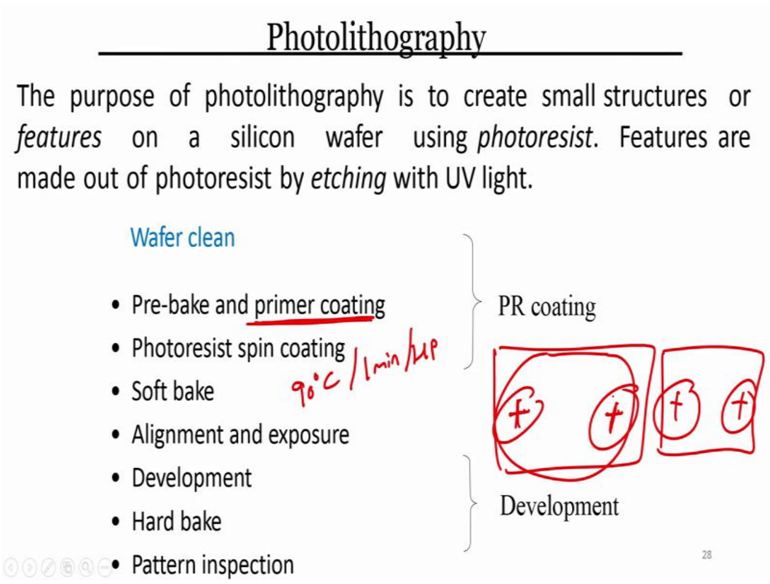

After this step, the next step would be alignment and exposure. You have to align these mass with your wafer . Suppose, this is an alignment mark on the mask like this, this element on the wafer. You have to align these marks, with the marks on the wafer. Alignment once it is aligned correctly, then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

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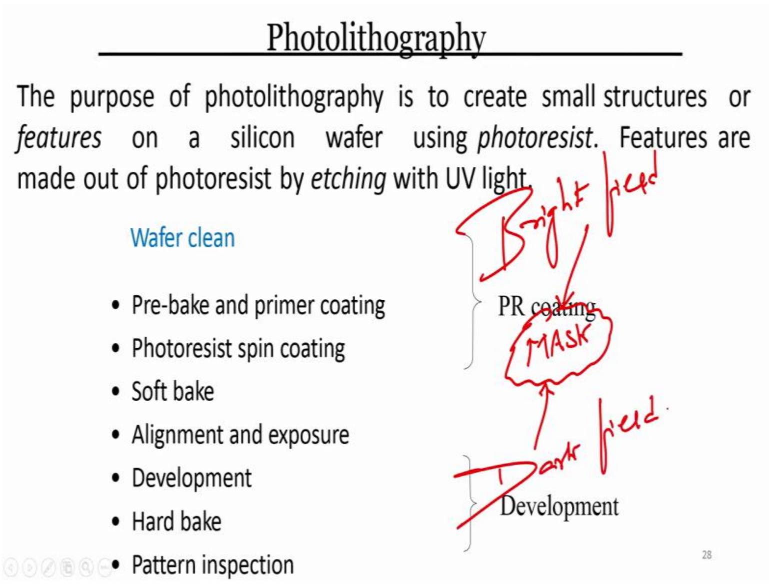

And when we talk about mask masks are two types of bright field and dark field; bright field and dark field mask . this is about your alignment and exposure. After that, you have to develop the wafer.

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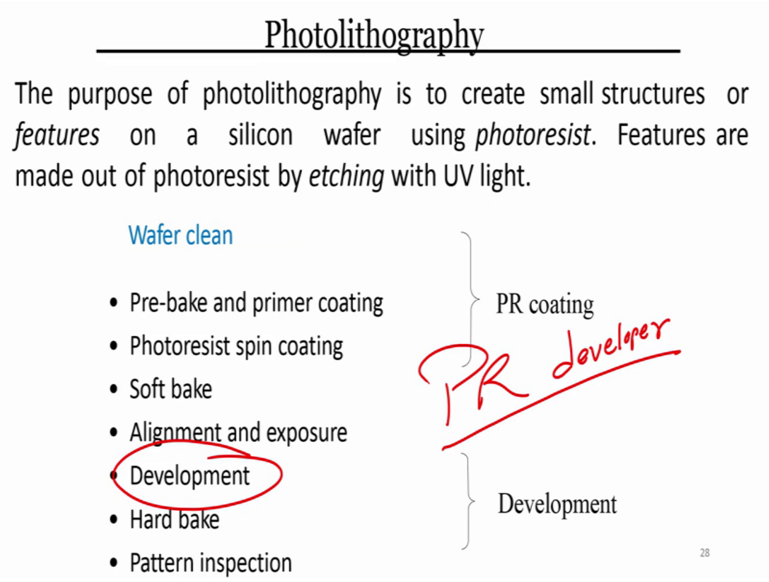

Developing wafer can be done with the help of photoresist developer. After you develop photoresist, the next step is hard bake.

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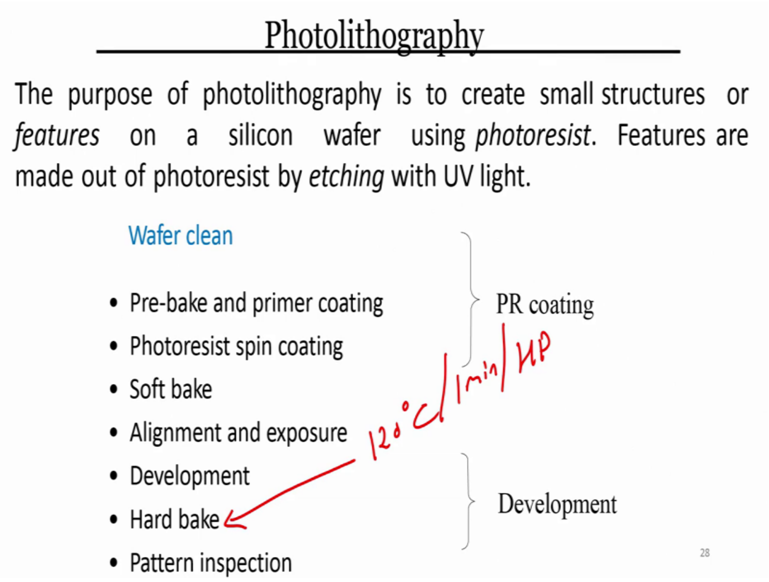

And hard bake is done at this is hard bake hard bake is done at 120^0 C for 1 minute on a hot plate. After you perform hard bake, you will form look at the pattern inspection. Let us understand now the process flow. did you understand what exactly we mean by each step; the first step is you take the wafer.

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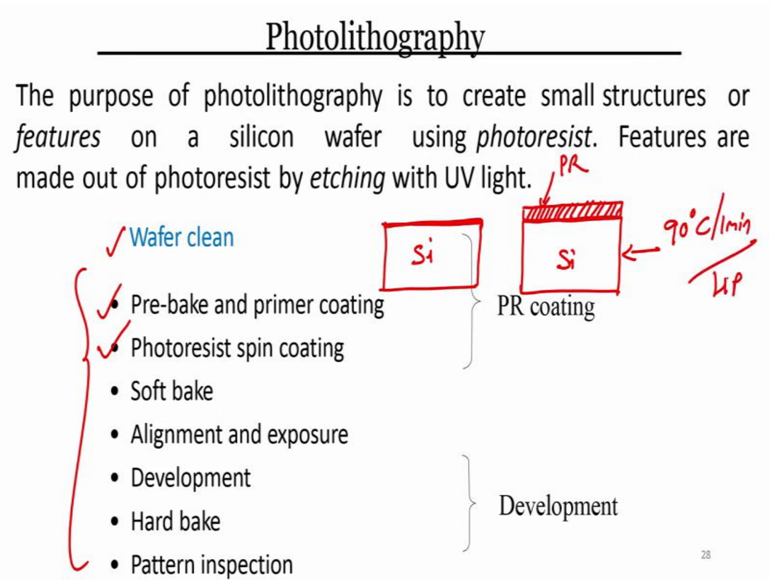

So, I will take a wafer, I am drawing a cross-section of it right, let us say it is a silicon wafer then I clean the wafer. After a free cleaning, I will heat the wafer or pre-bake the wafer at 120^0 C and then I will coat primer. this is a like a primer coating, a thin layer of primer is coated onto this wafer. This will improve the addition of photoresist. After the primer coating, the next step is, primer coating, next step is photoresist spin coating.

So, let us say this is a photoresist. This pattern that I am drawing is your photoresist all . pre-bake is done, primer coating is done, then photoresist spin coating is done. What is the next step? 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. Next one is I have to align and expose.

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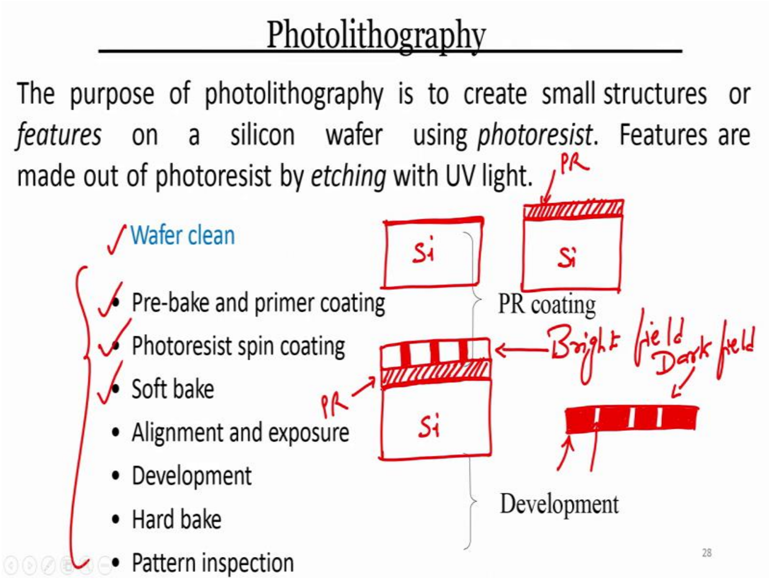

So, I will take my wafer load into a photoresist UV lithography system or it is called a mask aligner system. There are several mask aligner systems. And then I will load the mask. this is my silicon, this is my photoresist, and this is my mask. Now, the red bold area is the red this one blocks in this design are some pattern onto the mask, some pattern area onto the mask. 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. When the field is bright and the pattern is dark, is called a 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 the dark-field mask one that I am drawing right now. You will see that wherever we want to pattern something I have kept it like 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, c h r o m e, chrome mask. this is my dark-field mask, dark field. The field is dark, the pattern is bright. In the bright field mask, the field is bright; the pattern is dark easy . Now, the next step let us see next step. After I load the mask and align the mask with the wafer, I have to expose it.

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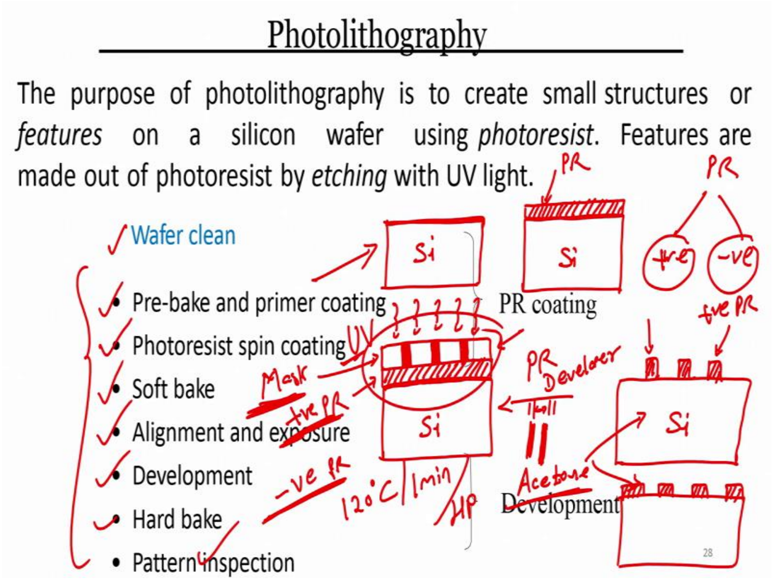

So, I will expose this with UV light. After I expose it, I will unload the mask and dip this wafer in a photoresist developer. When I do that, what will happen? That if it is a positive photoresist, if a positive photoresist, I told you photoresist are two types, positive and negative. Positive photoresist will have the same pattern that is on the mask; negative photoresist will have the opposite pattern.

That means, that if I use positive photoresist if I expose this my mask looks like this. And 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 red blocks are the area which 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 used 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 opposite of or reverse of whatever there is there on the mask; if I use positive photoresist I can have similar features which 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 the hot plate. After I perform 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 and depends on the exposure time, developer time. And if the patterns are not correct, what we can do is, you can 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 as per the mask all.

So, this is the photolithography step. 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 a metal all right, let us take an example.

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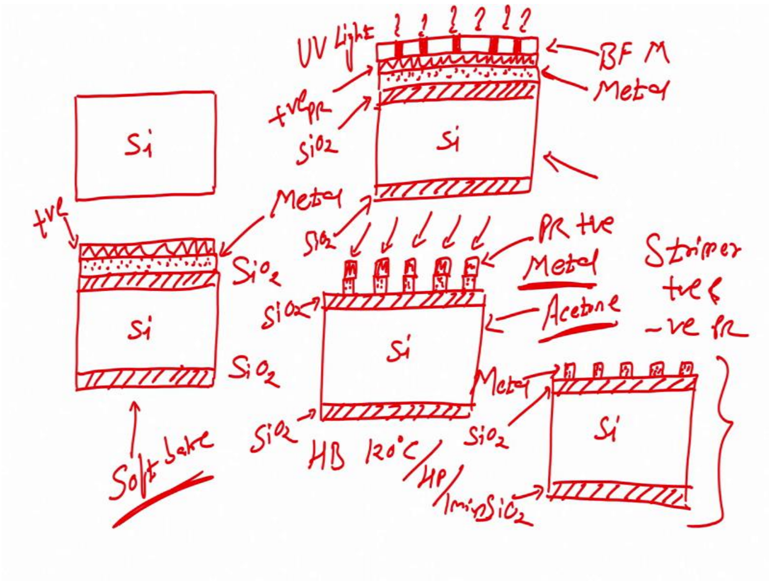

I have a silicon substrate, I want to deposit metal. If I want to deposit metal, I will have an insulating layer because silicon is a semiconductor. I will grow let us say silicon dioxide Si O 2, this front and back. Next step is I will deposit a metal. the dotted pattern is of metal.

Now, I want to pattern this metal such that I can form an interdigitated electrode as shown on the screen all. This is my metal silicon dioxide, silicon, silicon dioxide on this metal I am coating primer and then I am spin coating photoresist. photoresist, this is a positive photoresist. The photoresist that we are a spin coating on the silicon dioxide or oxidize silicon substrate with metal deposited using physical vapour deposition is my positive photoresist.

Next step is soft bake. Next step is to load the mask. You have the wafer, silicon dioxide is on the backside, silicon dioxide is in 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 your metal silicon dioxide on top, silicon dioxide on the bottom, silicon is a substrate, and after you load the mask you have to do lithography. you are exposing with UV light.

Soft bake load the mask exposes the wafer using UV light. 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 next step would be hard bake. after I perform 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 the metal etchant, what will happen that the area which is not protected by photoresist; 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 will get etched in the metal etchant.

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 photoresist. your acetone will strip off positive and 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 technique I had given you one example where you can create an interdigitated electrodes with the help of photolithography. 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 and 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.