Soft Nano Technology
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Lecture - 13
Photo Lithography – 2

We continue our discussion on photo lithography.

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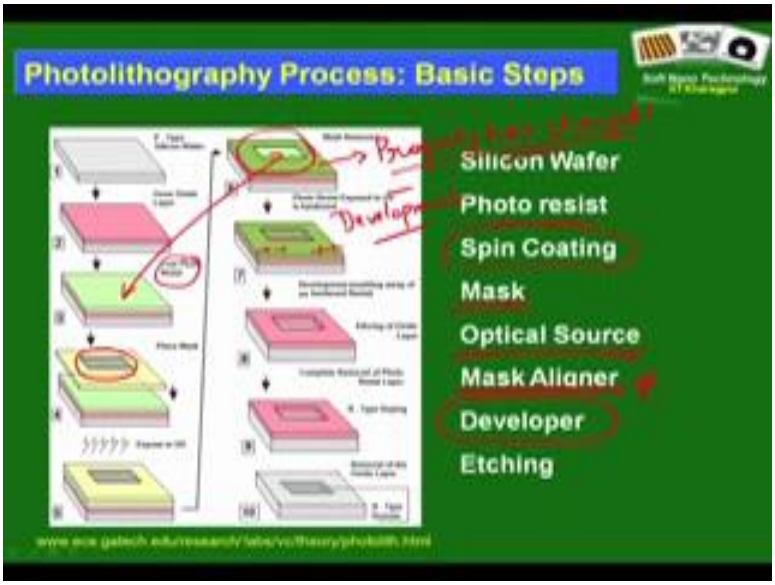

We just started to make the build the concept. We now know at least know about this photo resist. We also have heard or discussed or just talked that this photo resist is applied by spin coating and I promise that as we make progress, we will understand what is spin coating, then we find another term which is it should be new to many of you is a mask. So, what is a mask? In fact, in mask so what is our objective? Let us recapitulate it once again.

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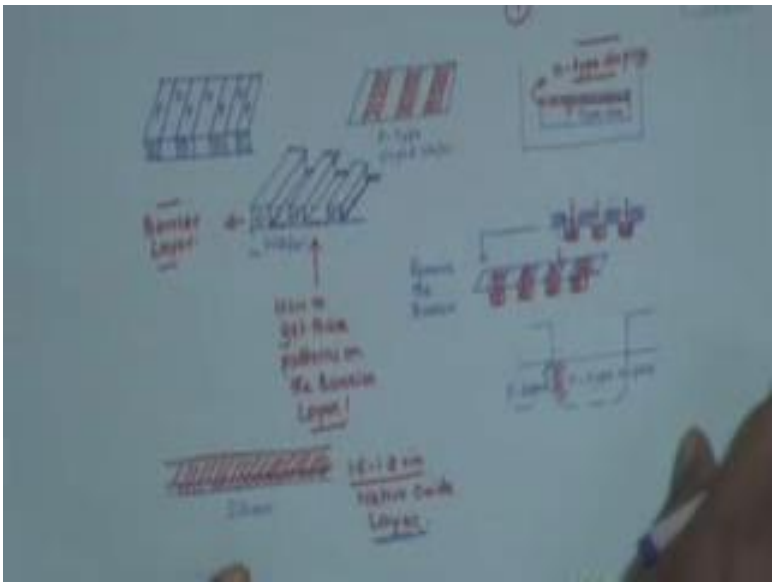

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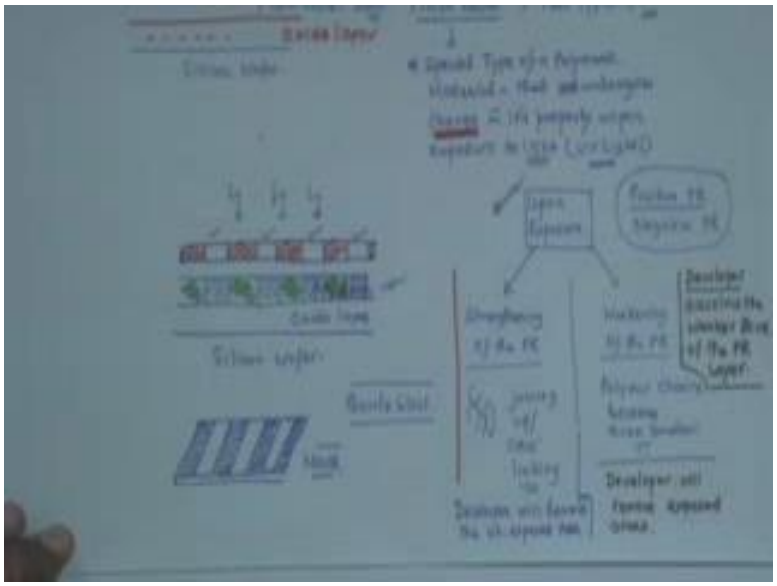

Our objective is to create some structures like these on the barrier layer, that is on the oxide layer, but in order to that what we have done so far we have on the wafer, we have grown an oxide layer and then we have deposited or yes we have deposited photo resist layer, but we would like to pattern and why we have let me also tell you the philosophy why we have used this photo resist layer. I am not trying to directly pattern the oxide layer because there is no mechanism by which we can pattern the oxide layer. We need the help of the photo resist layer to pattern the oxide layer and that is the whole idea, but

where is the pattern? In fact, this pattern you have to create on a piece of item that is called the mask.

Simple concept; on the mask you actually have patterned domains through which the UV light can pass and some areas the light cannot pass. As simple as that, how you do that? When we discuss the mask in detail we will talk about it. So, this is how the mask looks like. So, now, if you bring in the mask on top of your photo resist layer. Now you should start correlating, what we discussed here. The photo resists changes property of an UV exposure. So, this is how the mask is going to look like. The shaded areas let us say, these areas will prevent propagation of UV light and the unshaded areas or these areas allow UV light to pass.

Whatever is the structure, you actually want to create on the oxide layer and for that you want to create the same structure on the photo resist layer. You can assume at this stage that you actually create it on the mask. How you create it is another question. So, I will talk about it later, but mask is that hardware device which actually contains the pattern and what is the pattern, the functional form of the pattern typically one takes a piece of pure silica glass or a quash glass and chromium is a very good absorbent of UV light. So, these patches are created of chromium. So, again the question is, this is again a fabrication issue yes you need some micro fabrication platform. What you typically do is you take a glass that is fully covered with chromium and then etch out some of the areas so that the light can pass.

And so you now start understanding one more state in this flow diagram. So, this is the mask let us say in this particular figure what we are showing the area that is grey it will not allow the light to pass and the other areas will allow the light to pass and it can be the other way around also, does not really matters and once you place the mask of course, the immediate next thing you are going to do is you are going to do the UV exposure and that is where you need your optical source. These are very simplified picture you may not be just doing some patterns for the sake of some fun, but you need to actually make multiple layers of structure to actually make a transistors.

Therefore, you need to sort of place a second mask along the contours or the preexisting structures made in the earlier level. Therefore, you need to have a mask aligner also. So, that I will discuss in brief this is not very important to know the fundamentals of photo

lithosphere, but it is good to know. So, what you do? After you place the mask and do an optical UV exposure. Now you see, so this is now you see the color. So, this green color corresponded to the photo resist layer. The original photo resist layer and now you see that the areas where, we claimed that light has passed I mention that this the grey patch the light cannot pass. The areas where the light has passed you see I have used a different color.

What does it mean? It obviously, means that only this area was not exposed to the UV light and therefore, the photo resist layer over that area does not undergo any change in property. Without knowing whether it is a positive photo resist or negative photo resist you cannot comment at this stage that, the areas where the photo resist layer was exposed to UV light whether it has strengthened or weakened, but you can definitely comment that over these areas property has changed.

Please do not jump to conclusion and it is very important that you build your concept slowly. What you can claim? You can claim the areas of the photo resist which fail below the transparent portions of the mask have undergone change in property. Now what you need to do is you rinse this whole thing in a developer solution. You all know that every material, many material or let us say polymer films at solvents where it dissolves. The developer is also nothing, but a solvent, but it is a very special type of solvent that if you try to develop and expose photo resist layer and that is; that means, that what is an exposed photo resist layer? That you have exposed the photo resist layer under a mask, so that means, that the exposed photo resist layer has special variation in its property.

Depending on whether what is the photo resists stone? That also I have not yet defined. I will define it as the time comes. The photo resist upon exposure the parts of photo resist which has been exposed either might have strengthened or might have weakened. That is not the important thing but when you rinse or when you put an exposed photo resist layer in a developer solution, the role of the developer is to remove the weaker part of the film and that is very interesting.

The developer removes the weaker part of the film. So, in case the photo resist has strengthened upon exposure, developer will remove the unexposed area or the original photo resist. In contrast if upon exposure the photo resist has weakened just due to chain reaction or whatever then the developer is going to remove the exposed areas. I hope you

have understood it, but we will come up with better examples. Thumb rule is, it is not thumb rule it is a fact is developer dissolves the weaker zone of the PR layer. So, based on this concept so now, we also understand. So, what is the difference between a normal solvent and a developer? Developer is a very delicate combination. In fact, development process itself is a very critical process, that after all this so called so, if you expose for example. So, this is the set up you place the mask and then you expose it with UV light. What is going to happen? Along the contours of the patterns of the mask, these areas in the photo resist film are going to expose and change property. While the other areas do not change property; however, they are roughly the same material.

Your developer has to be very selective to only to the weaker part of the photo resist formulation and now let us look into this schematic we have. So, this is the development process, that is between this step and this step what has been done is this exposed photo resist layer has been subjected to development. That is let us say in a simple terms, let us assume that it has been rinsed with the developer solution for some time and you see that the area which was not exposed to UV light that is, where the photo resist the original property of the photo resist is retained is washed away.

Does it sound a bell? Does it give you an idea as to what type of photo resist you are using? Well, you can immediately say that we are using a type of a photo resist which, upon exposure has in fact strengthened which upon exposure has strengthened, as we know that the developer removes or dissolves the weaker part. So, with respect to the exposed part the weaker portion was the original photo resist. So, this is only possible that if the photo resist upon exposure has strengthened. Had we had the opposite situation that we use the same mask?

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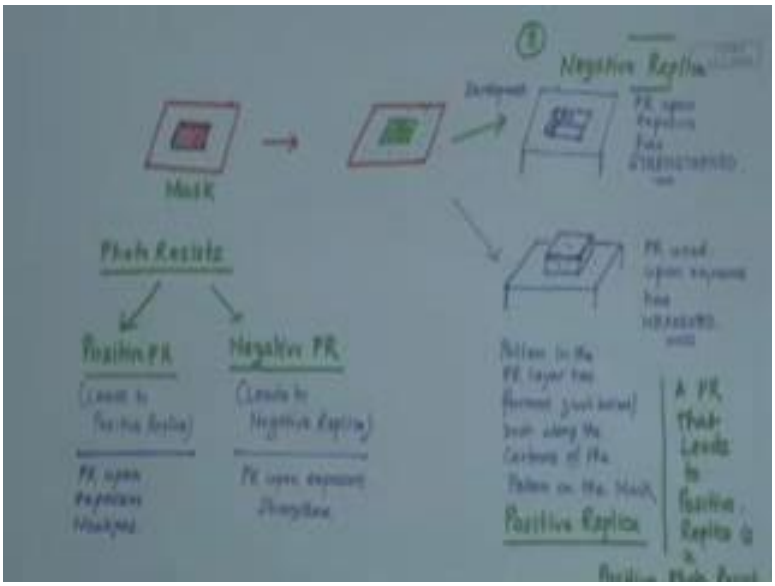

This is the mask. This is where the pattern on the mask is. You expose it and you have this configuration on the photo resist layer, after exposure and the schematic that we are using in the PPT is just coincidental that I drew it like that, no special reason upon development. So, this is the development stage. We find that the original photo resist that was resting over this area, has been removed. So, what are the conclusions? The conclusions are this particular photo resist upon exposure has strengthened as compared to the original photo resist and therefore, it has led to structure a like this.

What could have been the opposite scenario? Had the photo resist weakened upon exposure? In that case the structure that you would have got would have been like this. Why? Because upon exposure these areas in that case would have become weaker and that is why they have been washed away by the developer right. So, this picture tells PR used upon exposure has weakened.

Now, just compare the structures with the original pattern you had on the mask. You had a flat empty plate and in which you had this chromium patch only at the central location. If you look at this structure, the pattern in the photo resist layer; this is very important. Just below or just along the contours of the pattern on the mask. What we can say in a single word. In fact, what we can say is that we have created a positive replica and exactly opposite is the situation here we have in act created. So, wherever was that chromium layer there is no photo resist layer. The photo resist layer is surrounding is

present everywhere except the chromium layer where, the original pattern on the mask was.

What have you created? You have in fact created a negative replica and now at this point I define the photo resist stone. A photo resist that leads to positive replica, is a positive photo resist and a photo resist that leads to negative replica is actually a negative photo resist. So, now, we also understand that photo resist can be two types and how do we distinguish or classify? A positive photo resists is very simple, from the main itself it comes leads to positive replica and this leads to negative replica and now we understand this becomes possible, that a negative replica forms if the photo resist upon exposure strengthens. And like a positive replica forms that is very clear from this picture I hope you are now able to follow that. A positive replica forms photo resist weakens.

Discussion up to this point we have reached here, but what has happened is that, we have been able to create the structure on the photo resist layer, but not in the barrier layer and that is the basic requirement we have. So, there are mechanisms to now etch a way the oxide layer also along the contours of the photo resist layer, the patterns in the photo resist layer. This can be done by hydrogen fluoride or something like that and then you also remove the remaining photo resist layers. So, you transfer the structure you had created on the photo resist layer into the oxide layer.

This part should be there and then you expose into the doping chamber and then you actually have a doping over this area, the exposed area and as I already mentioned that for further processing you need to even remove the barrier layer or oxide layer. So, this is in a nutshell the entire steps associated with photo lithography. I hope you have got some bit of idea about what it is?

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Let us see this is sorry the video is not running I will just run it from the root. So, this is where it is, there is some problems I will run it sometime later. So, any way these are the important steps therefore, you can see some of it should make sense to you now. Surface preparation of course, then the deposition of the barrier layer or the oxide layer, then the photo resist application that involves spin coating. Soft bake what it is, we will learn then we need to introduce the mask, do the UV exposure, develop hard bake is something again we need to talk and then etch and resist strip is again I will discuss.

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This is in a nutshell. I will since the video unfortunately is not working. I will look into the schematic again. So, these are the steps and now, you understand the different stages. So, the oxide layer then the photo resist and these are exactly what we have to do and I will discuss some of the steps in somewhat detail to make concepts a bit more clear. So, the first thing is wafer cleaning. Of course, you start off as I mentioned you start off with p type doped wafer and you would like to first think because dust or any chemical in homogeneity is going to spoil your entire subsequent processes.

It is typically washed in all different types of organic, inorganic solution, surfactant solutions to get rid of all organic, inorganic and metallic impurities. In fact, in semiconductor process in the semi conductor industry cleaning is an extremely important step because I mean nobody in fact, knows what exactly is done, but it is believed that there are whole lot of steps associated with different solvents it is keen to remove all possible types of contaminants.

Once you have a cleaned wafer you need to of course, dry it up and then you start depositing the barrier layer of silicon oxide layer, which is again a very simple step. Just put it in oven, in an oxidizing oven you adjust the time. How long you would like to keep? You can control the thickness of the oxide layer simply by varying the, because oxide layer goes vertically in the z direction. So, you simply control the time and may be the oxygen flow rate.

Once you are oxide coated silicon wafer is ready, it is now ready for deposition of the photo resist layer which falls into the category of photo resist application. In fact, the step photo resist application involves several steps which we will.

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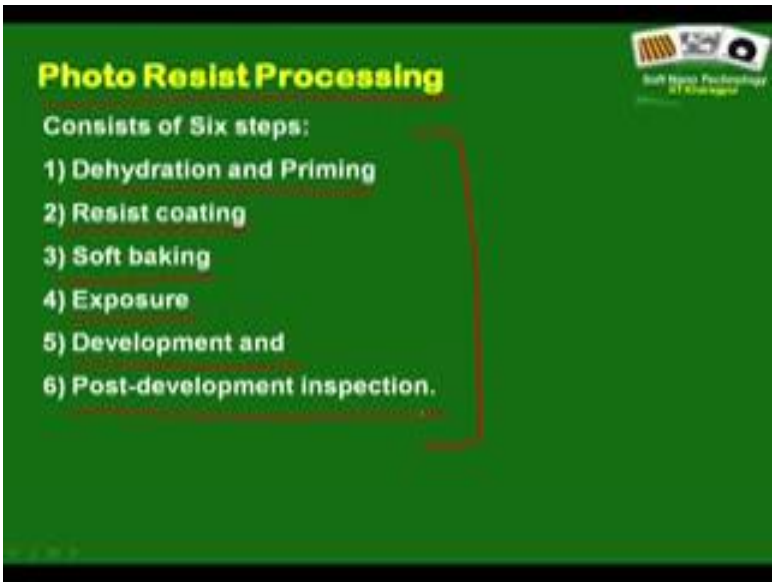

These are the photo resist processing steps. It consists of dehydration and priming resist coating, soft baking, exposure, development and post development inspection. You can sort of learn it step by step i mean do not have to really worry about what the industry people say about photo resist processing. So, we understand that you need to have first the barrier coated, the oxide coated silicon wafers comes and then you need to coat the photo resist, then soft baking is a particular step I will mention about it. Then you need to do the exposure then, you need to do the development and things on.

There is a bit of discussion in the PPT, since you will be having accesses to the PPT. So, I will not repeat everything a bit of discussion on the photo resist.

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Which fundamentally now you understand so, I will not go in to the all the details. Photo resist of course, consist of three components and this is a bit of materials aspects. One is the resin which is sort of binder of the film. 1 is the inhibitor or the sensitizer as it is called, it is the photo active ingredient and there is a third step is the solvent because you need to dilute it for subsequent processing of spin coating and things like that. These things you can read from this PPT.

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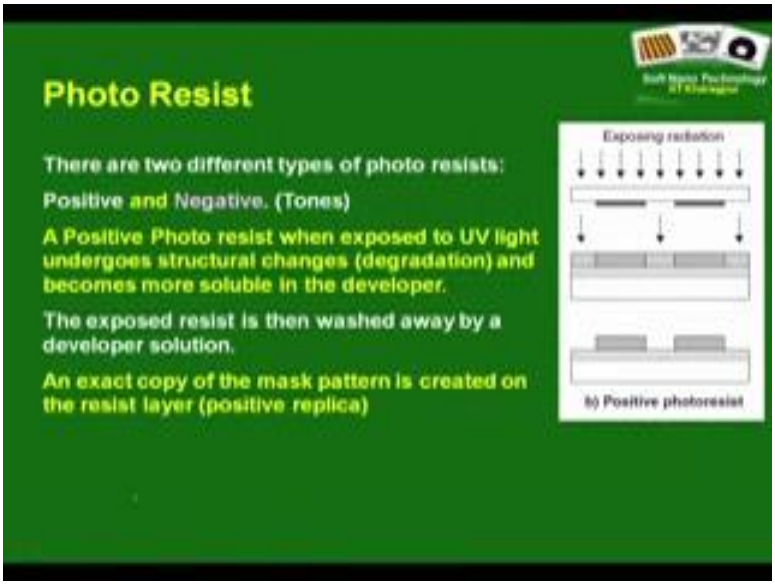

You now, already know I am not going to repeat it, that you have positive and negative resists and the simplest way I think we sort of understood it in a very very simplistic manner. Simplest way to understand is a positive resist is something that gives a positive replica of the mask pattern. A negative resist is something that gives a negative replica and in order to achieve a positive replica, you actually need to have the resist upon exposure degrading. In order to have a negative replica you need to have the resist up on exposure strengthening.

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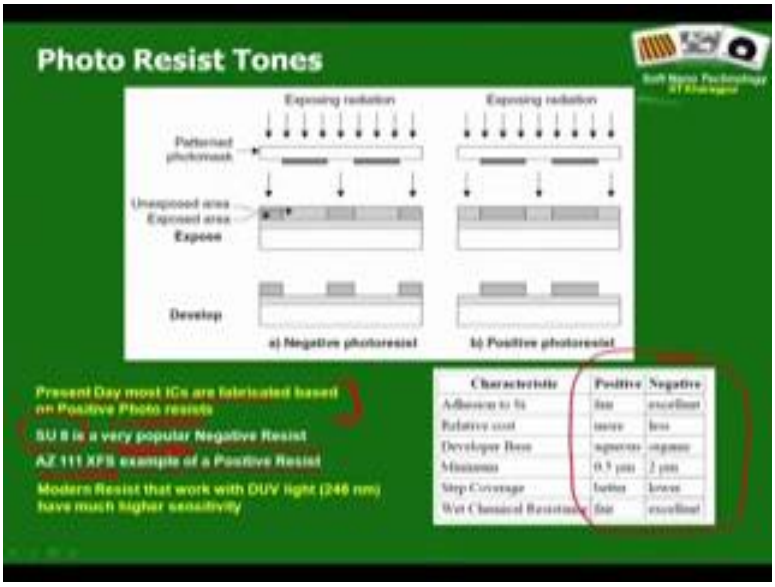

You can just read these things and there are certain comparisons about what is the? Let us say, the competitive properties between a negative and a positive resist. This is for your information and there is these are not very important things because you can always refer to the manual or the internet and get an idea about the individual properties. SUH is a very very popular resist which is very widely used.

Particularly in academic and research it is used very widely in fact is a negative resist. These are some examples of a specific number of a positive resist. Most of the ICs fabricated present day, the industry they use a positive photo resist. So, that is a bit of idea about photo resist and then we are now ready to discuss photo resist processing steps.

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Photo resist is applied through a method called spin coating which we will discuss, but where it is going to be applied? And it is going to be applied on if you remember on this oxide coated silicon wafer on which the photo resist is going to be deposited or spin coating. So, what is the first step? Just the way before growth of the oxide layer you cleaned your silicon wafer. You need to ensure that your oxide layer after the barrier layer has formed is clean and dry, that is the most important thing because silica also observes lot of water and if water is present that is going to be disastrous for your photo resist processing.

The 1 of the things that is before the resist is coated, the first step is dehydration and priming you need to dehydrate the oxide layer. You just heat it up to temperatures between 400 and 800 degree centigrade's. So, that all your water gets evaporated away and after dehydration there is bit of detail one can coat it with a three layer it is not the photo resist, but a layer you can spin coat which sort of enhances the addition between the photo resist and the barrier layer.

This is, it is typically done in the industry, but and it is not a mandatory requirement. It is just a functional details but it is a coated with a priming layer which sort of enhances addition between the PR and the barrier layer. So, we are running out of time. So, I will stop this class here, this lecture here and pick up the subsequent steps of photo lithography from the next class.

Thank you.