**Advanced Neural Science for Engineers**
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**Lecture 15**
**Photolithography -II**

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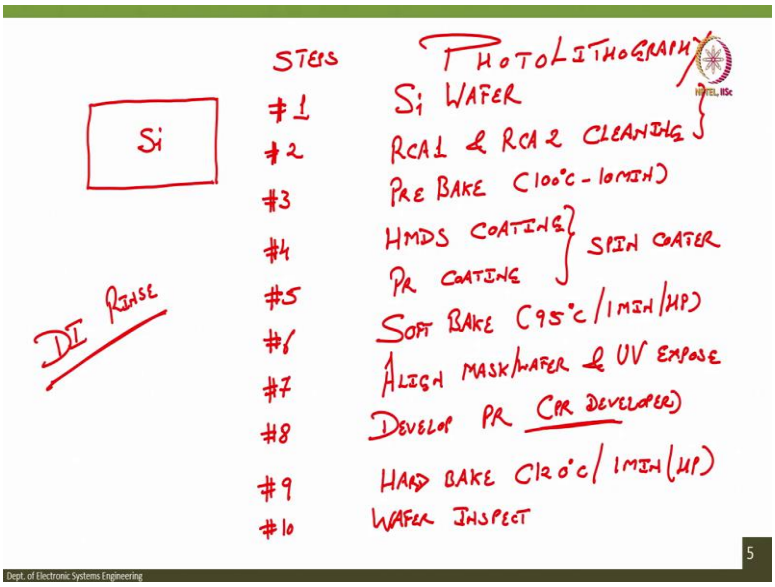


Hello everyone, welcome to this second session of the photolithography class, now let us see how the process flow, steps for the process flow are for the fabrication. So if you see the screen, the first step anywhere where we start we have the silicon wafer right, we have the silicon wafer, so step number 1, here I will write down the steps.

Step number 1 is you have a silicon wafer, second step is you have to do RCA 1 and RCA 2 cleaning, cleaning of this silicon wafers. Step number 3, you can use, you have to do pre baking, pre baking, let us write down in capital so that everybody can also understand, silicon wafer RCA 1 and RCA 2 cleaning then pre-baking generally around 100 degrees centigrade for 10 minutes.

Next step is HMDS coating, this will improve the addition of the photoresist onto the silicon wafer, next step is photoresist coating, this coating is done using both whether the HMDS coating or photoresist coating is done using a system called spin coater, all right spin coater, spin coating machine.

So silicon wafer, cleaning, pre baking, HMDS coating, PR coating, after PR coating next step soft bake, soft bake is done at 95 degree centigrade for 1 minute on hot plate. Next step, mask align alignment of wafer with respect to mask and UV exposure next step is you unload the mask, load the mask align and expose, next step is unload the mask and then after unloading you have to develop, develop what, develop photoresist in photoresist developer.

Once you develop photoresist in photoresist developer the next step would be whenever we use any chemical that is the wafer is exposed to any chemical there is always a step of DI rinse, deionized water rinse whenever there is any chemical that is exposed to the wafer after that generally we perform DI rinse so after PR developer there is a DI rinse followed by hard bake.

So what are the steps again see, step 1 you start understanding what are the things are there of course after hard bake the last step is wafer inspection, wafer inspection so the steps for photolithography are these are the steps, I have still added this thing as a separate thing so it can be just directly you can say that pre bake HMDS PR coating like that but just to explain you in detail I have written or break the you know the steps are further broken into sub steps.

So now if you if you just understand step 1 to 10 what are the steps, let us read once again step number 1 is silicon wafer, you get a silicon wafer then you perform RCA 1 and RCA 2 cleaning, step number then next step is to pre bake, pre bake is to remove any moisture from the wafer, next step is HMDS coating, HMDS coating is used to improve the addition of the photoresist onto the silicon wafer.

The next step is photoresist coating both HMDS coating and photoresist coating are done using a system called spin coater, next step is soft bake you have to bake it on a hot plate, bake what, the wafer that is coated with photoresist is baked on the hot plate for one minute at 95 degree centigrade, the next step is you take the mask align it with the wafer or you take the wafer align with the mask and expose it under ultraviolet light, the exposure time and the dose depends on the material that we are exposing.

Next step is to develop the photoresist using the photoresist developer, you have to develop the photoresist with the photoresist developer, next step is the hard bake which is at 120 degree centigrade for one minute on hot plate and finally you need to inspect the wafer, easy?

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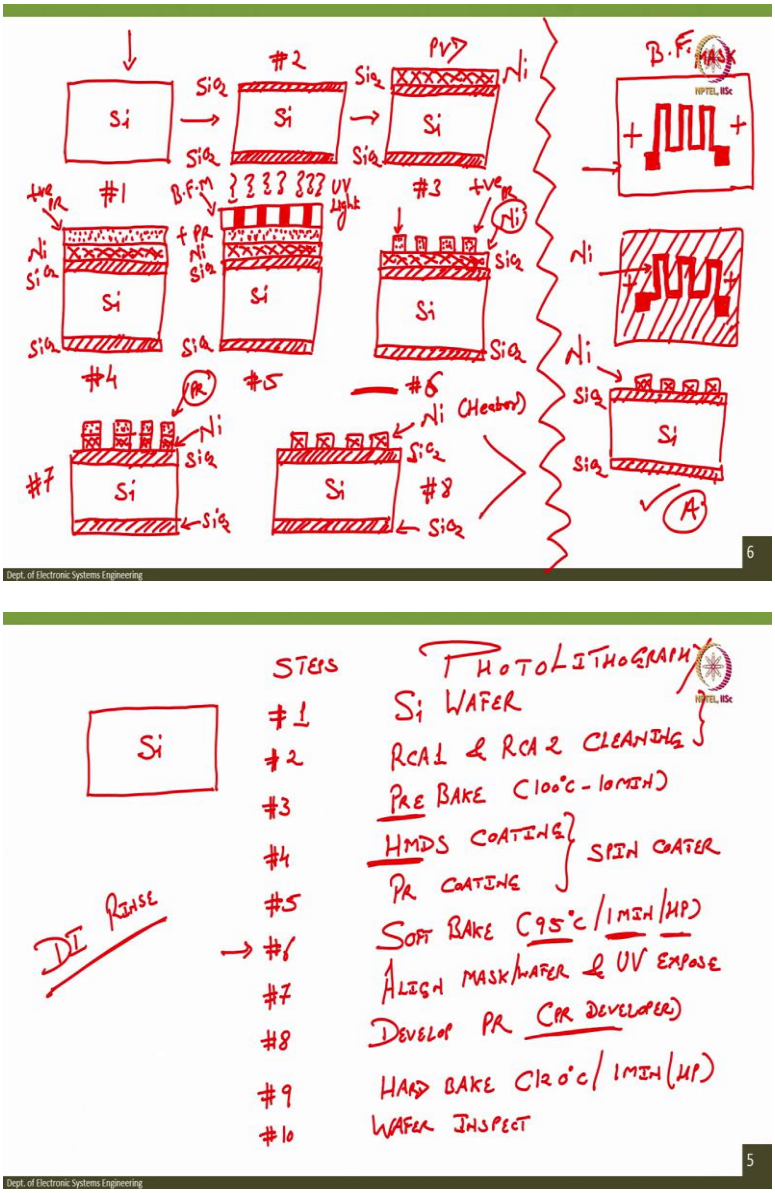


Now let us take an example, let us take an example so you further understand, so I will start with the silicon wafer and what I want is a wafer, oxidized silicon wafer with a micro heater if I draw the top view, this is a micro heater with a metal, excuse me for my drawing skills, oh, this is what I want, a micro heater this is the top view and this is the side view, side view or cross sectional view, both are oxidized silicon wafer, this is the top view, this is also silicon, this is silicon dioxide and this one is let us say nickel, Ni, nickel, this is your nickel.

And of course there is a if I just want to draw the silicon dioxide, just drawing a pattern actually as you have seen silicon dioxide there will be some color depending on the thickness of silicon dioxide, just for the understanding I am just trying this lines as a pattern as a

symbol for silicon dioxide, so this is the silicon dioxide, now this if I want from silicon wafer what are the steps.

So let us understand the steps. So first step is take this silicon wafer good, then next step is so when somebody asks you to draw a process flow start drawing the rectangle, next step is what we have oxidized silicon wafer so you have to grow the oxide on silicon wafer, what are the techniques that you have learned till now for growing oxidation, only two techniques and that too also sub techniques.

The overall technique is called thermal oxidation in which you can have wet oxidation or you can have dry oxidation, so this work that we are drawing right now, so the thermal oxide are oxidized silicon dioxide is grown using thermal oxidation. Next step you will learn PVD, what is PVD, physical wafer deposition.

So using physical wafer deposition, what you want, what is the heater material, heater material is nickel, so you deposit nickel, you deposit nickel you need to deposit uniformly and let us draw nickel by X so this is nickel, your $SiO_2$ remains as it is, silicon is as it is, nickel is using what PVD, thermal evaporation or Electron Beam evaporation.

So if I number, step number 1 step number 2 step number 3, next step is what are we going to do we have to pattern this nickel so that we have our micro heater, is not it, we have to pattern the nickel so that we have the micro heater, so we have to we have to spin coat the photoresist, so let us assume that photoresist looks like this, pattern for photoresist, what kind of photo resist we have used, so this is your nickel SiO2, silicon, SiO2 and this one is your positive photoresist, after positive photoresist what are the steps?

Now you see pre-bake is done, HMDS coating is done and then we went for PR coating, so I am just, I am not going into all these details, it is assume that after the nickel if you want you can use HMDS or you can just directly sprinkle the photoresist HMDS will improve the addition but it is not required that every time you have to go for HMDS so you can directly go to PR coating.

Here RCA1 and RCA 2 cleaning, it should be done when we get the silicon wafer here, after silicon wafer we perform the cleaning step then we do the pre-bake then we when we grow this thermal oxide then you deposit Nickel in using PVD then your spin coat positive photoresist then after the spin coating for positive water resist.

What is the next step? The next step is to pre-bake it, pre-bake it at 95 degree centigrade for 1 minute on hot plate, you see pre-bake 95 degree, sorry soft bake not pre-bake, soft bake 95 degree centigrade 1 minute on hot plate, so we will do that. The next step is to align and expose, so we have to draw a nickel, we draw a photoresist and then you have a mask.

You have the mask I will just draw number 2 here, number 2 here so what you have you have your nickel then you have your photoresist and then you have your mask, this is your bright field mask, bright field mask, so if I draw the top view of this mask how the masks will look like, the mask will look like this I will draw here, this is how the mask will look like, bright field mask.

So the cross section will look like this one, bright field mask, what we have photoresist positive then nickel then SiO2 then silicon then SiO2 correct, so after pre-bake or soft bake at 95 degree centigrade for 1 minute on hot plate we will align the mask with respect to the wafer or wafer with respect to the mask and then expose with UV light, this is UV light, after exposing with UV light you have to unload the mask and develop the wafer, unload the mask and develop the wafer.

So when you unload the mask and develop the wafer what you assume, what you will have, you have your silicon dioxide, so develop the wafer means develop the photoresist, your nickel layer is there and now you have positive photoresist bright field mask, I told you that you can replicate the mask pattern with positive photoresist as it is that means the positive photoresist upon development will have, right.

The unexposed region becomes stronger when we go for positive photoresist, when you go for positive photoresist unexposed region becomes stronger but are we here in this one we are not still there because in this case the nickel is developed but here nickel is intact so after this what is the next step we go for the hard bake, hard bake and then after hard bake what will happen the photoresist will become stronger.

Once the photoresist becomes stronger we develop this wafer in nickel etchant because this is nickel so we develop this wafer in nickel etchant upon developing this wafer in nickel etchant what we will get, the photoresist will remain intact, nickel which is protected by the photoresist will be intact, nickel which is exposed to the nickel etchant will get etched, you see the wherever there is a photoresist the nickel is still intact, wherever there is photoresist nickel is still intact.

So now the next step is you dip this wafer in acetone, dip the wafer in acetone, so if I dip the wafer in acetone, acetone is a stripper for the photoresist, it will strip off the photoresist so photoresist will get stripped off, it will get removed from the wafer and after dipping this paper in acetone what will be, what we will have, we will have only nickel left because as acetone is stripped off, because acetone is stripped off, just to make sure that we have same thing here.

So what you have now, acetone has stripped of the photoresist when you dip the wafer this number 7 into acetone the photoresist will be stripped off and you will get the wafer number 8 where you have your nickel as a heater you have your silicon dioxide, you have your silicon and again you have your silicon dioxide so what you have, you have nickel, you have silicon dioxide, silicon and silicon dioxide, is number 8 similar to A, is number 8 similar to A.

The answer is yes, so this is how the photolithography is done to pattern or to achieve the design of a micro heater right from silicon all the way to micro heater but how can we do it let us repeat it once again. You start with the silicon wafer you go for RCA 1 RCA 2 cleaning then you try it, pre bake it then you load this wafer in thermal oxidation you can go use for wet oxidation, you can use dry oxidation.

As we know masking oxide as wet oxidation can be used so we will have about 0.5 microns to 1 micron silicon dioxide grown on silicon wafer followed by depositing nickel, nickel we can deposit using physical vapor deposition either it is thermal oxide, thermal evaporation or it is electron beam operation or it can be sputtering. After depositing nickel the next step is to pre-bake it or to first you know we use HMDS.

And then you know you go for the pre-bake, you go for the photoresist coating or if you do not want to go for HMDS directly go for the positive photoresist spin coating or for positive photoresist on the oxidized silicon wafer with nickel and then you pre-bake it after pre-baking you load it, pre-bake is done at 95 degree centigrade 1 minute hot plate, you load with the mask after you load with the mask you expose with UV.

After exposing with UV they unload the mask and develop the different photoresist developer which is step number 6 when you do that the unexposed region will be intact as you can see here or in other way because it is positive photoresist the same pattern that is there on the mask will be replicated on the wafer which you can see number 6.

After that you need to you know dip the wafer into the nickel etchant because you have to etch a nickel and when you do that before that before you dip the efferent nickel etchant the next step would be after 6 hard bake, hard bake is done at 120 degree centigrade 1 minute hot plate followed by nickel etchant when you dip the wafer in nickel agent what will happen the photoresist, wherever photoresist is protecting the nickel the nickel will stay intact.

The remaining area nickel will get etched after that you dip this wafer in acetone which is wafer number 7 and when you do that the photoresist will get stripped off to form your nickel micro heater or nickel heater. These are the steps for photolithography, these are exact steps that we have talked here only after hard bake which is what we do in step number 6 after this step number 6 where you inspect the wafer.

And then you have to dip the wafer if the pattern is correct if the photoresist is correctly you know showing the pattern which is of the mask then you have to dip the wafer in nickel etchant followed by photoresist stripping followed by the device which is realized at the end of the process flow.

So this is also called a process flow for fabricating the micro heater, so what we have learned, we have learned how the process flow for photolithography works from step number 1 all the way to step number 10 and beyond because now in this case we have taken an example of nickel as a micro heater and I have shown it to you how we can utilize it, so we will stop here now we have taken one example we understand the process flow.

So we will break this class into multiple smaller classes so that you understand, absorb and if you have questions, ask questions through the portal and now in the next class we will look at the theory part of the photolithography and followed by taking few more examples because here we have nickel that means that we have only one wafer one mask and that is it, but what if I want to fabricate a device which is little bit complicated than what is shown here.

For that we will see the process flow and we will see how we can pattern multiple materials onto the single substrate in the next class, till then you take care, if you have any questions ask us to the portal feel free to ask us and we will try our best to answer the queries that you may have while you learn this particular course, till then take care I will see in the next class. Cheers.