Chemical Engineering Principle of C V D Processes
Professor R. Nagrajan
Department of Chemical Engineering
Indian Institute of Technology Madras
Lecture No 06
Film Structure and Properties

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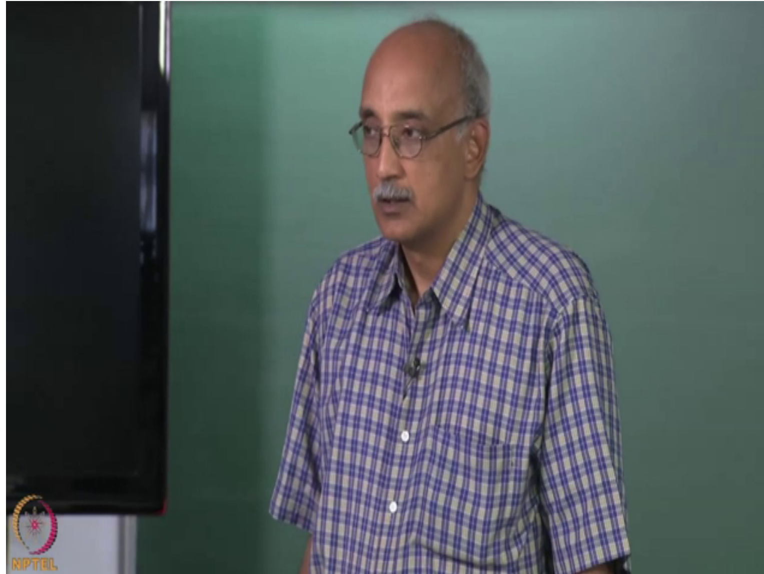

Good morning and welcome to this lecture in our course on Chemical Engineering principles of C V D processes. In the last class we started discussing the structure of C V D films, types and structure. And so we kind of classified the types of C V D films into predominantly 3 categories, semiconductors, conductors and insulators or dielectrics and the structure we classified into crystalline, polycrystalline, amorphous, right?

And we spent most of the time talking about essentially single crystal silicon as the C V D film and, so we talked about various aspects of the film structure, the properties of the film that we need to be concerned about, also talked about various methods of growing crystalline films on surfaces. We also talked a little bit about possible defects that can happen in single crystal film structures.

So in this class, we are going to discuss polycrystalline and amorphous films and after that we will also talk briefly about C V D of the dielectric materials as well as the conducting materials.

Now as I mentioned in the last class, what really finally determines the structure of the C V D film is the surface on which it deposits. If you want to have an epitaxial silicon on the surface, then the surface on which the film deposits must also have a crystalline structure to it.

Because the arriving atoms will typically orient themselves to the crystalline configuration of the substrate on which they land. So if we have a very clean and oxide-free and crystalline silicon surface, then you can form an epitaxial silicon film on top of that. But suppose you want to grow a polycrystalline or amorphous film, how would you do that?

Well couple of strategies that you can use. The first thing is, typically low pressure C V D is employed. Whereas to get crystalline structures, you would try to employ high pressures, meaning atmospheric pressures; to get a less crystalline structure, you can use a low pressure process.

You should use a lower temperature. The typical deposition temperature for a crystalline film is of the order of 800 degrees Centigrade and above. In order to get a polycrystalline or amorphous film, we are talking about temperatures in the range of 600 degrees Centigrade.
So by lowering the temperature and lowering the pressure, essentially what you are doing is lowering the energy level of the deposing atoms when they arrive at the substrate and you are also lowering the energy level of the substrate on which the atoms land.

So because of this, the tendency of orienting is significantly reduced and the arriving atoms are not able to move around and align themselves to the crystalline structure. So you essentially get a structure which is less crystalline in character.

So lower pressures, lower temperatures. The other thing that you can do is basically provide a structure on the substrate which is itself amorphous or polycrystalline so that the arriving atoms will also orient themselves the same way. So an easy way to do that is to oxidize the surface.

So frequently in order to get amorphous silicon on a crystalline silicon substrate, the first step is to actually oxidize the silicon to grow a silicon oxide film on the surface, very thin film and then deposit the silicon layer on top of the silicon oxide film.

Because now the structure of that silicon layer is not going to mimic the structure of the silicon substrate but rather the silicon oxide layer that is sitting on top of the silicon. So these are kind of tricks that you can use to get an amorphous or polycrystalline film on a surface.

The drawback of the polycrystalline or amorphous film is that the, the films are not very strong; you know because they do not have this structure to them, they tend to be a little more weakly bonded to the surface.

So for example one of the tests we will talk about later is the etch test. When you etch a C V D film that is amorphous in character, its etch rate is going to be much higher. That means it is more easily destroyed or disturbed and so what you really want is an amorphous structure but at the same time you want it to be fairly well adhered to the surface.

So the way we do that is you deposit the amorphous layer at low temperature but then do an annealing where, at a higher temperature. So you can take the C V D amorphous film on a substrate which has been deposited, let us say at 600 degree Centigrade and do a post-baking or annealing at say 100 degrees plus, somewhere in the 650 to 750 degree Centigrade range, you can actually change the properties of the film without affecting its structure.

So it will still remain amorphous or polycrystalline but by doing this annealing process you can make it behave more like a thermally grown oxide. So you can make it denser, more scratch resistant, more etch resistant and so on.

Another occasion where we preferentially deposit polycrystalline or amorphous films is when we are actually trying to dope the film with another material. It is very difficult to dope a crystalline or a single crystal material because the accommodation potential is going to be very low.

But if we have a polycrystalline or amorphous film, it is actually not that difficult to dope it with another element. Two most common dopants in C V D systems are phosphene P H 3 and boron nitride B N 3. These compounds are typically used to then incorporate not, not P H 3 and B N 3 but actually P 2 O 5 and B 2 O 5 as constituents in your film.

This is particularly of use when you try to make, as we will see later when we talk about dielectrics like glass. Glass has certain properties which are not desirable. One thing, it is very fragile. And for another, glass is very permeable with respect to moisture.

So in order to increase the moisture barrier characteristics of these oxide films you impregnate it with either phosphorus or boron. So when you are using these dopants in your process, the doping process really only works when the film is amorphous or polycrystalline. It does not work if it is a single crystal film.

So for particular applications where you are relying on changing the properties of the film by using certain additives or dopants you have to set the conditions of the reactor such that you first obtain a polycrystalline or an amorphous film so that now you can incorporate the dopants and then you can again do the finishing process, high temperature baking or annealing process to improve its physical characteristics.

So the difference between amorphous, polycrystalline versus single crystal is both in terms of processing conditions and even the carrier gas. Now usually when you are trying to make a crystal, you want to sort of minimize the number of chemicals in the process and also use conditions under which reaction rates are very high.

You want to use a very aggressive chemical reaction system. So for example silicon, if you want to deposit as a single crystal film, you are more likely to use S i H 2 C l 2 which I think we discussed last time. It is a high temperature process. You can use high temperature and get a nice crystalline film on the surface.

On the other hand if you are trying to make an amorphous silicon, then you are probably better off using the silane route, S i H 4 going to S i plus H 2. The reason is that in the case of

deposition of silicon from silane, you have, you used to use hydrogen as a carrier gas. Or in some cases you use nitrogen as a carrier gas.

It is possible to control the properties of the C V D film by changing the flow rate of the carrier gas. For example if you want to have less of a crystalline structure, then you would essentially use more carrier gas.

The H 2 or N 2 that is used as a flow gas can be absorbed by the C V D film and essentially its crystallinity and increase its amorphous character. So simply by playing around with volumetric flow rate of the carrier gas, you can actually impart certain characteristics to the film.

So again when you are using a C V D process to get a amorphous or a polycrystalline film, make sure that you design it as low pressure, low temperature process and use a carrier gas and use the concentration of the reacting species versus the carrier gases as one of the tunable parameters to get the physical properties that you are looking for, Ok.

Now when we talk about the various types of C V D films, that is semiconducting versus insulating versus conducting, each of these can have all three types of structures. You can have, you know, crystalline, polycrystalline and amorphous structures possible in each of these.

However when we talk about semiconducting films versus the, particularly the dielectrics or the insulators such as silicon oxide or silicon nitride. The insulating films are very unlikely to be in pure crystal form for one reason; they incorporate more than 1 atom.

So you really cannot have a single crystal structure when you are talking about dielectric it is a polycrystalline structure. But even there the crystallinity is not your greatest concern. You know, if you are growing a single crystal it is very important to have, to focus on getting that structure right.

But when you are growing a dielectric film on a surface you are more concerned about its physical or functional effects. For example if you are depositing S i O 2 on a surface, right? What are the properties you look for? Why do you do that usually?

Well it has multiple purposes depending on the application, it could be that you have a conducting surface and you want to make a certain region of it non-conducting, right? So it is essentially to provide a change in properties of the substrate.

So in that case, what your really care about is, how conducting or non- conducting the film is. It is also used sometimes for isolation purposes. Suppose you have a conductive substrate. And you want to have certain regions on it conducting but you want them to be separated. So then you would essentially put down the dielectric layer as a separator to isolate certain regions on the substrate.

Or it could be a barrier layer, you may want to have high conductivity in one region of your substrate but you may want to have very little conductivity on the remaining regions. Then this dielectric layer that you put down will act as a barrier and make sure that the conductivity is confined to the area that it is supposed to be confined to.

So when we talk of these oxides, in semiconductor manufacturing the primary purpose is to provide electrical functionality. However in other industries, these oxide coatings can be put on for various other reasons, surface protection against oxidation, corrosion you know, other types of surface damage.

In such cases, the more important properties of the surface oxide or its physical properties, how resistant is it to whatever is the aggressive environment that the substrate finds itself in. For example if it is a high temperature environment, then oxide layer that you have to put down has to be thermally resistible. If it is an environment with a lot of corrosive materials then it has to provide corrosion protection and so on.

And so the functional properties become more important than the crystalline structure of the film. Now S i O 2 is probably the most widely deposited C V D film among dielectrics,

followed by silicon nitride S i 3 N 4. In fact there are many companies that offer commercially C V D deposited S i O 2 films. They actually go by various trade names.

For example, Fairchild offers something called Vapox, Applied Materials offers, there is one called, what is that, Pyrox and there is one called Silox, so these are all trade names but essentially they are all silicon dioxide.

And in fact just down the road, Saint Gobain who has a research facility on OMR, who will soon be locating their research facility in research part, has coating called Reflectasol which is essentially a silicon oxide coating that they put down on top of glass in order to achieve certain critical properties of glass such as...

Basically what they want to do is they want to allow light in but they want to keep heat out in order to optimize the energy consumption in building. So this coating has a special property of virtually 100 percent light transmission but very, very low heat transmission. So for that purpose the C V D film of silicon oxide is extremely useful.

Silicon nitride on the other hand is actually being increasingly used as a replacement for silicon oxide because it has certain properties that are actually superior. It is more dielectric than S i O 2 so if it is the, you know non-conducting nature that is of interest to you, S i 3 N 4 actually is superior to S i O 2. It is also harder and refractory coating material.

So if you are using the, the coating for purposes of hardness, then S i 3 N 4 provides certain improvements. It is also a better moisture barrier. In general vapor transmission rates through silicon nitride are much lower than vapor transmission rates through silicon oxide. So that is the other reason.

In fact the only negative for silicon nitride over silicon oxide is flowabiliity. It does not flow; it cannot be made to flow as easily as silicon oxide. Now flowability is important when you are trying to achieve uniform coverage.

So the only deficiency that has been noted with silicon nitride is that, other things being equal the uniformity of surface coverage is not as good with silicon nitride as it is with silicon

oxide. Now when you look at the processes for depositing S i O 2 films versus S i 3 N 4 films, the dielectric films as I mentioned earlier are typically deposited at low pressures and low temperatures.

But even among that, there are grades. So for example if you are able to use the temperatures that are of the order of 600 degrees Centigrade then the preferred route to get to S i O 2 looks like this. So this is the, what I term the high temperature process for S i O 2 film.

Again when we say

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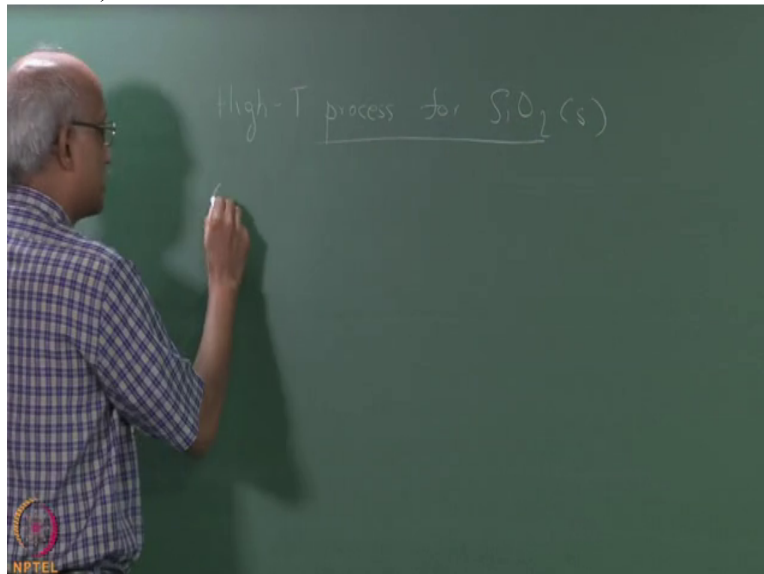

high temperature in this context we are talking about approximately

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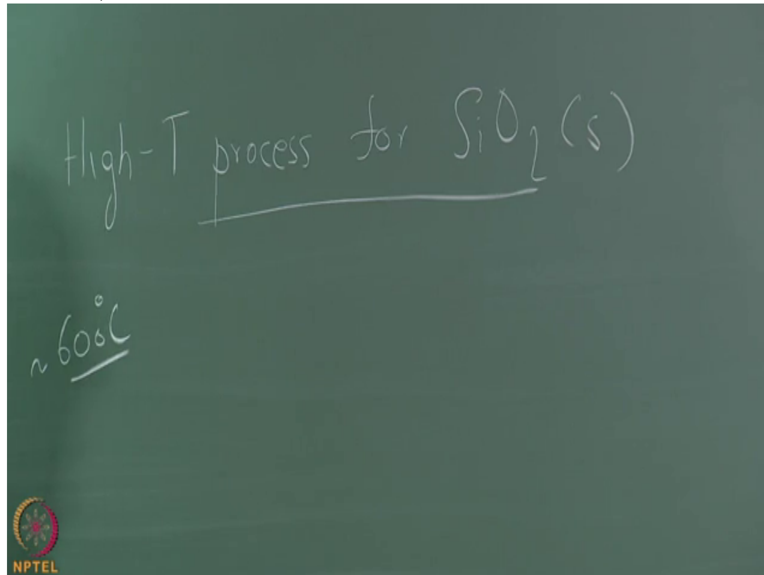

600 degrees Centigrade. So you do this by taking S i H 2 C l 2 and you react it with N 2 O, nitrous oxide

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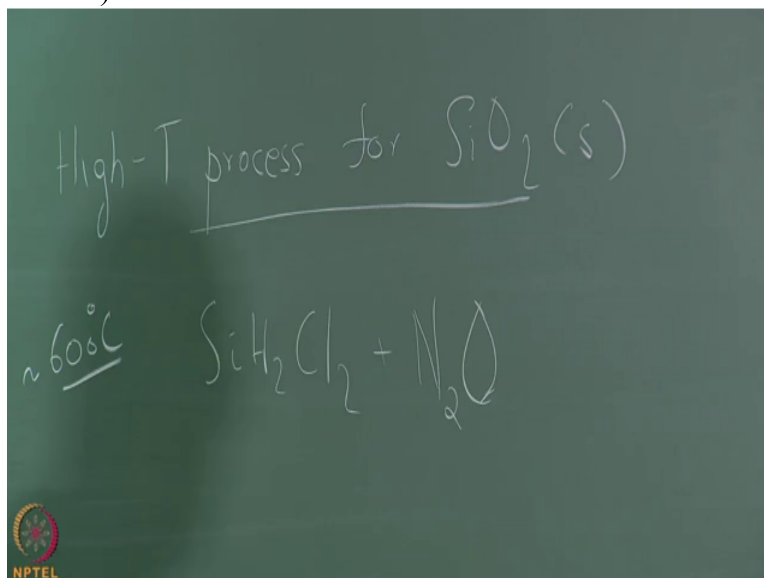

to get S i O 2 plus N 2 plus H C l where S i O 2 is the deposit.

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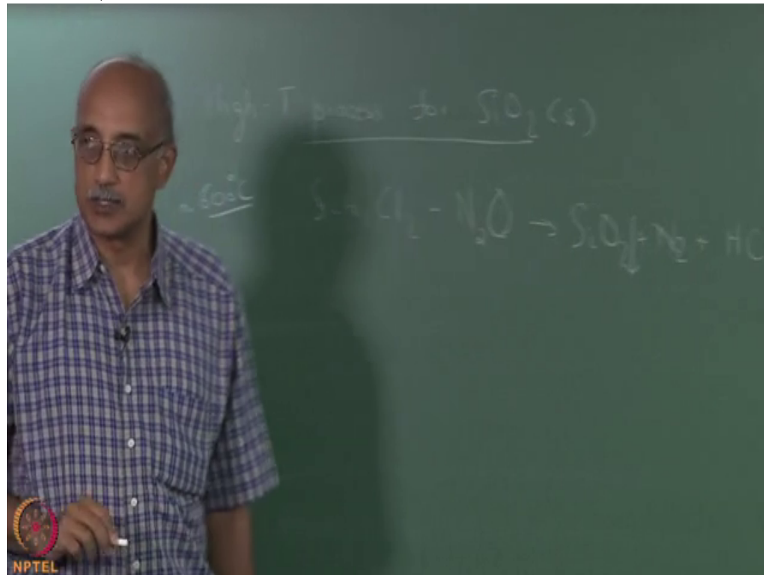

But actually the most common precursor to make S i O 2 film is T E O S which stands for tetra ethyl ortho silicate.

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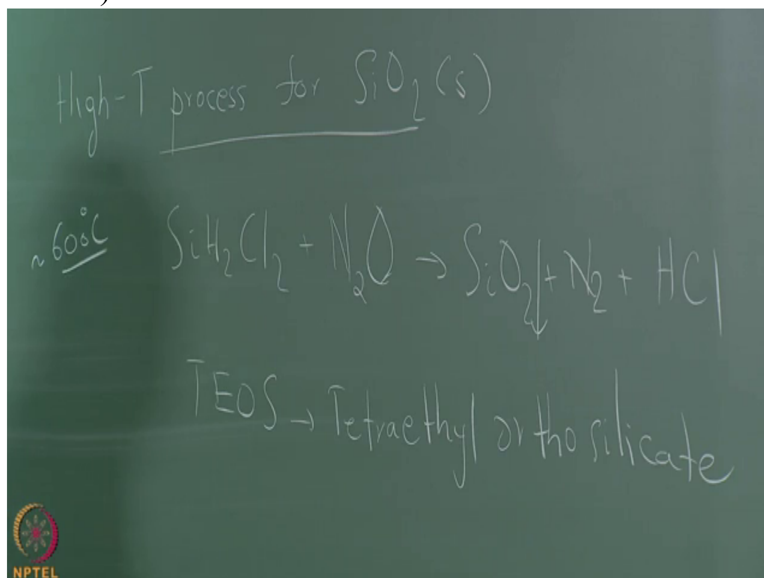

T E O S can be made, used to get S i O x films even at temperatures as low as 400 degrees Centigrade. So it is the lower temperature option.

Obviously this is what we would call a metal organic C V D process or M O C V D. This process is what we normally term L P H W C V D where L P stands for low pressure, H W stands for hot wall, again it does not necessarily mean the wall is heated. So what it means is that the substrate temperature and the reactor wall temperature are comparable. The reactor temperature or the substrate temperature is not much greater than wall temperature.

So this would be known as low pressure hot wall M O C V D, metal organic C V D. If you want to run the process at even lower temperature, for example if you are trying to put this down on say, aluminum

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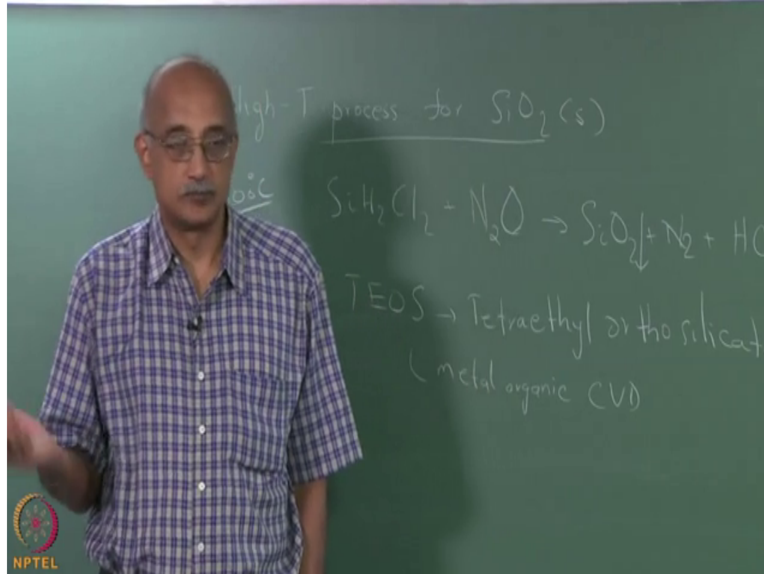

which is a metal that is very reactive and will oxidize even at the temperatures of the order of 400 degree Celvin/Kelvin, Centigrade, then around 300 degrees Centigrade you can use S i H 4 plus N 2 O plus N O 2 and run this over a plasma, Argon plasma to get S i O 2 as the deposit plus N 2 plus H 2 O.

So this is what we would call plasma enhanced C V D. So here because the temperature is essentially too low to provide sufficient energization of the substrate, you are relying upon impingement of the substrate with plasma ions to provide the energy increase.

So if you look at these 3 processes for making S i O 2

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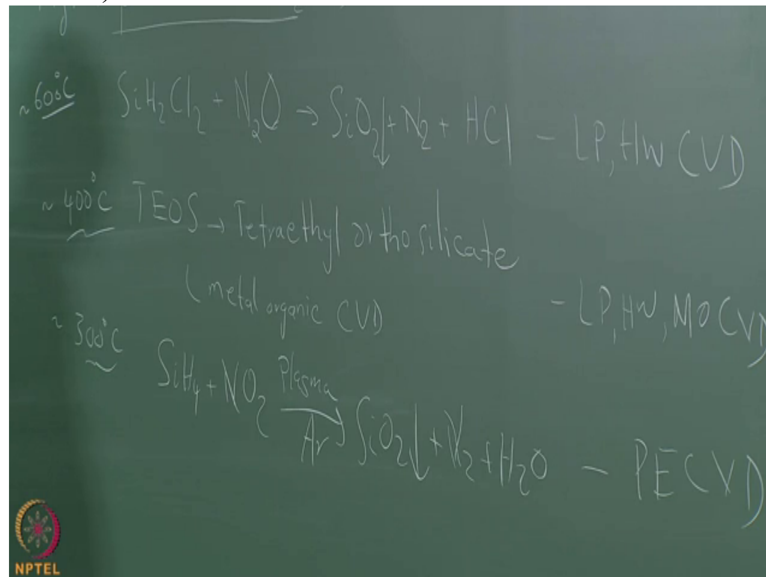

they run at different temperatures. They use completely different set of precursors. And even the source of energy is the same. So clearly the S i O x or S i O 2 film that is going to result will look very different in the 3 cases. And in fact as you go this way, is it going to become more amorphous or less amorphous?

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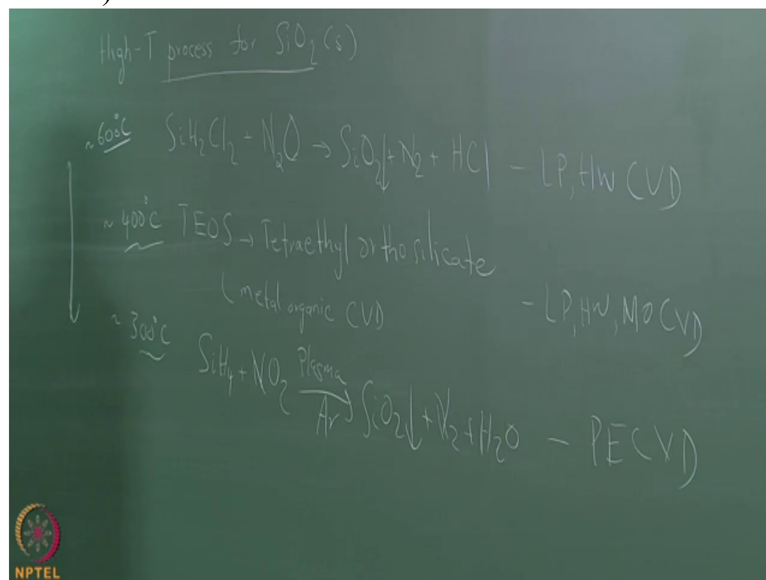

(Professor – student conversation starts)

Student: More amorphous

Professor: More amorphous, right? So depending on how amorphous you want the film to be, you can choose to operate at any of these operating regions.

(Professor – student conversation ends)

By the way if you want to make

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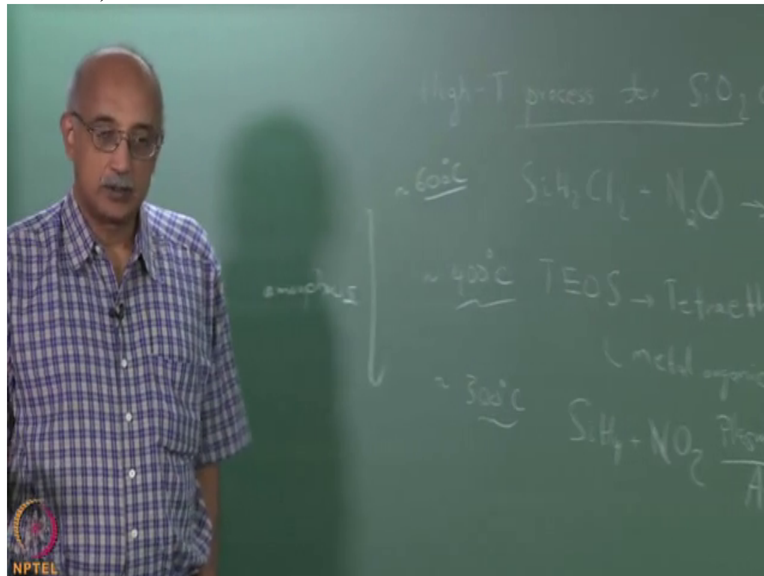

S i 3 N 4, again there are processes available at various temperature ranges but one of the processes that is widely used runs again at very low temperatures and typically involves S i H 4 plus nitrogen or it could also be N H 3, again under plasma conditions to make S i 3 N 4 plus N H 3.

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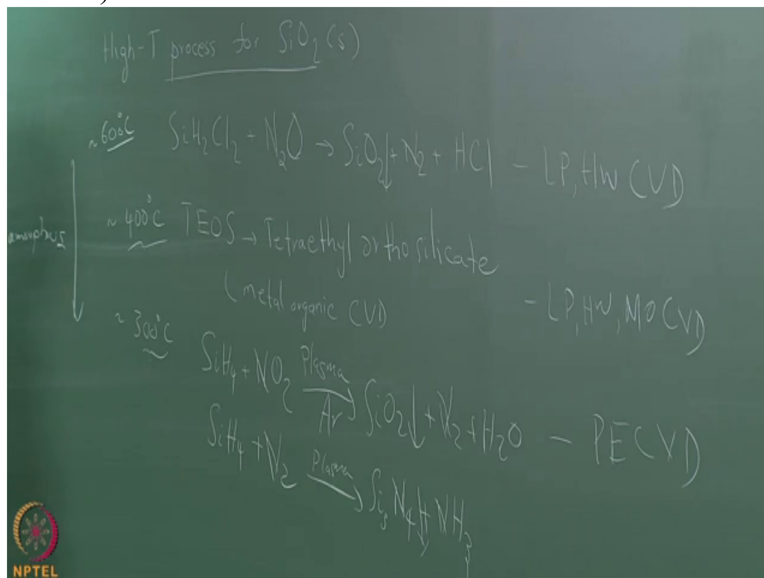

Now as I was mentioning very frequently these oxides and nitrides as they are laid down, do not have all the properties we are looking for. So we use additives to improve their properties or dopants as they are called.

And P H 3 or phosphene and B 2 H 6 boron hexa hydride are frequently used

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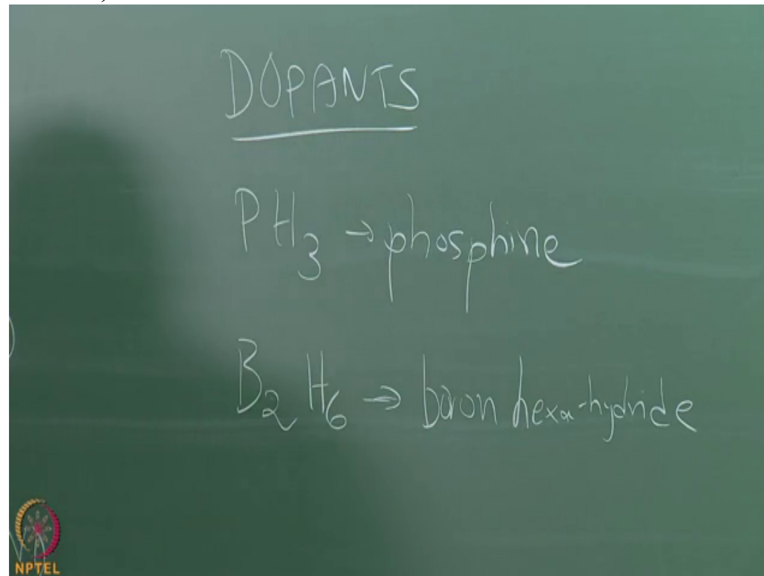

as precursor species or dopants in order to produce, as I was mentioning earlier P 2 O 5 and B 2 O 5 as the components in the film itself.

Now this kind of material is known as P S G, this is known as B S G where P S G stands for

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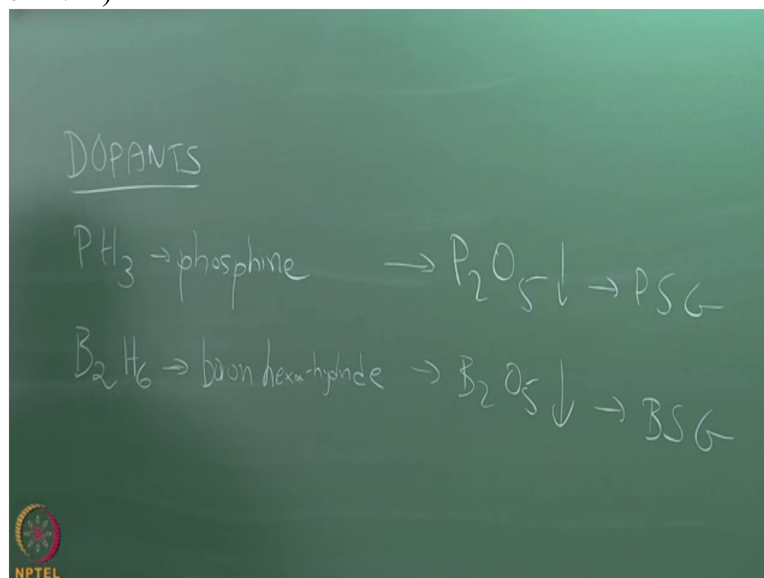

Phospho silicate Glass, so essentially take S i O 2, it is a silicate glass, add phosphorus to make phospho silicate glass and similarly you take S i O 2 and add boron to it to make boro silicate glass and in fact there are glasses that have both and those are known as B P S G which is boro phospho silicate

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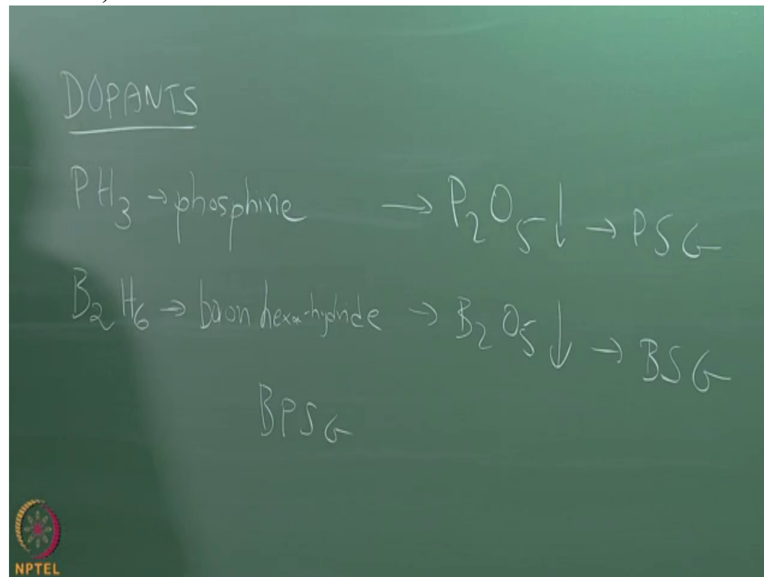

glass.

So all these are commercially available and again the reason you want to add these dopants to silicon oxide is a, to improve their moisture barrier properties. That is the number one use of these doping elements. Moisture barrier property improvement. The second one is that, they enable us to essentially 0:25:41.3 any ionic impurities that may be present.

So the boron and the phosphorus that are present in this glass matrix will scavenge any ionic impurities and prevent them from causing corrosion or other adverse reactions. So they improve the chemical inertness of the glass. And the third reason that you want to do this is to improve the flowability.

Again flowability is important for uniformity. Or another way to look at it is for planarization. If you are trying to achieve a planar film of the oxide and you want it to have a planarity which is as perfect as possible, the use of these dopants enables us to make the oxide flow by heating it to say, 1000 degrees centigrade and solidifying it.

So when you use this process of inducing the flow of the oxide and then resolidifation, you get a very uniform film if you use either of these dopants. When you use dopants you have to be careful to control their concentration.

For example with boron, if you use too higher concentration, in fact the limit is about 8 percent. If you use more than 8 percent of the boron additive or dopant, what happens is it makes the film hygroscopic. That is it actually starts attracting moisture which then reacts with the boron and you starts forming boric acid.

And similarly in the case of the phosphor additive, if you don't control the amount of phosphor properly, then essentially it can start acidifying and start forming H 3 P O 4 and both of these are obviously not desirable.

So you have to control the amount of these dopants in such a way that you get optimized behavior or properties of the, of the glass but at the same time you don't have an access of these things that can cause you a problem afterwards.

And again the point here is that, when you are trying to use these dopants and the idea is to incorporate certain materials into the oxide itself there is no way you can do this if the glass has a crystalline structure to it.

You can only do this if it has a polycrystalline or amorphous structure to it and therefore particularly in applications where you know that you are going to be using dopants it is better to, I mean it is pretty much a requirement that you have to run under conditions where the surface is highly, it is somewhat deformable so as to speak.

Now when we talk about, so far we have talked mainly about semiconductor films and dielectric or insulating films. The other kind of films that is frequently deposited on the surface is the conducting film such as a metal or metal composites.

Now when you deposit a metal film on a surface, what is the critical requirement, once again it is going to be that the metal must have characteristics that provide a certain functional property primarily. The structure once again is not going to be as crucial as in the case of the single crystal material that we deposit, which are usually semiconductors.

So metal deposition also is typically done under low pressure C V D conditions and hot wall conditions. The most commonly deposited metal is tungsten. Tungsten is a material that kind

of lends itself to C V D because it is a very reactive metal. So in a C V D system, if we introduce a species containing tungsten, the tungsten will quickly react with whatever elements are present in the system and form various, a whole family of vapor phase compounds.

And the whole trick to actually running a C V D process is to have a highly reactive system. If you have inert elements, obviously you cannot even do C V D right? Because you can only do P V D. So by definition the depositing element has to be highly reactive in order for us to even consider a C V D process. Otherwise just use physical vapor deposition or other means of making that film happen.

Tungsten because it is a highly reactive metal, is highly suited to C V D and in fact, there are two mechanisms by which you can deposit tungsten on a substrate. So in a C V D reactor with a substrate, let us say that you have a silicon substrate and you want to make a tungsten film

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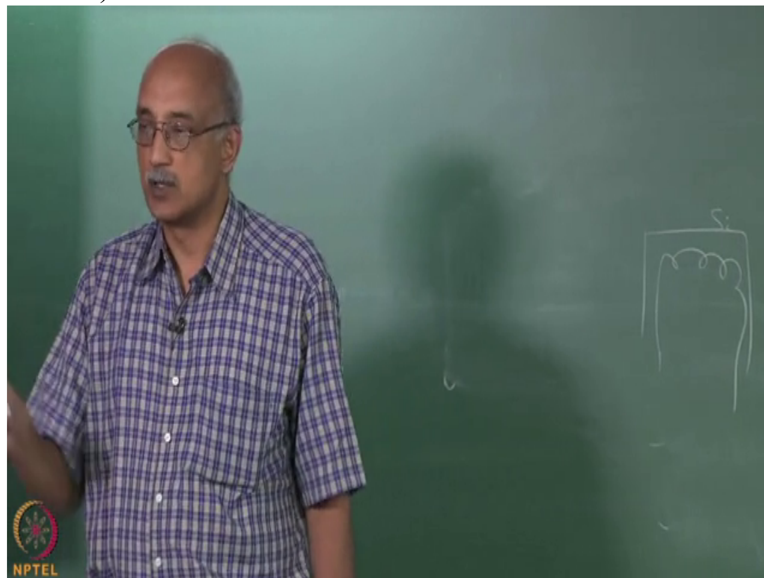

on top of the silicon, right?

So you have a reactor in which you are flowing the gas. So let us say that you are using W F 6,

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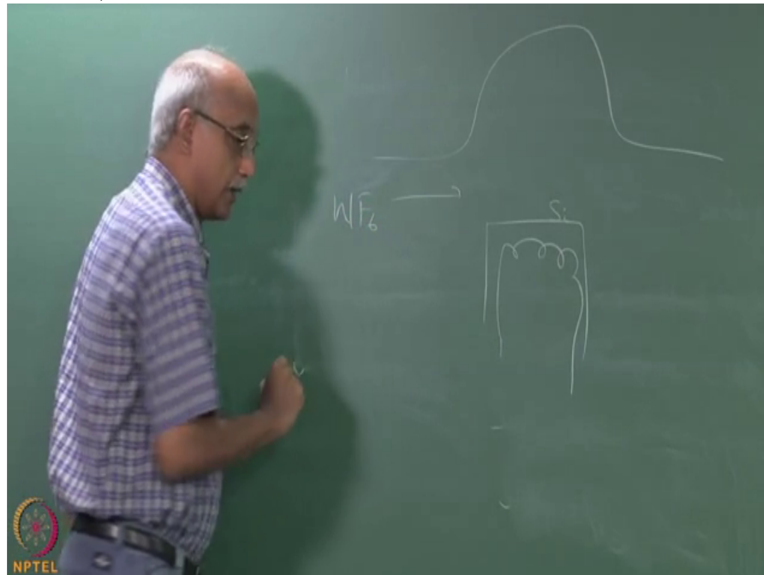

tungsten hexa floride as your precursor for the C V D. The deposition can be done through a heterogeneous reduction process or through a homogenous reduction process.

So in the case of heterogeneous reduction process, this W F 6 will actually react with the S i substrate itself and make W plus S i H 4 plus H 2.

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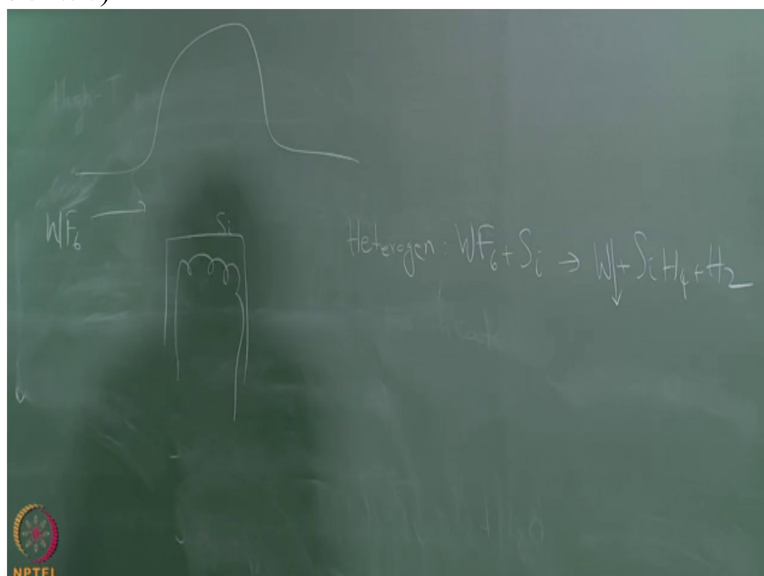

So tungsten compounds are sufficiently reactive that they can chemically interface with the substrate itself and have the deposition happens at the surface.

So in this particular case, only W F 6 really gets transported through the C V D reactor. The substrate, the silicon is the substrate itself so it is not something that is being introduced as a reactant into your system.

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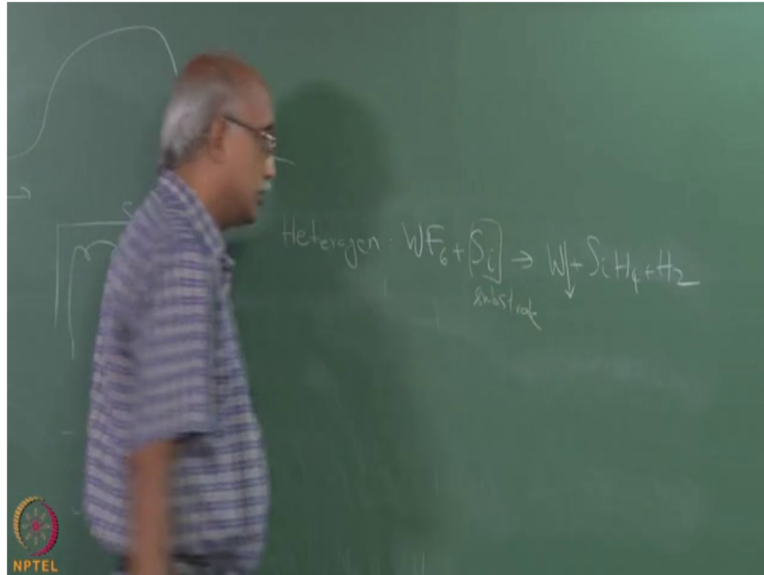

The reduction happens right at the substrate when you deposit the tungsten.

Now is this actually C V D or is it more like P V D? Well, strictly speaking it is C V D because the film has a different composition than the reactant gases. However in the gas phase itself, there is no necessarily, you don't have to have chemical reactions taking place. The W F 6 can stay as W F 6 until it reaches the substrate and then react at the substrate.

An alternative method for doing this, which is, I would call more classical C V D is when you take W F 6 and you react it with, let us say hydrogen to make again W plus H F in this case.

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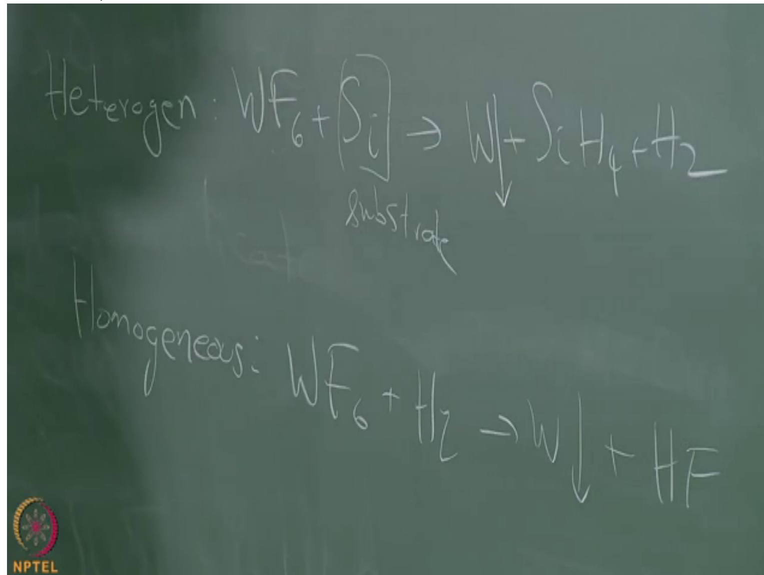

So the advantage here is that the nucleation process will occur in the gas phase itself and the deposit will form on the surface.

The real advantage of this is that you don't, the W F 6 does not have to stay as W F 6.It can be transformed into various chemical species in the C V D reactor. They can react among themselves, as long as the end result is the formation of the tungsten deposit, we do not care, ok. The drawback to this, what is the main drawback to this process that you can see?

(Professor – student conversation starts)

Student: 0:33:42.4

Professor: Yeah, H F is the, you know, byproduct. So not easy to handle and so you have to provide appropriate protocol to make sure that the H F is captured and not emitted into the atmosphere. And the other drawback to this approach is, as I mentioned earlier, homogenous nucleations are always more difficult, or homogenous reactions require more energy to drive than heterogeneous reactions.

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So this process can be run at a lower temperature compared to this process

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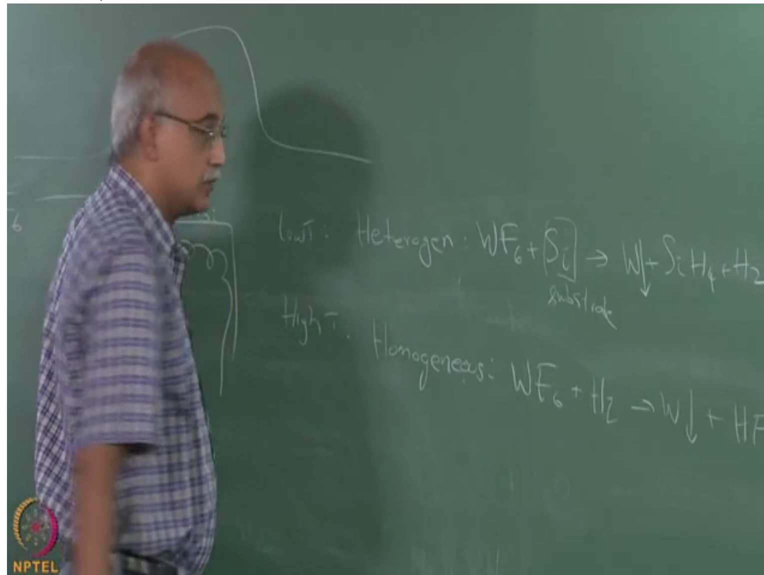

which would need to be run at a higher temperature. But on the other hand, if you are trying to grow a thicker film, you know, depends on how thick you want the tungsten film to be, if you want a very, very thin film, you are better off using this approach where you can use a low temperature process.

On the other hand if you are looking for high rate of growth, high rate of deposition of the tungsten film then you are better off using a high temperature process. Now in addition to tungsten, other metals that are commonly deposited using C V D include aluminum, copper, aluminum copper composites, tungsten carbide composites, titanium nitride composites, so many of the metals and

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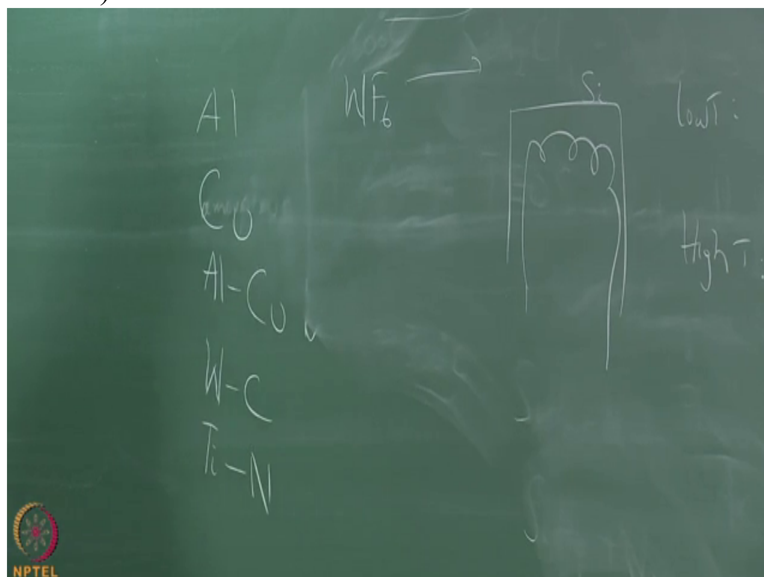

composite materials that are used particularly in highly demanding environments, for example very high pressure or very high temperature environments.

You follow this process just like with epitaxial silicon, you may want to take an existing aluminum substrate and on top of that you can lay down another very thin film of aluminum using C V D which can have very controlled properties.

The other advantage of C V Ds for making composites is, all this requires is, is if you want to , for example make let us say, aluminum copper composite, then all you have to do is to have 2 precursors that carry aluminum and copper. The process kind of handle happens automatically.

They deposit that forms as long as you have controlled the reaction conditions properly will include aluminum and copper as a composite material. You don't have to do any manipulation at the film level, right and that is a huge plus because the other way of making films which is essentially what is known as molecular self-assembly requires that you first realize molecules of the material on the surface and then custom arrange them so that they have a certain structure, they have a certain form and so on. So these are like designer materials.

Now it sounds very good but in practice, it is very difficult to achieve. Because you are talking about manipulating materials at atomic levels or molecular levels; a, this requires a very high degree of precision which implies high cost and b, it requires very high purity also. You cannot have any foreign substances present.

A C V D process for making these films on the other hand is much more forgiving because any impurity that is in the system, it should not be in the substrate. There is a good chance that it will react with other species that are present and essentially become a byproduct which can be exhausted from the system.

So a C V D process for making thin films is much more robust process, in that it is much more forgiving of certainly impurities that are present in the system and even temperature and pressure excursions. As we saw last week, you know I drew a diagram of rate of film formation or rate of deposition as a function of temperature; you can choose to operate your

reactor in a region where you can minimize the dependence of the process on the controlling parameters.

So depending on whether you have the best control over your pressure or your temperature or your flow gases, you can essentially choose your reactor to operate in a suitable region. If you remember the diagram that we had last week,

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and we look it now in the context of where would you grow various types of films Ok, so what I plotted was 1 over temperature versus logarithm of deposition rate or rate of film formation.

And the typical curve look like this, right? And we said

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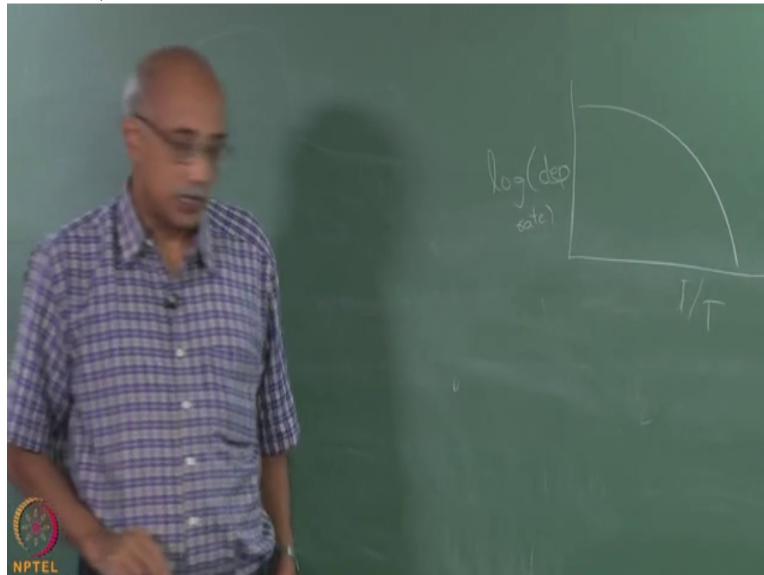

that in this region, that is high temperature region

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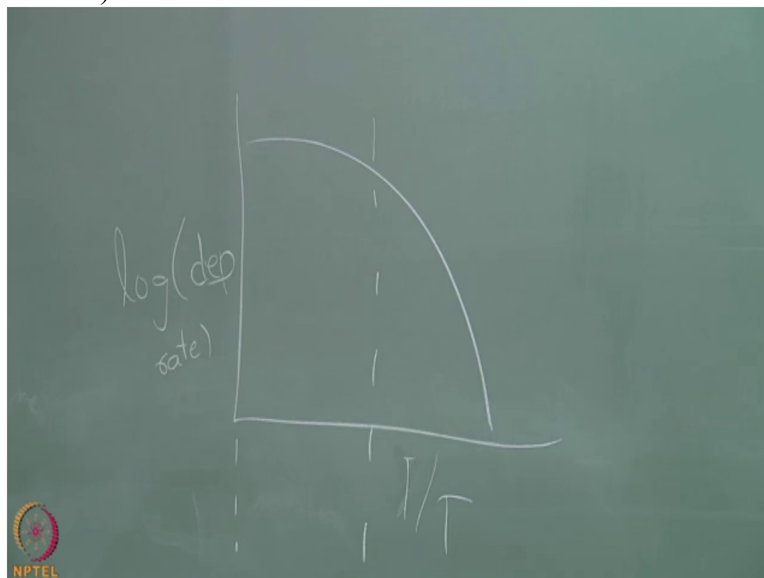

you are transport controlled. And in this region you are kinetically controlled. So let us say that

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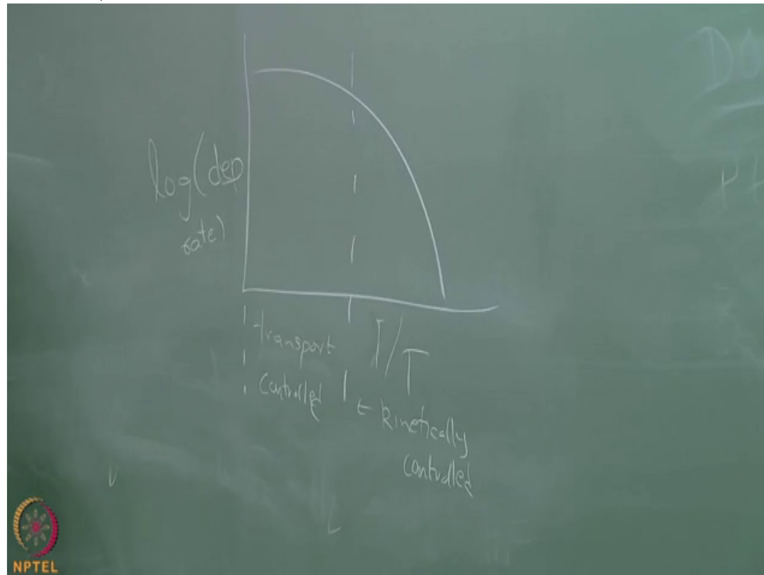

you want to make a crystalline film, a single crystal epitaxial film. Where should you be on this graph? Should you be on this side or this side, left or right? How many vote for left?

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Why?

(Professor – student conversation starts)

Student: 0:40:01.3

Professor: Temperature is higher but is that the only parameter?

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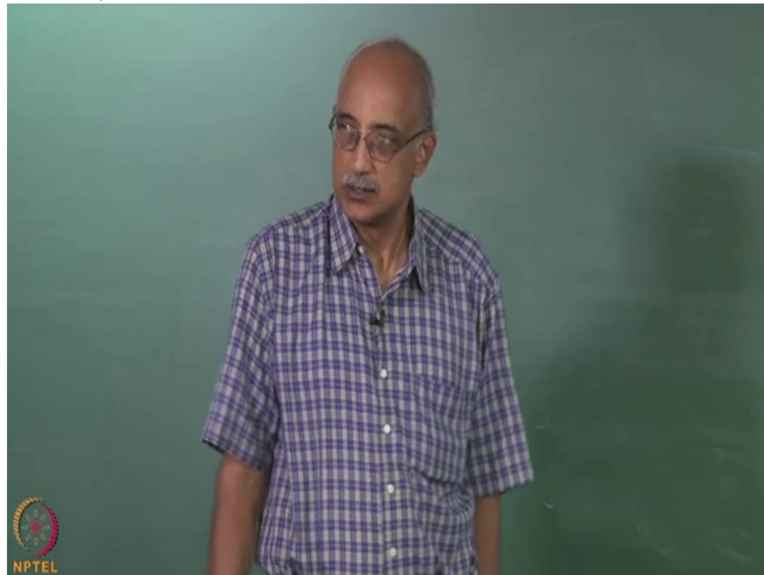

Student: 0:40:06.7

Professor: See what you also have to think about is, I think we discussed this, that we also have to think what is the controlling process. When you say transport is controlling, what it means is that you have to essentially do a single substrate at a time. You cannot take a whole bunch of parts and put them in, right?

(Professor – student conversation ends)

So a single substrate, the answer is correct. I mean you want to operate in this region for crystalline structures but the primary reason that... there are multiple reasons.

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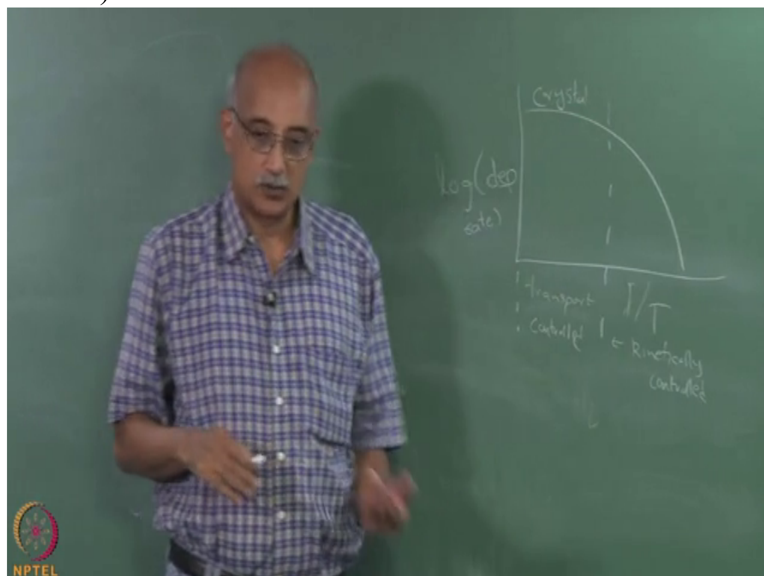

The first reason, the high temperature certainly helps in giving that crystal structure but the other factor is that you are, you have essentially in this temperature region, you have tight control over the transport process itself. And therefore you can, you have much better control over the composition and uniformity of the film that you are forming.

In this region, I mean this is basically where your polycrystalline or amorphous films will be grown.

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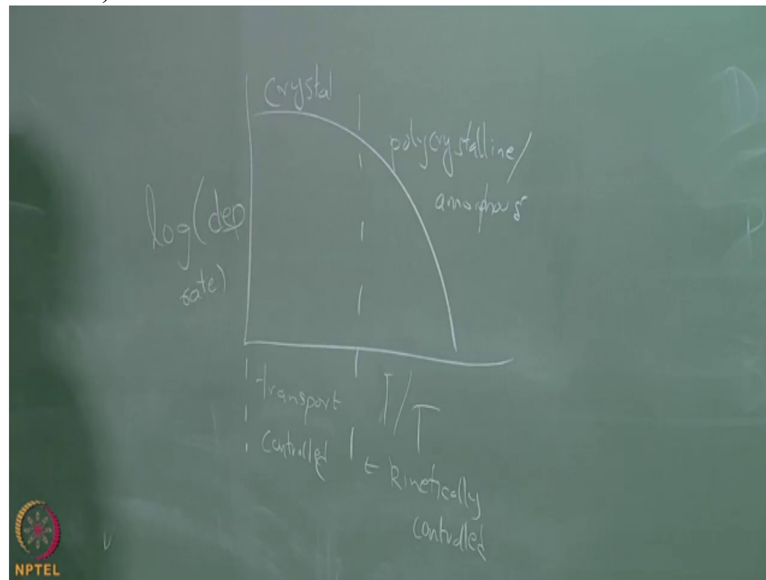

The temperatures are kept low enough that even small variations in the temperature can have significant influence on the nature of the film. So in this region you have to make sure that you have very tight control particularly over the temperature distribution in your reactor but flow itself is not a big factor.

So this region again lets itself to processing of multiple substrates at one time. From a cost viewpoint, which is better? Right side, right? So this is essentially a high quality but high cost region and this is low quality but high volume, we can do a lot of products on a daily basis.

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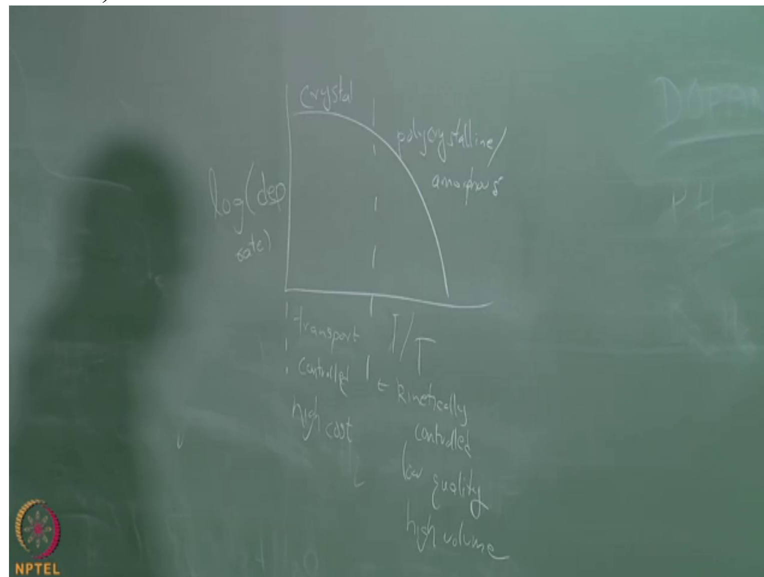

How about semiconductors versus insulators versus metals, where would you like to be? Again for semiconductors most of the time you are looking for a very crystalline structure because of the types of applications they are used in. So semiconductor C V D is typically done in this region where temperature essentially does not have a significant influence on the deposition rate where as your dielectrics and conductors are more likely to be deposited

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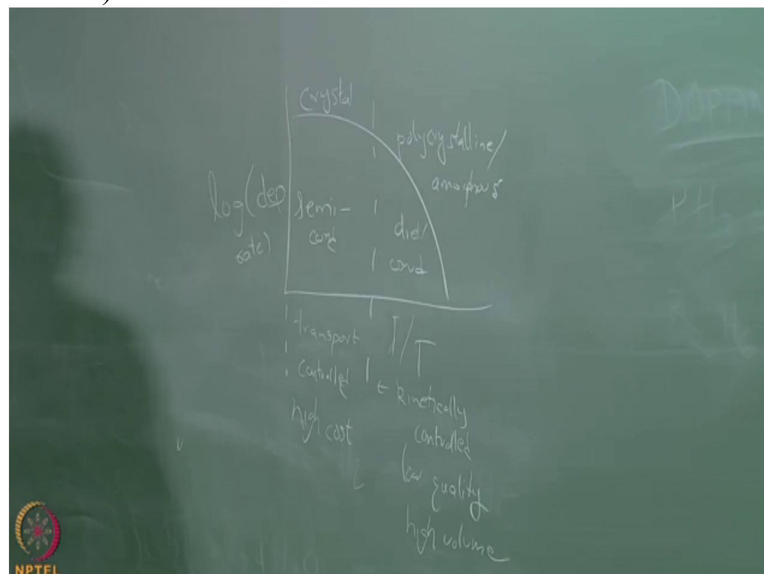

on the right side of this curve.

So what effect would pressure have? Suppose I ask you, sketch this curve if I change the pressure, if I reduce the pressure by half. What will it do to this curve? Will it move up or

down? Will it be the same in both regions or will it be different? So let us take this region, Ok.

Suppose I lower the pressure by 10 times. Will it increase the deposition rate or decrease? It is transport controlled, right? So what is the transport properties that is affected by pressure? Diffusivity. And as pressure decreases, diffusivity will increase.

So in this particular case, as you lower the pressure you will actually see an increase in the deposition rate. So, the deposition rate will increase as, but how about here?

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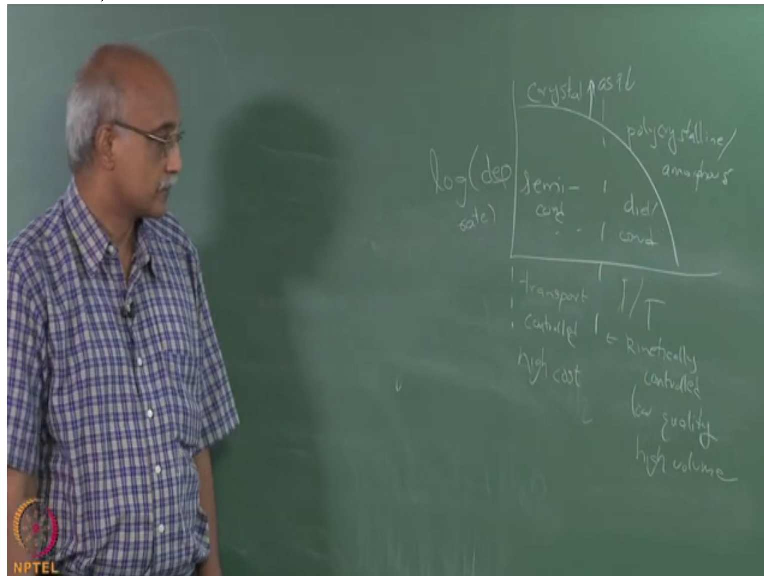

Lower pressure would make kinetics run 0:44:11.1 even slower, right? So it will have the reverse effect.

The process will slow down and film may not even happen if pressure is too low. So here the deposition rate decreases as pressure decreases. So overall if I want

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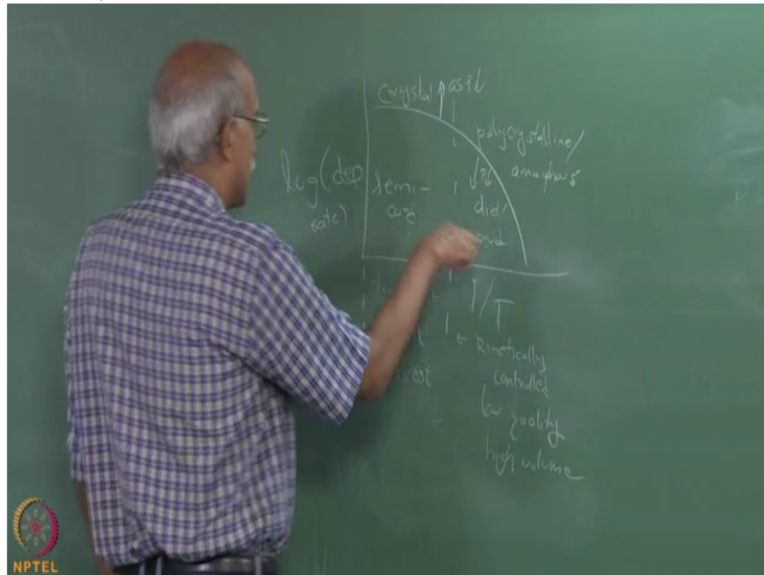

to sketch the effect of pressure on this curve, and this may be one of the questions in your quiz, we have to know these qualititative dependences right, so it may look like, you know something like this.

Will the dew point change in this case,

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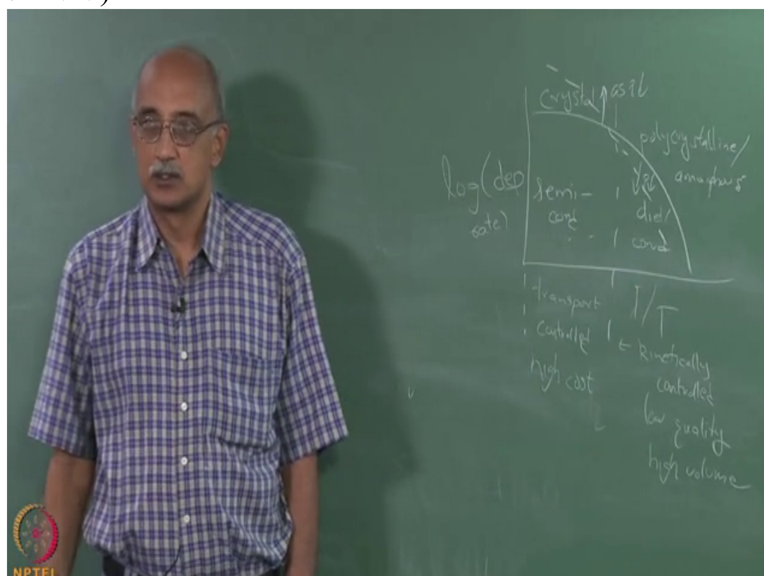

if you are playing around with the pressure? The dew point is a thermodynamic parameter. So yes, pressure and temperature will play a role on the dew point. So yes, it will change and most likely the dew point will move to a higher temperature. What does that mean; makes it more difficult to deposit, right?

What are the other parameters we can vary? Temperature, pressure, I think, yeah, I think last week we discussed the effect of concentration, right. If you change the concentration of your reacting species, if you double the concentration, what will happen to the deposition rate?

In that case, in this region, in the transport controlled region you will see a corresponding increase in the deposition rate because it is transport controlled but in this region, you would still see the effect, I mean it will still increase but as you start approach the dew point, it will start converging. So I think that dependency we already talked too last time.

So I think, if you are getting a general sense overall of C V D, I think the most important takeaway is that you really have to have a good understanding of the thermodynamics, the kinetics and the transport phenomena in order to be able to design a C V D reactor effectively and cost efficiently for the application that you are driving, Ok.

The properties of the film are obviously important and again they can be divided into functional properties and non-functional properties. And as I mentioned in the last class, the functional properties may be easier to measure but, but it is the physico-chemical properties of the film that ultimately yield the functional properties.

So you really cannot do process optimization simply measuring the functional properties. You have to be able to measure the physical and chemical properties of the film. So starting in the next lecture, we will talk about certain methods of measuring the properties of films.

First we will talk about the functional measurements and then we will talk about the non-functional measurements. Another way to think about it is qualitative versus quantitative. Qualitative characterization is good, well it is necessary but not sufficient. The quantitative characterization is what you need in order to maintain tight control over the process.

So we will talk about some methods of qualitatively characterizing C V D films and quantitatively characterizing C V D films and after we do that, I think we would have covered most of the background material and we will really start focusing on the transport processes that are happening in a C V D reactor particularly the mass transport process. Any questions? Ok see you in the next lecture.