A Brief Introduction to Micro Sensors

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Lecture - 15

Deposition and Lithography

Hello guys. So, in a last class we have already discussed about etching which is a material removal technique mostly right. Now we will be talking about material addition.

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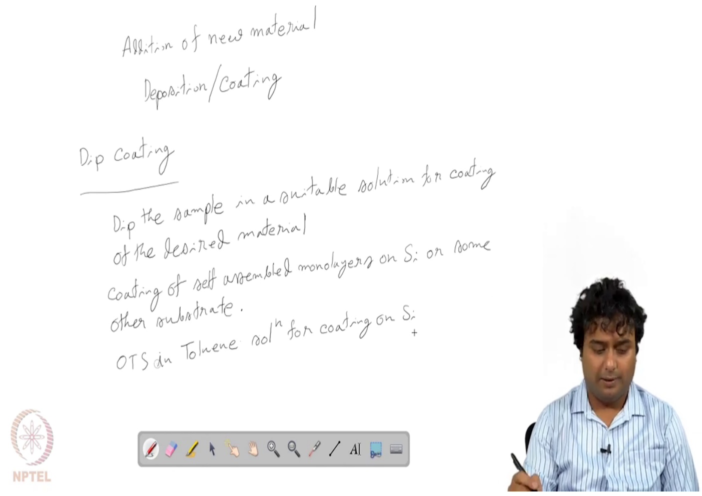

Addition of new material

Deposition/Coating

Dip coating

Dip the sample in a suitable solution for coating of the desired material

Coating of self assembled monolayers on Si or some other substrate.

OTS in Toluene sol^n for coating on Si

So, this is addition of new material. And we have different techniques for that like deposition or collect coating. For deposition or coating now we have different techniques, like how we put a new material on your on a sample right and for that the first we will discuss about the most simple technique that is called dip coating.

So, in this technique what we do, we have the sample right and then we dip the sample in a suitable solution for coating of the desired material ok. And this dip coating technique will depends on many parameters, like what kind of ambience we are actually doing this experiment, like what is the humidity temperature of the ambient and of your solution then what is the concentration of the solution etcetera, and according to that the thickness of the coating may change.

So, what are the example? Example, of this technique is like, coating of self assembled monolayers. On let us say silica or some other substrate. So, what is self assembled monolayer? So, these are the material or these are the molecules which actually assemble them self according to their molecular arrangement and all of the molecules are arranged in similar fashion ok.

So, on a sample then they coat similarly. So, in this what we can do is like one particular example is like OTS, OTS is octadecyltrichlorosilane ok. It is it has 18 carbon atoms and it usually get coated on silicon very easily. So, OTS is coated using a toluene solution, OTS in toluene solution for coating on silicon. So, what we do we take some OTS which is also liquid and then we can prepare a solution of OTS in toluene solvent.

And then we just take our silicon piece and dip into the solution. Now how precisely we are going to dip and what is the speed of retraction like while you are taking out the silicone piece from the solution depending on all that OTS will be coated on silicon. So, this is a simple example of dip coating. Another kind of coating is called spin coating, is called spin coating.

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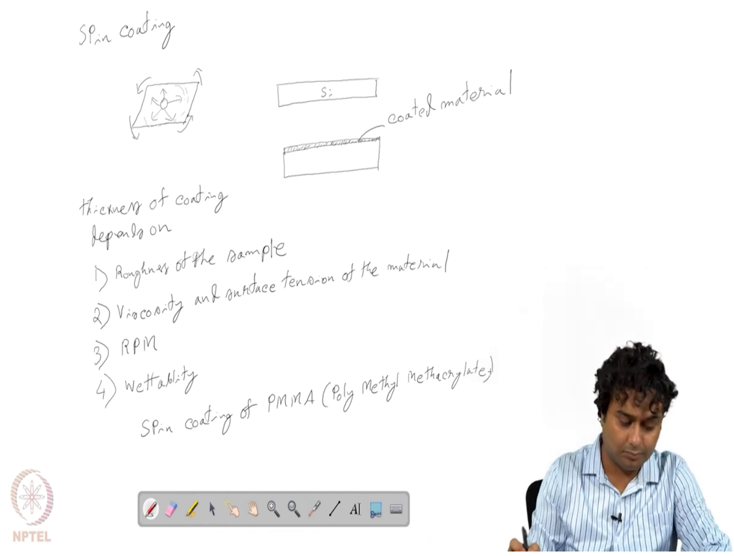

Spin coating

Si

coated material

thickness of coating
depends on
1) Roughness of the sample
2) Viscosity and surface tension of the material
3) RPM
4) Wettablity

Spin coating of PMMA (Poly Methyl methacrylate)

So, in spin coating what we do we take a silicon piece or glass piece whatever is our substrate let us say like this and then we put the material which we want to coat. So, like a drop so, this will be a liquid solution of the material so, we just put a simple drop on that. And then we rotate the sample with very high speed ok. So, let us say this is the sample then on top of that you put one or two drops of the solution which material we want to put and then just rotate this sample,

And because of the rotation what happens that, because of the centrifugal forces this material spreads over the sample right. Material spread over the sample and it gets coated almost uniformly on the sample. So, if we see the cross section image so, let us say this is a silicon piece, and then after doing spin coating we will have a, we will have a thin layer of the material which is coated on silicon, this is coated material.

So, later on we give specific example of. So, later on we will give specific example of spin coating, but before that what are so, how does that thickness of this coated material depends on different parameters. So, thing depends on so, there are different parameters right one is roughness of the sample, roughness of the, roughness of the sample. If the surface is very rough then coating will not be uniform also like it will be sorry. So, if the roughness is very high then the coating will not be uniform and also the liquid will get abstracted on the surface itself to move right.

So, the roughness of the sample is one important parameter. Then viscosity and surface tension so, how viscous is the solution. So, if the same sample is very viscous than with the same rotation speed it will move lesser amount towards the periphery or in compared to less viscous solution right, and also the surface tension how the liquid sample interacts with the solid surface on which it is actually coated.

So, this things are important then definitely another important parameter is RPM that is rotation per minute right. So, how what is your speed so, as you increase the speed it should spread more and the thickness should be lesser, but this has also a limitation this is not linear so, the that can be discussed in some other course this is not the part of the, but with for this purpose what we should know that if you increase the RPM then the thickness will decrease.

Then it is the wettability which is also related to some extent to the surface tension, that how the surface is how the material like whichever is coated and whichever is your substrate like each other so, that wettability etcetera are different parameters on which the coating thickness will depend. So, one example, of spin coating is just to mention is like spin coating of PMMA. What is PMMA? PMMA is poly methyl methacrylate.

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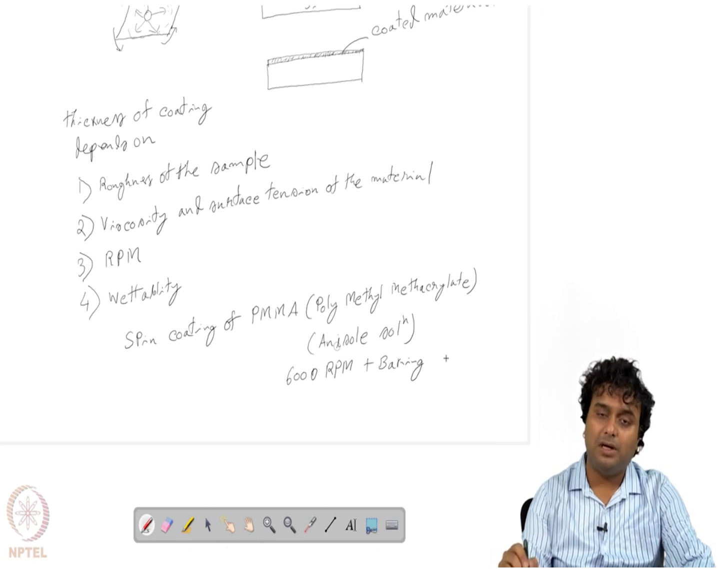

thickness of coating depends on

1) Roughness of the sample
2) Viscosity and surface tension of the material
3) RPM
4) Wettablity

Spin coating of PMMA (Poly Methyl Methacrylate)
(Anisole solⁿ)
6000 RPM + Baking +

So, this is a polymer so, this is a polymer and we make a solution of this polymer in anisole solution. So, you get use anisole, when use anisole as solvent ok, and then we make a solution of PMMA and then we will take the sample and put this PMMA solution on in at the middle a few drops and then rotate the sample with very high rotational speed like something about 6000 RPM, plus we do some baking like before and after spin coating we do some baking or heating.

So, after the spin coating we actually do some kind of baking or heating of the sample. So, that the solvent gets evaporated and only PMMA is coated on the sample.

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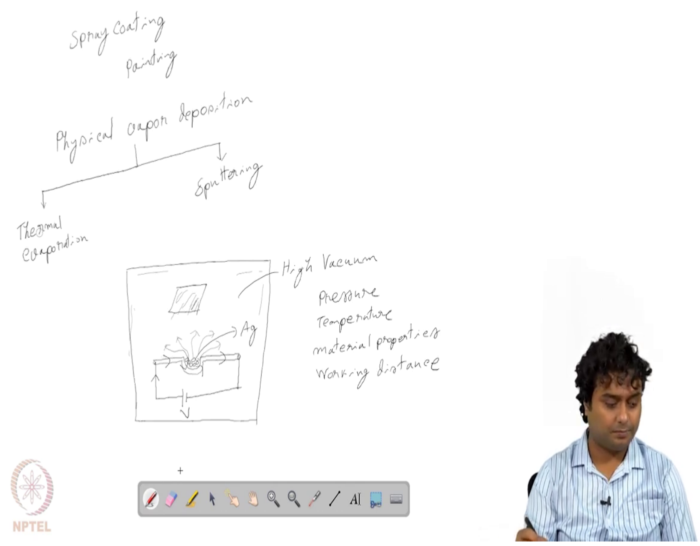

Another important coating technique is spray coating though it is not much used in micro fabrication technique, but this is good to know while we are talking about coating and deposition. So, in these case we actually make the solution and spray it on the sample like for different kind of painting, and also some time for dispersing carbon nanotubes etcetera on a sample we use spray coating.

So, till now whatever we have discussed is useful for like coating of different polymers or the material which are available in a liquid form right. Whether we take dip coating or spin coating or spray coating we are making some kind of solution of the material and then coat it. Now next we will talk about how we coat metals or which are available in solid form usually, so, for that the one of the most popular technique is physical vapor deposition.

What is physical vapor deposition? As the name suggests this is the vapor of the material will be deposited on the sample, and we will discuss now that how that is possible. So, this is this has two major categories; one is thermal evaporation, thermal evaporation and then another is called, another is called sputtering. So, what is thermal evaporation? In this technique what we do have the material in some beat form and then we heat the material to evaporate it and so, that vapor or the evaporated material get deposited on the sample. So, for that we use this kind of setup.

So, let us say this is the operation chamber, and then inside we have some kind of boat, boat means which will hold the material and it is some metal which can conduct current. So, what we do this is just like a metal boat which is like for kind of a holder for the sample and this thing can carry current this is a conduct and high temperature it can withstand. Then we apply let us say some kind of voltage some high voltage to that and then the current flows in this path.

So, because of that this gets heated up now we put our material like beats inside the boat. And we keep our sample let us say at the top. Now as the current flows, as the current flows through this boat copper boat or it is not a copper like a tungsten or some high temperature material now this gets heated up, and because of this heating let us say some material which is need to be coated let us say let us assume that we need to coat silver a g.

So, that silver beats are kept here now this beats starts melting and then starts evaporating and that material or the vapor goes everywhere right, as I we while we boil water then the water vapor goes everywhere. And then accordingly it gets coated on the sample its gets coated on the sample now not necessarily it is only coating on this coating also on the chamber walls and everywhere right, but some amount of that also gets coated on the sample.

Now, depending on how much is a current or how much temperature we are using to melting it, then what is the distance between the boat and the sample and also like what is the pressure inside the chamber? So, we need to use very low pressure because otherwise what will happen that inside if we use if we try to melt this inside here then this will be oxidized and also will change its properties right, and thus holder also will get damage. So, because of that we create a high vacuum actually inside the chamber, and then we deposit the material.

And the thickness of the material like how much it will be deposited depends on many things, like this pressure, temperature, then material properties like what kind of material it is and what is the pressure vapor pressure of the material working distance working distance, means; the distance between the sample and the holders like boat. Using this technique different metals like gold, silver, then aluminum, titanium, even like copper etcetera can be deposited.

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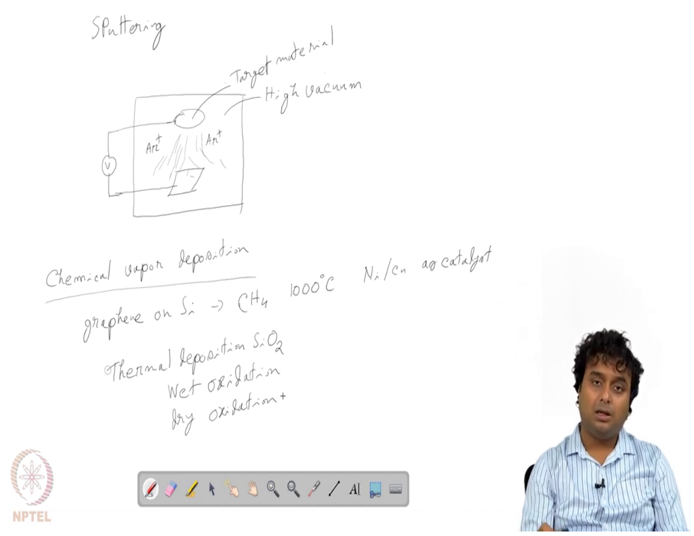

Now, we will talked a little bit about the sputtering so, actually the physical vapor deposition work the thermal evaporation and sputtering to go details this is a vast topic, but for the scope of this course we will not go into details of each parameters how it controls the deposition and all, rather we will have some idea about how this processes happens ok.

So, that you will know that how exactly this materials are deposited, and if you are interested you can learn about this techniques more in detail. So, that how to control the thickness or deposition rate etcetera. So, in sputtering what we do is we use ionized gas, like let us say we can use a ionized gas like argon, why argon? Because argon is a neutral gas ok. So, there will be similar kind of high vacuum chamber as we have used for thermal evaporation and then there will be a target.

So, there will these high vacuum chamber similar kind of, and then there will be a target. So, target is the material which we want to coat so, let us see if we want to use if we want to coat gold and silicon then we will be using gold targets, means; this target will have already gold coated on this ok. Then we fill the chamber with argon gas so, the vacuum will get reduced to some extent right and then applying high voltage we ionize it so, it becomes argon plus ions.

So, this argon plus ions while applying so, this let us say this is the sample. The sample then we apply a high voltage, apply a high voltage in between the target and the sample right and then this argon plus will get attracted. So, let us say this is a if we apply negative electrode this side then will be attracted towards the negative electrode and because of that this will be kind of bombardment on the target.

And because of this bombardment that target material like let us see if this is gold then gold atoms will get dislodged from the target and get coated on the sample. It will also go other places also, but some amount it will be coated on the sample so, accordingly you can get a gold coating using the sputtering technique. Now, in real case actually we use ac voltage and also use magnetic field to control the movement of this argon plus ions or to create the plasma this is ionized gas this can be called as plasma.

And so, there are different parameters like voltage, pressure, working distance etcetera how we control the exact deposition rate as well as the deposition thickness, on a sample also you can apply some like sample bias to attract, to attract this atoms and also to control the surface morphology also you can heat it.

So, they are at different parameters so, which we will not discuss for the part of this course, but this is a popular deposition technique. And the most popular sputtering technique is actually r f magnetron sputtering where we use a c at r f frequency or radio frequency, and in that case also we use magnetic field to control the movement of the ions.

So, that is why it is called r f magnetron sputtering and very frequently used for deposition of different metals. Now after physical vapor deposition or p v d in short you can say we will talk to we will talk about c v d or chemical vapor deposition. So, in chemical vapor deposition what we do we use chemical technique; that means, some reactive gas will be there inside a particular required pressure and temperature and that gas will react with the sample to deposit a particular material.

For example, like while deposition of graphene. For example, while coating graphene on a silicon sample we use, you can use this chemical deposition technique chemical vapor deposition technique. So, in that case we use methane gas for deposition of carbon graphene or supplying the carbon and then at 1000 degree centigrade 1000 degree centigrade temperature and also at very high pressure.

We can actually we can break this CH_4 into carbon and hydrogen and that is carbon get deposited on the silicon sample. So, actually we here we use nickel, can use nickel or copper as a catalyst. So, nickel and nickel and copper help to dissociate the CH_4 into carbon and hydrogen and that carbon get deposited on the nickel surface ok. Nickel surface or copper surface and then you get a graphene film accordingly.

Another example can be another example can be thermal deposition of SiO_2. So, at high temperature we take a silicon wafer and at high temperature we use H_2O plus O_2 mixture right. So, H_2O also dissociate and gives oxygen and that oxygen at very high temperature reacts with silicon and becomes deposit this SiO_2 layer.

So, this is called wet oxidation where we are using actually H_2O for supplying the O_2, but without H_2 also just with the help of oxygen also we can do oxidation and that is called dry oxidation. But in case of wet oxidation the growth rate is higher whereas, for dry oxidation growth rate is lesser, but the surface is for dry oxidation is much smooth.

So, in some cases like where we need let us say 1 micron of; 1 micron of oxide to be deposited on silicon we can use both the wet oxidation and dry oxidation together. Like let us say first 10 nanometer of the oxide we grow it by dry oxidation. So, it will be rate will be very low, but the interface property between the oxide and silicon will be better because the surface roughness will be lesser.

Now, after the 10 nanometer the 900 nanometer we can deposit by wet oxidation. So, in that case the oxide quality will not be so good well like the surface roughness etcetera, but the growth rate will be very higher right. So, we can deposit, but that 900 nanometer of oxide in very small time. Then after that the rest 90 nanometer or 50 nanometer whatever we choose that we can again deposit by dry oxidation. So, in that case the top surface will be made by dry oxide.

So, in that surface will be much better and for it will be suitable for device application, and the whole oxide film can be deposited in much smaller time. Rather than that if we have choose the dry oxidation for the whole 1 micron then it would have taken lot more time. Now there are many other deposition techniques also like electrochemical deposition etcetera, but we are not going into those details because for the part of this course we have mostly discussing the most popular techniques and to a very short extent.

Like what is the basic working principle and how these techniques has been is usually carried out inside a lab to get this kind of device structures ok. Now before so, this is about deposition so, physical vapor deposition and chemical vapor deposition of the most popular two techniques for deposition and as well as like spin coating or dip coating these are the popular coating techniques. Now before going to the next topic I will again revisit little bit about the material removal or etching.

But last time we have talked about etching using KOH or TMA solution. So, now this KOH or TMAH is a liquid right. So, this is that is called wet chemical etching. Now after wet chemical etching we are going to discuss dry etching.

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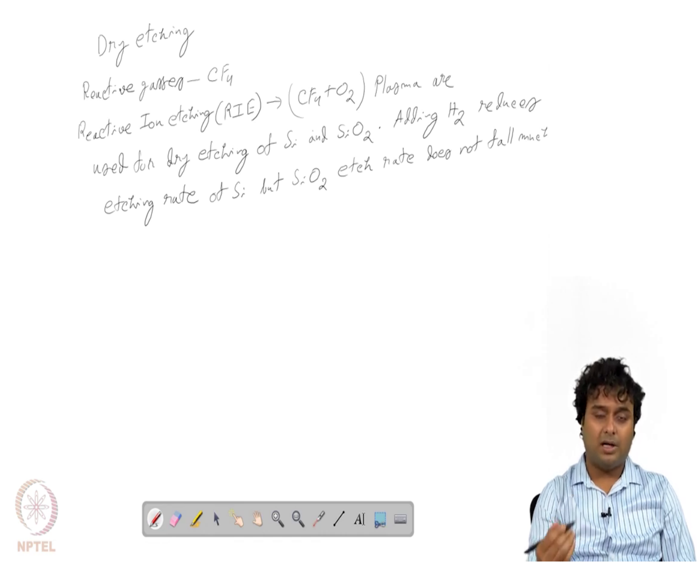

Dry etching

Reactive gasses — CF_4

Reactive Ion etching (RIE) → $(CF_4 + O_2)$ Plasma are
used for dry etching of Si and SiO_2. Adding H_2 reduces
etching rate of Si but SiO_2 etch rate does not fall much

So, as the name suggests in dry etching there will be no wet part, what does it mean? Means we will not be using any liquid to etch the material or to remove the material. So, in place of liquid we will be using reactive gases. Like one kind of very reactive gases CF4 then CF6 etcetera, and this also we use not only this reactive gases we also ionized it ionize it and that is why this is called reactive ion etching, or in short RIE. So, in reactive ion etching what we do we use ionized CF4 gas let us say so, we use only CF4 or CF4 plus oxygen plasma.

So, we put this gases inside a chamber at high vacuum and then, we need to maintain their partial pressures that how much of concentration of CF4 will be using and how much will be the concentration of oxygen. And then what we do we apply some electric potential also to ionize the gas and then this CF4 actually reacts it relieves that fluoride radicals as well as fluoride ions and that reacts with the silicon or SiO 2.

So, see this CF4 plus oxygen plasma are used for dry etching of silicon and SiO 2. Now the etching rate for silicon and SiO 2 at the not definitely same, but if we add hydrogen to this mixture then it reduces the etching rate for silicon whereas, SiO 2 etching rate are not reduced by that much as it compared to the; as compared to the silicon. So, if we need different kind of etching rate for silicon and SiO 2, let us say in our sample we have silicon and as well as SiO 2.

And we need more for some device application to make some device we need SiO 2 to be etched while we do not want the silicon to be etched. So, you can add with this mixture we can add hydrogen then the silicon etching rate will be reduced by like substantial amount whereas, SiO 2 etching rate will not be reduced much. So, SiO 2 will get etched while silicon will not get etched by significant amount.

So, this is this while using CF4 this is called fluorine chemistry because we are using fluorine gas here as the main reactive gas. Then we can use taurine chemistry also where we use c c l 4 etcetera gases for the same purpose. So, that is also for etching silicon SiO 2 and this kind of material. The advantage of dry aging is it is more clean process, because we are not dipping it into any solution so, there are some cases where we have the problem of stiction, means; while we while we take out a released cantilever after etching.

Then because of the trapped water in between the cantilever film and the substrate there is a chance that the can release cantilever can snap onto the surface or can stick to the surface because of the surface tension right. But in this case as we are using dry etching so, no meniscus no liquid meniscus is formed. So, there is no chance of stiction for dry etching and the etching rate is also very high and also you can get anisotropic etching according to our choice.

I mean that we apply you can apply more voltage in one particular direction like let us say vertical direction or horizontal direction and accordingly we can get more etching rate in one of the directions or one of the sides. And this is not silicon property this is not from the silicon crystal property this is from the this will be possible even for SiO 2 or other materials also, because we are changing the we are giving a direction to the phenomena itself or the etching technique itself.

So, now after discussing about etching and deposition that is removing material or adding material to a substrate we will discuss about patterning or lithography. So, the first question is what is patterning or lithography.

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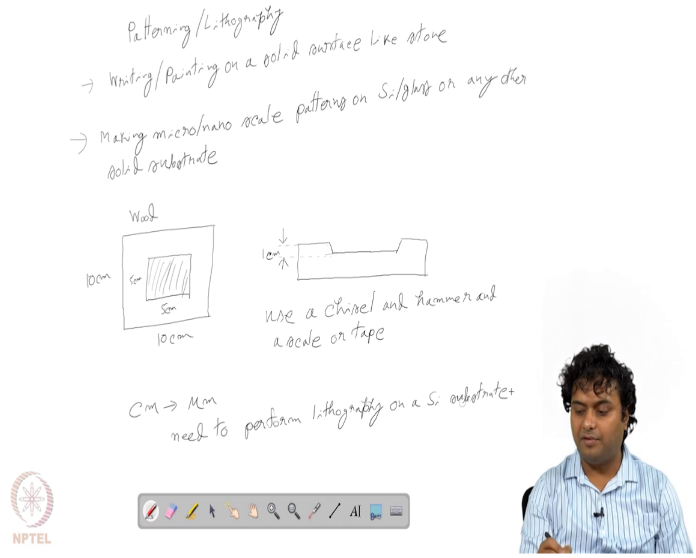

Patterning / Lithography

→ Writing / Painting on a solid surface like stone

→ Making micro/nano scale pattering on Si/glass or any other solid substrate

use a chisel and hammer and a scale or tape

cm → μm

need to perform lithography on a Si substrate

It is like if we consider it from the its terminology from ancient times it is known as like writing or painting on a solid surface like stone. Now in our context we use lithography, while we use lithography we want to mean that making micro or nano scale patterns on silicon glass or any solid substrate, on a solid substrate.

Now, so simply we can, simply we can say that lithography means making patterns or writing patterns on something, on a piece of silicon or on a piece of glass or on a stone like that. Now for micro fabrication we use what we mean actually lithography is a completely different technique what we use at macro scale. So, let us say I have this wood piece, so this is a wood piece and you are seeing the top view here and this is the cross sectional view ok.

This is a simple wood piece like this let us consider this is a wood piece ok, and this has a dimension of something about 10 centimeter by 10 centimeter ok. Now I want to make a square hole inside that which hole will be about 1 centimeter depth right, and it will have a let us say 5 centimeter by 5 centimeter arm side. So, this is a square hole and each of the sides are 5 centimeter, and if we see in the cross sectional view then let say it is something like that, and this is about 1 centimeter ok.

So, on a 10 centimeter cross 10 centimeter wood piece I would like to make this 5 centimeter by 5 centimeter square hole which has a depth of 1 centimeter. So, how we can do? We can use a chisel and hammer. And definitely we need a scale or tape right to measure. So, its simple like this that we take the wood piece then we make the drawing which is 5 centimeter by 5 centimeter using the scale.

And then using our hammer and chisel we can actually remove the material from this region right, we can remove the material from this region using the hammer and chisel. Now assume that, we want to do the same process, but in a different dimension, that is; we change centimeter to micrometer. So, now we have a 10 micrometer cross 10 micrometer wood piece.

Let us assume that this is not wood rather it is a silicon piece ok, because on wood microfabrication on wood is not well defined and it is not also part of this course so, let us talk about silicon. Now we have a silicon or glass piece of like the bigger size or maybe 1 centimeter cross 1 centimeter size, but we want to make a hole in that which will be 5 micron by 5 micron of size and 1 micron of depth.

Now, how we can do that can we use this wood can we use this chisel and hammer? No, because chisel and hammer both are much higher dimension than the dimension we need and another thing is that we even cannot see 5 micron so, forget about actually making a making the marking using a scale right. So, there we need to perform, lithography on a silicon substrate. So, you need to perform lithography. Now what are the lithography techniques?

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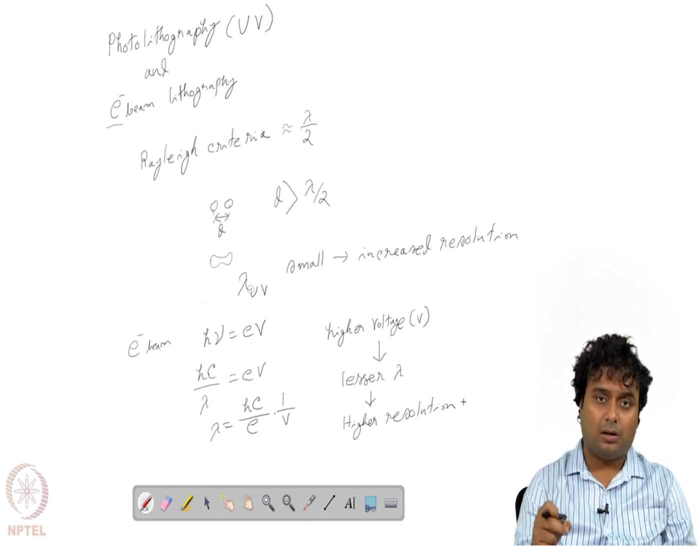

Photolithography (UV)
and
e^- beam lithography

Rayleigh criteria $\approx \frac{\lambda}{2}$

$d > \lambda/2$

λ_{UV} small → increased resolution

e^- beam $h\nu = eV$

$\frac{hc}{\lambda} = eV$

$\lambda = \frac{hc}{e} \cdot \frac{1}{V}$

higher voltage (V)
↓
lesser λ
↓
Higher resolution +

So, two most common and popular lithography techniques are known as photolithography and another is called electron beam lithography or e beam lithography. Now what we do in photolithography or e beam lithography, we actually use UV light for photolithography UV means ultraviolet ok. So, ultraviolet light for photolithography and we use electron beam as the name suggests for e beam lithography.

Now, this photolithography or e beam lithography what we do we use this laser source like UV laser source or e beam source as just like a pen. So, we have the laser source here and then a very focused beam comes from the pen and then accordingly we move the pen and write on the; write on the substrate, which is on silicon or we will see that what kind of material we actually write. Now before we discuss about that actually you need to understand that why we need to use ultraviolet or electron beam.

That is because we have a limit with our visible light what is that limit that is called Rayleigh criteria. So, according to Rayleigh criteria with our any kind of optical signal or optical light is resolution is limited by lambda by 2, almost equivalent to lambda by 2; that means, what does it mean? Means let us say we have two particles which have which are separated by a distance d by a distance d.

Then we if we use a visible light of wavelength lambda then we can actually this will we can actually see these two particles as separate, only if this d is greater than lambda by 2 ok. If it is not if the d is smaller than lambda by 2 then we will see almost a merge image something like this ok. So, we cannot reserve two particle separately. So, this is the physical constraint which we cannot overcome with using any kind of instrumentation.

So, our visibility medium like where we are while we are seeing some object we are seeing by the usual light right, which has different frequencies like from violet to the red and using that we can maximum result in this limit. Now ultraviolet light can have much higher frequency or much lesser lambda so, what happens using ultraviolet light we can actually decrease lambda of a UV light is, lambda of a UV light is pretty small.

So, we have increased resolution, and for electron beam from quantum mechanics we can show that particle duality etcetera that for a electron beam we can define its wavelength of an electron beam by this formulation, like h nu equals to e v where, e is the electron charge v is the applied voltage. So, you can create an electron beam using a high voltage. So, for electron beam its frequency or wavelength is defined by this formula, that is where that comes from wave particle duality.

And they are we can write that h nu is equal to e v and where nu is the frequency of the electron beam and v is the applied voltage which is usually in some kilovolts and then h is Planck constant and small e is electronic charge. And then we know that this nu equal to h c by lambda where, c is velocity of light or velocity of the electromagnetic radiation right and then we get e v. So, lambda equals to h c by e into 1 by v so, here h c and e all are constant Planck constant velocity of light and electronic charge all are constant.

So, as we apply higher and higher voltage, as we apply higher voltage or v we get lesser lambda or wave length and; that means, higher resolution. So, that is why we use UV light and electron beam for micro and nano scale patterning, but because we can actually applying particular wavelength of U V light or it is a particular high voltage we can focus it at a nanometer scale or micrometer scale is any way achievable.

Now, we know that for photo for lithography we can use UV light and electron beam light electron beam source right, now what is the exact process. So, for that the general process is something like this.

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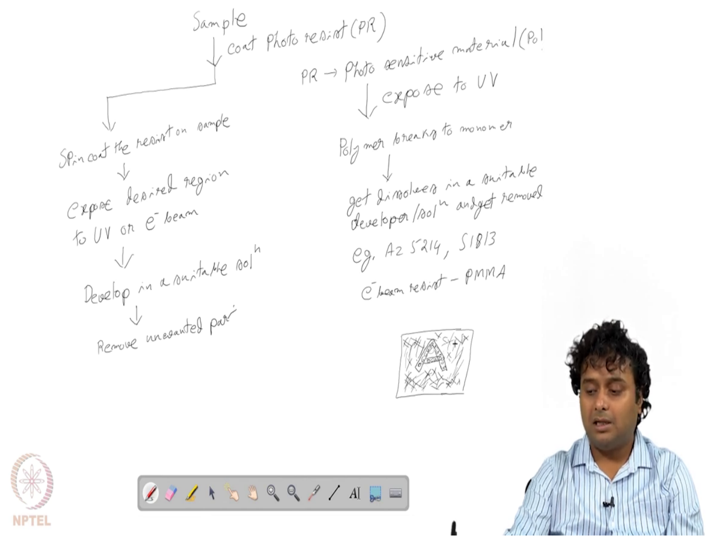

Sample

coat Photo resist (PR)

Spin coat the resist on sample

Expose desired region to UV or e^- beam

Develop in a suitable sol^n

Remove unwanted part

PR → Photo sensitive material (Pol

expose to UV

Polymer breaks to monomer

get dissolves in a suitable developer / sol^n and get removed

eg. Az 5214, S1813

e^- beam resist – PMMA

So, first we have the sample and on sample we coat photo resist or short we call P R. So, what is photo resist or P R? These are photosensitive material. So, these are mostly polymer and this polymers what happens is, while we expose it, ultraviolet light then this polymer brakes, and becomes monomer.

Then this monomer can get easily dissolved in a, suitable developer or solution and get removed. So, we have the polymer let us say then if we expose the polymer to the UV then some whichever part of the polymer will be exposed that part will become monomer and then if we put it inside some kind of, some kind of suitable solution then this monomer will get dissolve and get removed.

Now, we can use this for photolithography so, how we are coming to that before that, let us give example of photo resist and they are like A z 5 2 1 4 or S 1 8 41 3, these are popular photo resist which are used for photolithography. And similarly e beam resist right, PMMA. So, earlier I have discussed that polymethyl methacrylate this is an e beam resist.

So, electron beam falls on that then this polymer breaks into monomer and can get easily dissolved in developer like m i b k etcetera. Now what are the, what are the steps of photolithography then? We will have the sample and on top of that, we will spin coat, spin coat the lesser we are talking about electron beam lithography then, what we will do, we will use PMMA so, PMMA in anisole solution.

And then we will take the sample and that PMMA in anisole solution and we will put a few drops on the sample and then we will rotate it as we have discussed for the spin coating. So, accordingly this will be coated on the sample or the substrate right, and exposed desired region to U V or electron beam. So, if this is my sample and if I need to, let us see if I need to write this pattern A I need to write this pattern A.

Then what I will do, I will coat this with polymer everywhere and then with using a laser source I will just expose only on so, I will put the laser source I will move the laser pin such that UV pin or e beam pin such that it will be only exposing this region right, this shaded region this will be only exposing this region and the other places like these places will not be exposed to the UV or the electron beam right.

Then what we will do we will develop it in a suitable solution. So, if it is let us say PMMA then we will use m i b k which is a developer for PMMA and then, what will happen that this region from this a region all the PMMA which has been exposed to e beam and has become monomer that will get dissolve and get removed. So, because of that only this portion will get removed, this portion the PMMA will get removed right.

But the other regions, so PMMA will get removed only from that a region the other region it will be still there it will be still there, so remove unwanted part. So, if this is a silicon wafer then this region only, this regions only the silicon is exposed because, PMMA has been removed from this region this circles regions right. Whereas, in the other parts like this shaded parts there PMMA is still there correct.

So, this is like we have written this a pattern in a very fine scale like in micrometer or nanometer scale on a silicon wafer such that the empty spaces as a space is silicon and the other spaces is that this is all polymer. Now we can do some more we can do some more process like if we etch the silicon here; if we etch the silicon here using KOH etching or dry etching then what will happen that only according to this a pattern the silicon will get etched, but the other region it will not get etched.

Because it is protected by the PMMA on top of that. So, this regions silicon will not get etched let us say I put this sample now in a KOH solution and etch it then this region will not get etched whereas, this a region will get etched right. And then what we will get, an etching on silicon according to this A pattern and then we can put it in some solvent like acetone which actually dissolve all the like all PMMA polymer whether it is polymer or monomer acetone dissolves it.

So, all the polymer will be actually dissolved in acetone and then we will get a changed in a pattern of A right. So, that we will discussed more in the next class and before the, before we finish actually this, before we finish this photolithography what we need to note here is there. Other than this steps there is also some baking steps require like pre baking and post baking, and what does it mean?

Means before the spin coating also actually we need to hit the sample to a bit because we clean the sample and after that some water layer very fine water layer is formed on the silicon sample. So, using like baking it over let us say 150 degree centigrade or so, for some amount of time like 1 minute we can get rid of that water layer ok. And after spin coating also we need to bake it let us say 95 degrees centigrade for 1 or 2 minutes to get rid of the solvent.

Because there it is A z or it is PMMA there is some solvent which is used for the spin coating, and once we get rid of the solvent then we have the pure photo resist or e beam resist on our sample. And even after development also we need to use baking because development is done usually in liquid solution whether m i b k or m f 26 which is used for is it kind of photo resist are ultimately liquid solution. So, that solvent also sometimes get soaked into the sample so, for that also you can heat the sample for some time to get rid of that liquid material.

We will talk about the next processes in the next class ok.

Thank you.