Processing of Semi Conducting Materials
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Lecture - 19
Chemical Vapour Deposition-I

Chemical Vapour Deposition, as the name it see implies you see from the you graph the reduce the Chemical vapour deposition or in sought.

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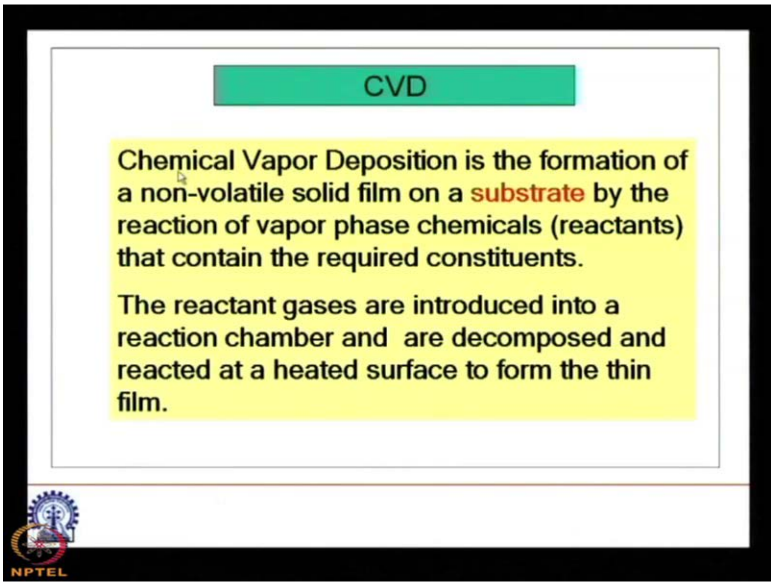

CVD

Chemical Vapor Deposition is the formation of a non-volatile solid film on a substrate by the reaction of vapor phase chemicals (reactants) that contain the required constituents.

The reactant gases are introduced into a reaction chamber and are decomposed and reacted at a heated surface to form the thin film.

It is the CVD, is the formation of a non volatile solid film on a substrate, by the reaction of vapour phases chemical. This vapour phase chemical basically, they are the reactants that contain the required constituent. So, one thing is that you have to have a substrate on which the film will be deposited and there will be, chemical reaction and this vapour phase of the chemicals, they will be subjected to some reactor which is known as the CVD reactor. And the chemical vapour deposition we will takes place.

The reactant gases are introduced into a reaction chamber and are decomposed and reacted at a heater surface to form the thin film. So, another important point is that there must be heated surface; that means, the substrate must be heated, so one thing is that you must have a substrate, second thing is that the temperature will be high because, the substrate will have to be heated. So, on the substrate there will be some decomposition of the constituent chemicals right.

Suppose, you want to make a silicon thin, so then what you have to do, then you have to have some chemicals containing silicon, say silane. Silane is a chemical containing silicon, that silane will have to be injected in the reactor chamber by means of some vapour. So, you have to make vapour of that saline, you have to injected in the reactor and there must be a heated surface; that means, there must be a substrate, for silicon thin film generally the if you have to make some apetectual film.

Then, what should be the substrate silicon, for silicon what should be the substrate for repitectual film deposition, silicon the best option is to use the silicon, then you have to use the silicon substrate and then you can have silicon epitaxy film in it.

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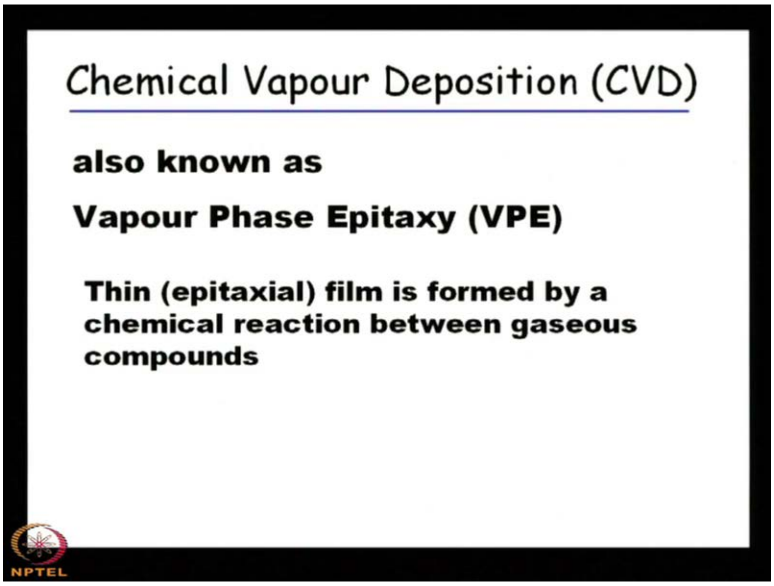

Chemical Vapour Deposition (CVD)

also known as

Vapour Phase Epitaxy (VPE)

Thin (epitaxial) film is formed by a chemical reaction between gaseous compounds

Now, this chemical vapour deposition, which is also known as the vapor phase epitaxy, you see that it is also known as the VPE Vapour Phase Epitaxy. So, that means that when you when you like to make some epitaxial film, then it is known as vapour phase epitaxi. Otherwise, permanently you can tell it as CVD the same thing, only thing only difference is that, if you use to make a make some epitaxial film out of CVD process, then that is known as the VPE. So, one important aspect of this CVD is that, you can make epitaxi out of CVD.

Because, we are discussing about the epitaxial technique of film growth and in our last class we have covered liquid phase epitaxy. And in the next day we shall cover the molecular epitaxy, today we shall devote our attention on the Chemical Vapour Deposition or the CVD.

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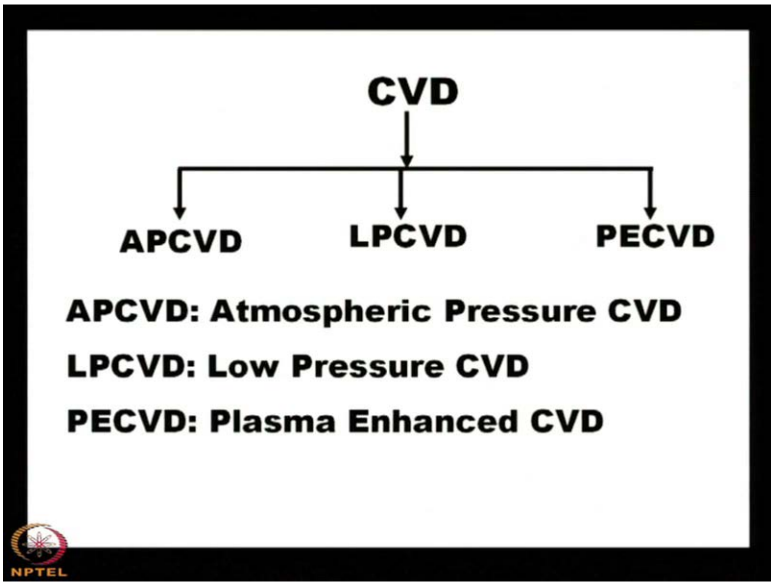

APCVD: Atmospheric Pressure CVD
LPCVD: Low Pressure CVD
PECVD: Plasma Enhanced CVD

This CVD can be of three types, you see that one is APCVD or the Atmospheric Pressure CVD, another is the LPCVD Low pressure CVD and third one is the Plasma Enhanced Chemical Vapour Deposition. So, broadly you can define CVD into three types of technique one is, LP Low Pressure, another is AP Atmospheric Pressure and third one is the Plasma Enhanced. So, as the name implies you see that, in atmospheric pressure CVD your CVD reactor will be in the atmospheric pressure.

So, what you mean by the CVD reactor, CVD reactor will will be a quartz tube type of thing, it is you have seen the reactor for the diffusion you you have seen the reactor for the diffusion, for the oxidation or ion implantation.

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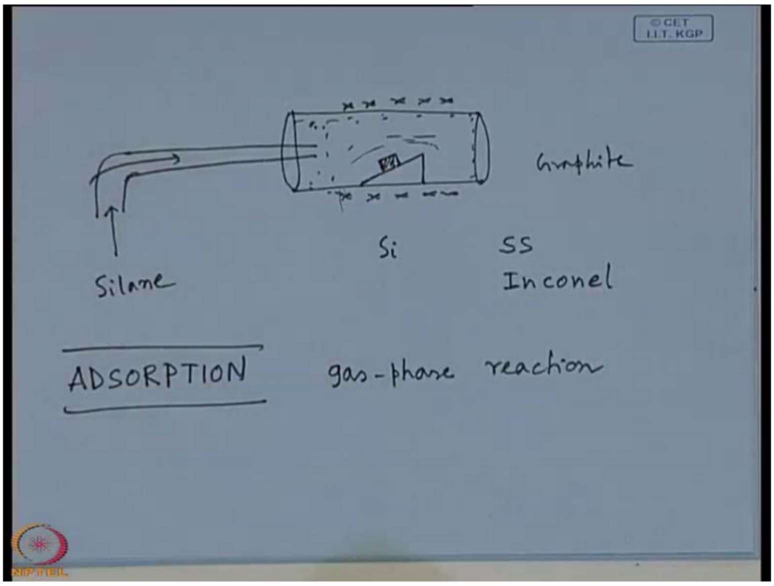

So, almost the same type of thing say, this is your quartz tube reactor this is a reactor here, this is the subsector, what is the subsector. Subsector is basically, the equivalence of crucible in bal crystal growth, in bal crystal growth we have used the, crucible. Here, we do not use the crucible instead we use the subtract, subtract is a graphite block, it is a graphite block on which the substrate is placed.

So, now, one question arise that if your gas or the vapour content oxygen then whether you can use graphite block as subsector, no you cannot because, at that temperature oxygen will react with the graphite right. So, if you use a gas or vapour which contents oxygen, than what are the subsectors we can use material, no it is basically the stainless steel which are used one thing. Another is the inconel, inconel you know that it is basically an alloy, which can, which stand very high temperature without it is degradation.

Because, you cannot use any thing which will react at that temperature with oxygen. So, one thing is the stainless steel SS, another is the inconel, one is the stainless steel another is the inconel that you can use. On the subsector you have to place the substrate, so this is the substrate, this is substrate which is placed on the subsector. And then through this gla gas simulate, you have to send the various kinds of gases, which you need for a particular type of plane position.

So, if you would like to make silicon, then what type of gas you have to use, say silane you can use an example. So, you have to inject silane which will be decomposed in the reactor chamber, then where should be the heating elements, the heating elements will be outside the reactor chamber. We, want to heat this subsector and this substrate; that means, if it is better if you can heat it locally, why, why the local heating is recommended.

It is because, if the whole volume of the reactor chamber is heated then before reaching onto the substrate surface, reaction will start reaction will start. So, on different parts of the reactor chamber, there will be the reaction there will be reaction, that will be a lost for you material will lost because, you want the film to be grown on the substrate surface only. So, that is the reason that you have to control the temperature in such a manner.

So, that the maximum heating takes place on the substrate region you cannot abide, but in those cases, in those parts of the reaction tube, the heat can be kept at a minimum level. So, that no reaction takes place that is known as the gas phase reaction, when it enters the reaction chamber we want to abide the gas phase reaction. In CVD what happens, adsorption takes place what is adsorption do you know what is adsorption have you heard the term adsorption, ADSORPTION have you heard the term adsorption what is adsorption.

Yes, very good atoms or molecules atoms or molecules arrangements of atoms and molecules on some far phases of the material that is known as the adsorption. So, in CVD the first stage of the film formation it is the adsorption, first the atoms or the molecules of the in case in this case the silicon, will have to absorb on the surface of the substrate then they will react. So, during reaction what will happen, some solid material will be found those are known as the nuclease.

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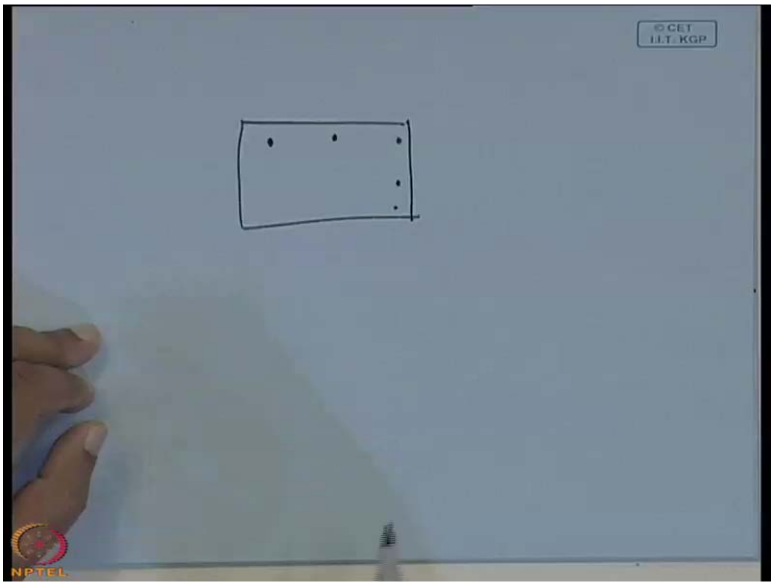

So, if this is yours substrate say on which the silicon will have to be grown, first there will be adsorption n the substrate surface. Then at that temperature some reaction will take place and in some parts, there will be some solid material that will be formed on the surface of the substrate. Though solid material will act as the nucleation of growth, that is the nucleation of growth, they will actually from the nuclease for the whole growth.

Then this nucleation sides with time passes, they will grow the will coagulate and finally, a film type of appearance will be absurd on the surface on the substrate. So, first thing is the adsorption, then there will be the decomposition of the various constituent gasses which are in the vapour phase at that temperature, some solid materials practical's types of thing will be formed, which will act as a nucleation site for the formation of the whole crystal. When we talk about the thin film basically it is a crystalline phase, it is a single crystalline film.

If the lattice constant of the material, matches will with the lattice constant of the substrate then you can say that it is an epitaxial film. In this case in semiconductor technology, the films are very thin of the order of some micron, in some cases less then that some angstroms, nanometer type of thickness is required. So, when we talk about APCVD; that means, the Atmospheric Pressure CVD or LPCVD.

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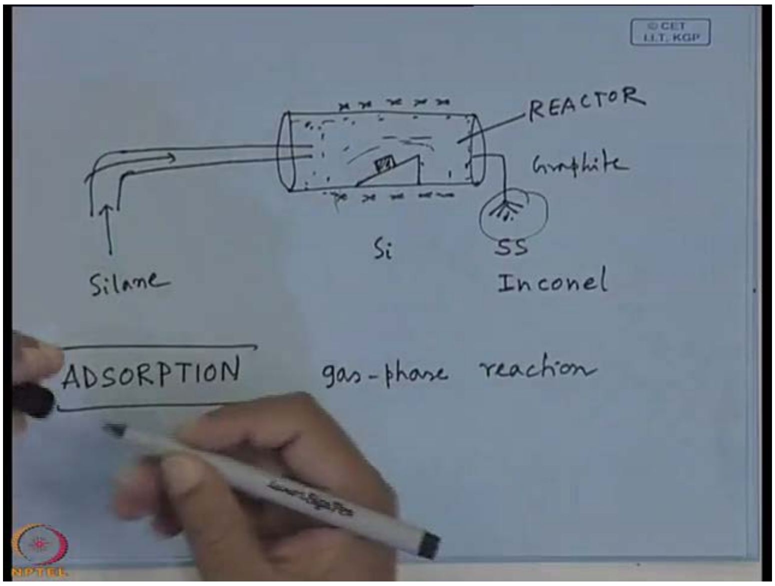

That means, these reaction chamber; that means, these is known as the reactor, this reactor will have to be kept in atmospheric pressure for APCVD, if it is kept at a lower pressure it is known LPCVD, but in PCVD as the name implies some plasma kind of arrangements must be there. Now, what is the difference these AP LP and PECVD is there any difference, why we shall deserve to LPCVD, if APCVD is sufficient why because, you know that for LPCVD you have to use some backward missionary here.

What is the difference APCVD and LPCVD, APCVD you need not to bother about the backward because, it is the whole atmosphere the pressure inside or the outside will be the same, but when you talk about LPCVD; that means, the pressure inside the reactor chamber will have to reduce, but how the how it is reduced it is reduced by some pumping arrangement. So, when you need some pumping arrangement; that means, the system becomes expensive, one thing, another thing is that it becomes complex.

So, why will go for LPCVD and another thing is that for PECVD more attachments are required, more attachments means, some gas must be there, inside the reactor chamber that gas will have to be converted into plasma, for plasma you know that high voltage or radio frequency bias is required which is very costly also and the system becomes more and more complex. So, now, we shall compare the characteristics of the film grown by these three types of process you have any question.

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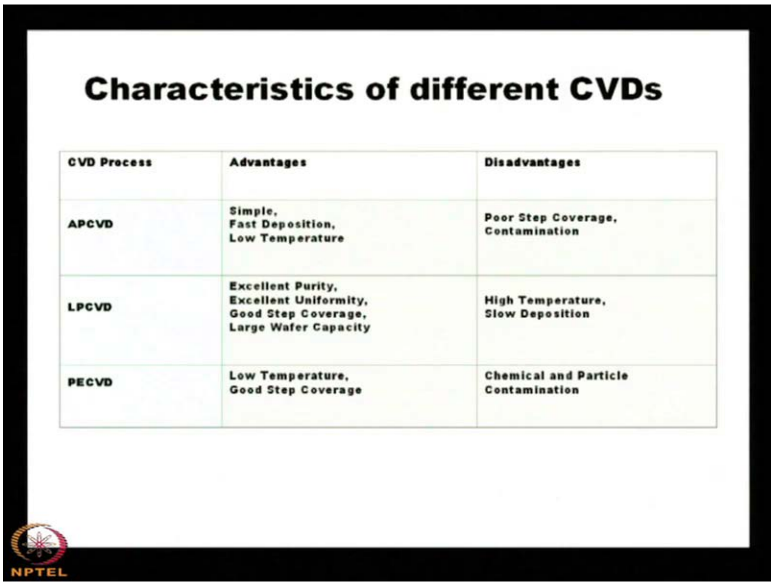

Characteristics of different CVDs

CVD Process	Advantages	Disadvantages
APCVD	Simple, Fast Deposition, Low Temperature	Poor Step Coverage, Contamination
LPCVD	Excellent Purity, Excellent Uniformity, Good Step Coverage, Large Wafer Capacity	High Temperature, Slow Deposition
PECVD	Low Temperature, Good Step Coverage	Chemical and Particle Contamination

This is the characteristics of different CVD technique, I do not know whether you will be able to see it for atmospheric pressure CVD you see that the advantage is that it is very simple, it is very simple APCVD.

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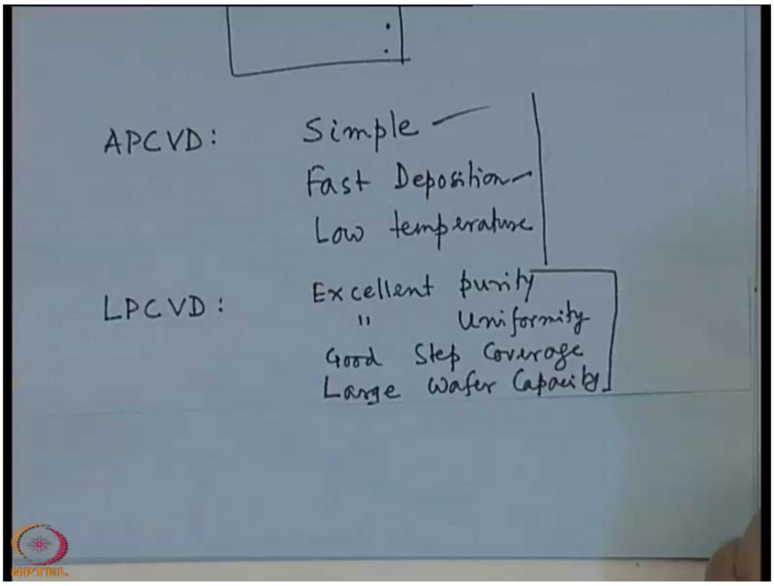

APCVD: Simple
Fast Deposition
Low temperature

LPCVD: Excellent purity
" Uniformity
Good Step Coverage
Large Wafer Capacity

It is very simple fast deposition; that means, the growth rate is very high, fast deposition and low temperature, so this the advantage of APCVD. Now, if you go for the LPCVD excellent purity, excellent uniformity, good step coverage and large wafer capacity. So, what is the difference you see, the difference is that in atmospheric pressure CVD it is very simple that you all understand. The deposition becomes fast in APCVD, in LPCVD it is not, so faster why for LPCVD it is not faster yes because, it is a low pressure growth it is a low pressure growth.

So, it will be a slow process because, there will be when it is low pressure; that means, continuously you are sorting something from the reactor chamber to the scrubber, scrubber means where the vast product or the materials are bound before airing top atmosphere. And in APCVD it is the low temperature you can use, in LPCVD temperature is not low, it is high temperature that we can use why ,because, if the pressure is low then temperature must be high, to crack the vapors for reaction, suppose you are using a arsenic.

So, you have to crack arsenic, cracking arsenic means you have to crack arsenic into arsenic molecules and hydrogen molecules. Suppose, you are using phosphine, so you have to crack the phosphine, phosphorus and hydrogen into phosphorus and hydrogen. So, for cracking you must maintain a temperature because, the cracking efficiency is different for different materials, another problem is that when you reduce the temperature a pressure, then you have to make the temperature higher.

Because, of the cracking efficiency to be higher, in LPCVD we have written that the purity is excellent why the purity is excellent because, it is evacuated the reactor chamber is evacuated. So, if you evacuate something; that means, there is no air inside if there is no air inside; that means, the purity level be higher. So, there is some advantage and another important aspect is that, it will it will have good step coverage what is step coverage, what you understand by step coverage.

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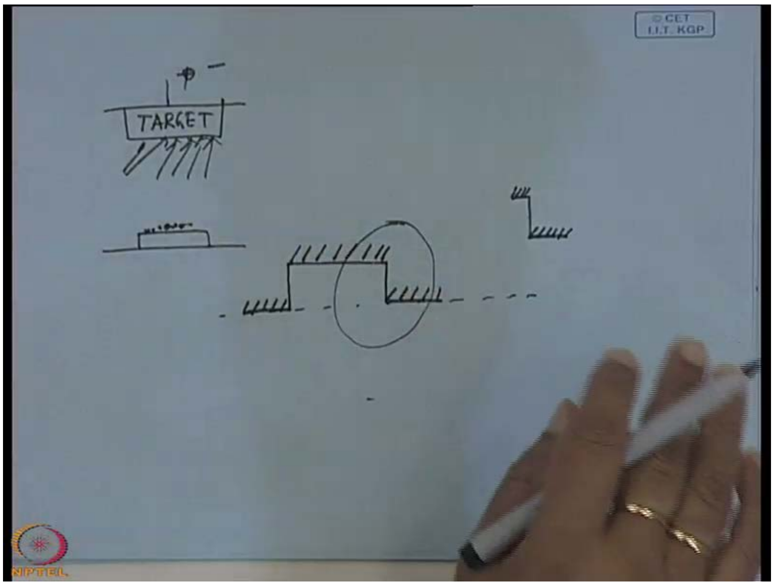

Step coverage means suppose, this is your substrate, the substrate is kept on the subsector, this is your substrate and it is kept on the subsector this is your subsector. When growth takes place, generally the films are formed on the surface, top surface, these surface and that surface, on the side portions there is no growth. So, that it appears like a step type of thing, this is a step, this is a step.

If you take the side view of this thing, this is basically a step where, there will be growth there will be growth on the side parts there will be for both AP and LP, but in LP it will be better why because, the growth will be uniform. In this case one thing I must inform you that, so far as the CVD is constant. So, here must be some PVD, what is PVD if CVD is Chemical Vapour Deposition, PVD is Physical Vapour Deposition, if there is something like physical, chemical vapour deposition, so there must be something like.

Yes, physical vapour deposition, can you name any technique where physical vapour deposition is used yes, but what is the name of the technique the process is diffusion (( )) one technique, evaporation one technique, thermal evaporation, spartading (( )) deposition. So, those are the basically the physical vapour deposition process, the difference between physical vapour deposition and chemical vapour deposition is that, in physical vapour deposition the step copper is very, very poor.

Because, you have to what is the fundamental process, inside the physical vapour deposition this is your material, say this is aluminum you want to make an aluminum film on say glass slight, glass substrate this is aluminum this is glass slight. So, what is the process, process is that this aluminum this is known as the target this is known as the target and this is the substrate. So, this target we have to be evaporated, so here also the whole thing is placed inside a back warm chamber.

Why back warm is used there are because of two reasons, one is that in back warm chamber there will be no air. So, contamination will be less and at the same time, the evaporated aluminum will be able to directly heat on the substrate, if there is air then what will happen yes there will be scatrading etcetera. So, this is the reason that there must be it must be in the evaporated chamber, another thing is that the melting of aluminum will be less, compare to in air melting point will be less.

So, that is the reason that the whole arrangement have to be kept inside a backward chamber. So, there must be something which will brake aluminum from the target, something means it can be a spurting technique, it can be electron beam, it can be normal thermal evaporation, it can be by the using of laser; that means, it will hit the target it will hit the target, where is the target the target is the aluminum high purity aluminum. So, when it will hit the target some aluminum will be coming out that aluminum will be in form of evaporated aluminum.

So, they will be deposited on the substrate. So, remember that in the chamber there is no whole the the whole volume is not the aluminum vapour, throughout the whole volume of the chamber it is not the aluminum because, your not using any gas, it is not any vapour type of thing, only a part of the aluminum will be coming out and it will be deposited on the substrate. So, the whole volume of the substrate will not be coated with aluminum, only front side will be coated a part of it will be coated.

So, that is the difference between the physical vapour deposition and chemical vapour deposition. So, the step copper will be less in physical vapour deposition.

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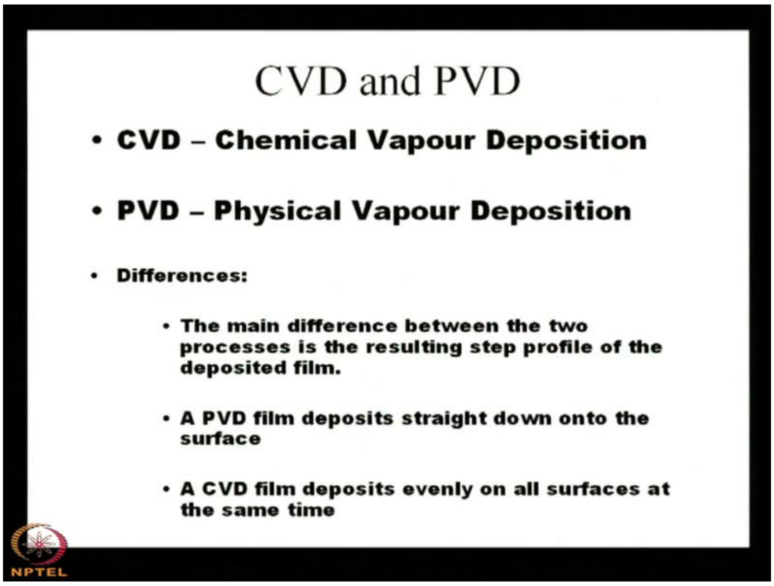

CVD and PVD

- **CVD – Chemical Vapour Deposition**
- **PVD – Physical Vapour Deposition**
- **Differences:**
  - **The main difference between the two processes is the resulting step profile of the deposited film.**
  - **A PVD film deposits straight down onto the surface**
  - **A CVD film deposits evenly on all surfaces at the same time**

Let me, show you that here you see that the main difference between the two processes; that means, the chemical vapour deposition and physical vapour deposition two processes, is the resulting state profile of the deposited film, resulted resulting state profile of the deposited film a PVD film; that means, physical vapour deposition film. Deposits straight down onto the surface a CVD film deposits evenly on all surfaces at the same time because, in CVD we are using vapour The whole reactor chamber is full with the vapour of the constituent chemicals right.

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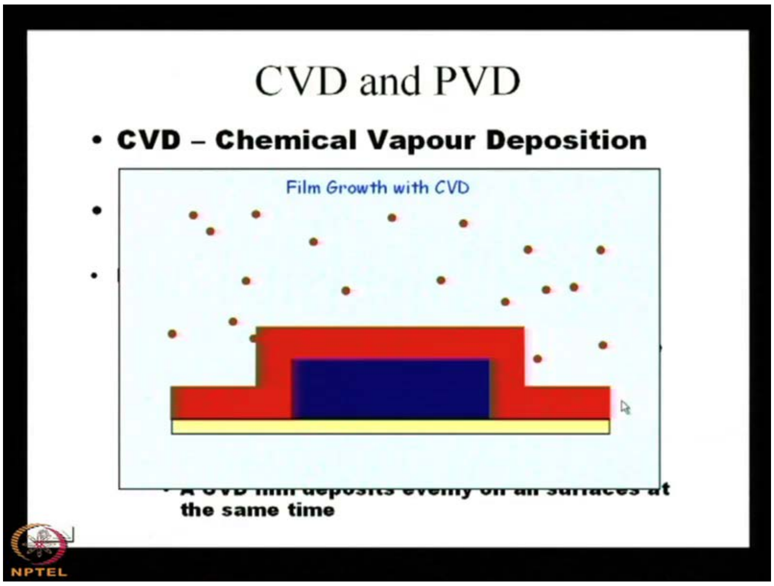

CVD and PVD

- **CVD – Chemical Vapour Deposition**

- **A CVD film deposits evenly on all surfaces at the same time**

Now, the next thing is that how the step coverage is there, these are the sepses of the chemical materials, this is the substrate yes you see what you see that on the sides there is no film, the red is the film, the blue is the substrate and the yellow is the subsector, the yellow is the subsector, blue is the substrate, red is the film. So, you see that the sides are not covered by any film, so the step coverage is not good now, you see that the CVD you see, good step coverage all sides are covered with the film.

Here, see these is the yellow is the substrate subsector, blue is the substrate and the red is the film. So, that is the difference between the physical vapour deposition and chemical vapour deposition. The step coverage is very, very important in case of the film growth.

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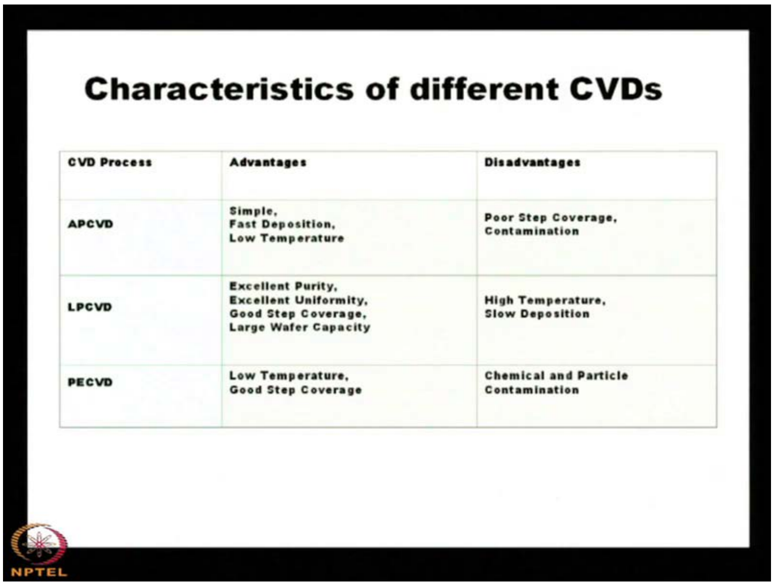

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So, then the next por next issue the PECVD Plasma Enhanced Chemical Vapour Deposition. In APCVD or LPCVD from where the energy comes because, the energy is required for which, one is for the decomposition of the chemical vapors, another is the atoms or the molecules must have some mobility. So, that they can absorb on the surface of the substrate, so for that you need some energy that energy comes from the thermal energy because, your heating the reactor.

For PECVD the energy is additionally supplied by the plasma, the energy is additionally supplied by the plasma. So, that is why it is known as the plasma enhanced chemical vapour deposition here, you see that the temperature is low and good step coverage temperature is low and good step coverage. So, if we compare all these three CVD you see that for APCVD low temperature, for LPCVD high temperature, for PECVD again low temperature.

So, from the temperature point of view AP and PECVD has some advantage, but for step coverage, PECVD has good step coverage, LPCVD has good steep coverage. So, for the supervisor steep coverage is concerned AP is inferior to LP and PECVD, another important factor is that LPCVD you can use large wafer. Now, 25 wafer we can use in LPVCD chamber, but in PECVD chamber only four vapors we can use because the efficiency is less in case of PECVD.

Another important thing is that using PECVD both sides of the substrate of the vapour cannot be covered with film, both sides in LPCVD both sides can be covered, but in PECVD only one side of the wafer because, in our laboratory we use 1 centimeter by 1 centimeter substrate, but in industry the whole 4 inch, 6 inch or 8 inch wafer is used because, otherwise it will not be cost effective.

So, in some cases say for micro electronics types of thing, where the metallization is done do you know how many transistors are there in the IC millions of transistors millions of transistors. And those transistors must be internally connected internally connected, connected with the power supply because, without power supply the transistors cannot be operated. Another thing is that you have to put the signal in the transistors.

So, for signal and power supply all those millions of transistors will be internally connected, how it is done it is done by metallization. And that metallization is basically layer type of metallization, first layer, second layer, third layer, fourth layer, fifth layer, sixth layer, six layers of metallization are done inside that miniature type of device. And all those layers must be separated by dielectric layers, why otherwise there will be short circuited.

Layer one metallization must be covered by some insulation layer, before making layer two then again before making layer three you have to use die electric layers, between in success in metallization. All those things are done by these process CVD’s or LPCVD or Physical Vapour Deposition what about the techniques. So, not only that the CVD are used for the epitexiay film growth, there are other use or application of these CVD’s type.

So, in that sense the whole wafer is put inside the CVD chamber, particularly for micro electronics type of thing. In PECVD only 4 vapors can handle at a time whether in LPCVD 25 wafer can handle at a time. So, for the cost effectiveness LPCVD is better then PECVD, so all the CVD's has there own characteristics, in some cases you will find that the temperature is low, in some cases you will find that the coverage is better, in some cases you will find that the wafer handling capacity is better in LPCVD than APCVD or PECVD.

But, there are some disadvantages also, one disadvantage is the in APCVD is very simple, but contamination is there because, we work in a atmospheric condition. In LPCVD deposition rate is low and also the temperature is high, compare to APCVD and for PECVD chemical and particle contamination is there why because, for making the plasma you have to use some gas, for making plasma you have to use some gas. So, the chemical and particle contamination will be there.

Now, what is plasma do you know what is plasma, plasma is the fourth state of matter liquid, solid, gas and plasma.

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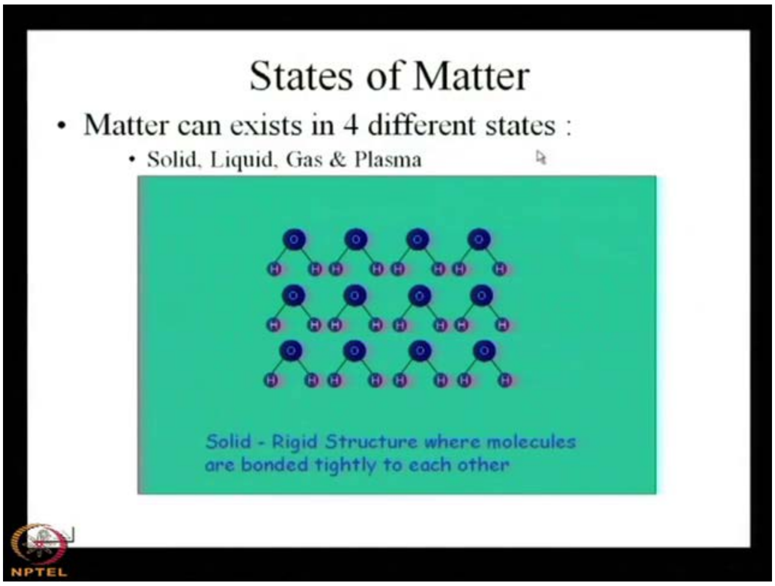

States of Matter

- Matter can exists in 4 different states :
  - Solid, Liquid, Gas & Plasma

Solid - Rigid Structure where molecules are bonded tightly to each other

So, you see that yes you see that, the states of matter, matter can exists in four different states, one is the solid then liquid, gas and plasma. In this diagram, we have taken the help of water molecule.

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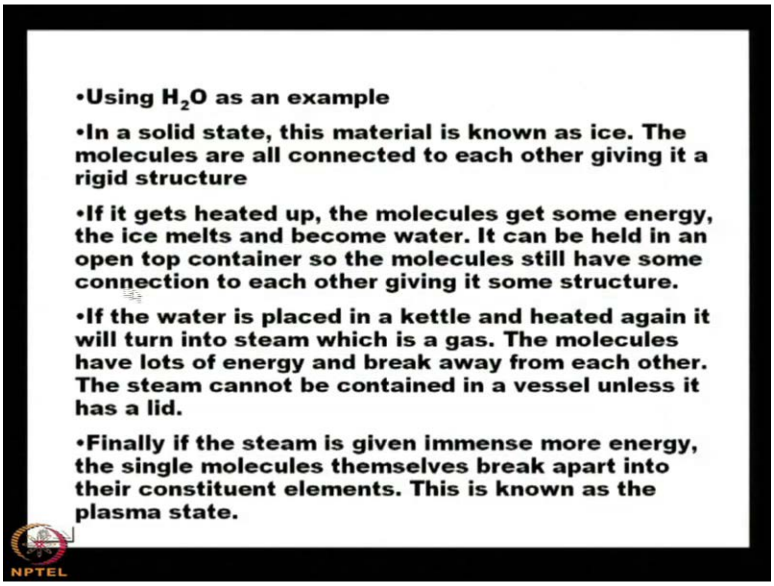

- Using H_2O as an example
- In a solid state, this material is known as ice. The molecules are all connected to each other giving it a rigid structure
- If it gets heated up, the molecules get some energy, the ice melts and become water. It can be held in an open top container so the molecules still have some connection to each other giving it some structure.
- If the water is placed in a kettle and heated again it will turn into steam which is a gas. The molecules have lots of energy and break away from each other. The steam cannot be contained in a vessel unless it has a lid.
- Finally if the steam is given immense more energy, the single molecules themselves break apart into their constituent elements. This is known as the plasma state.

You see that the in a solid state these material is known as ice ice which material water. The molecules are all connected to each other giving it a rigid structure.

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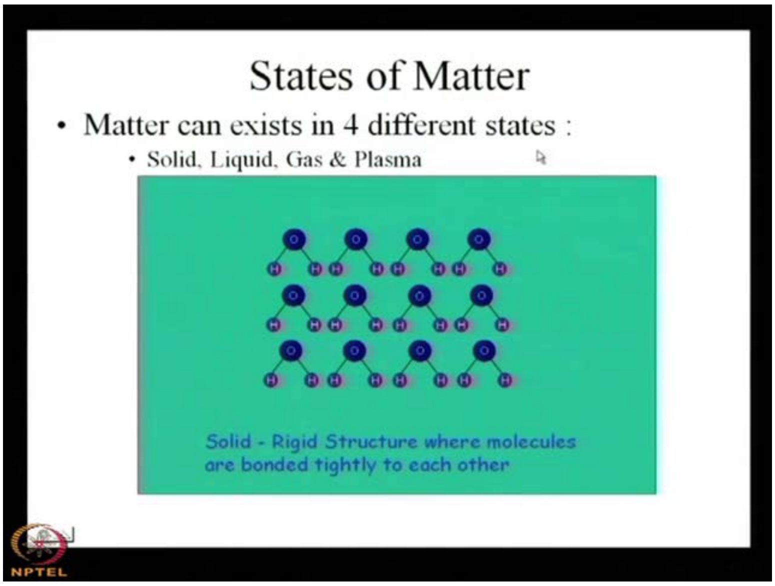

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Solid - Rigid Structure where molecules are bonded tightly to each other

Yes, giving it a rigid structure, a solid it is solid it has some rigid structure where the molecules are bounded tightly to each other, this is the oxygen molecules and these are two hydrogen H 2 O it is a structure you see, it is a rigid closely packed structure.

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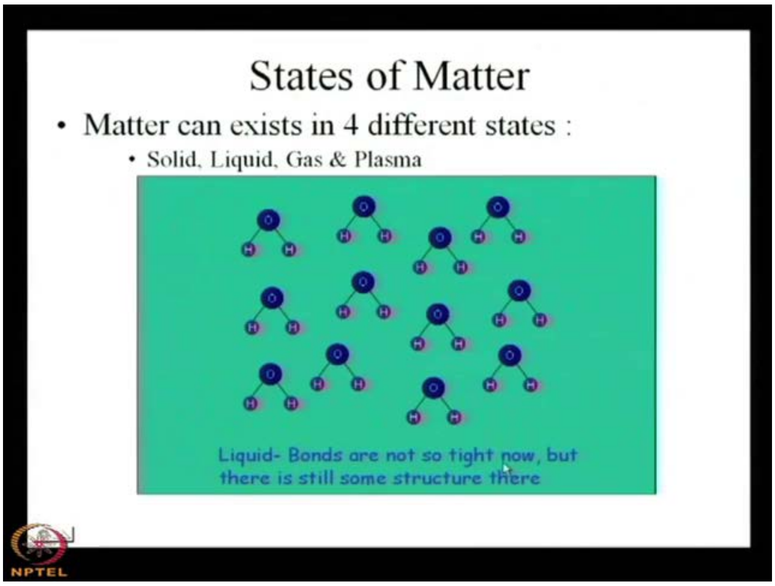

States of Matter

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Liquid- Bonds are not so tight now, but there is still some structure there

Then for liquid, you see that the bonds are not, so tight now, but there is still some structure there.

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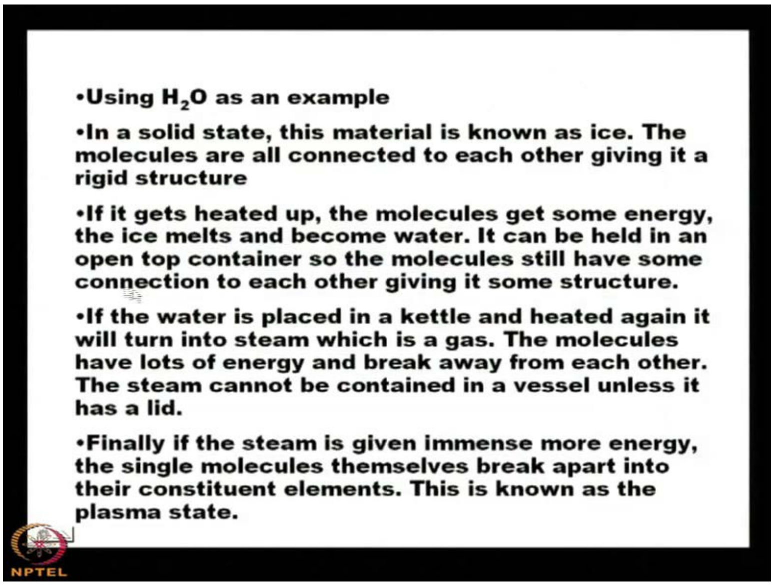

•Using H_2O as an example

•In a solid state, this material is known as ice. The molecules are all connected to each other giving it a rigid structure

•If it gets heated up, the molecules get some energy, the ice melts and become water. It can be held in an open top container so the molecules still have some connection to each other giving it some structure.

•If the water is placed in a kettle and heated again it will turn into steam which is a gas. The molecules have lots of energy and break away from each other. The steam cannot be contained in a vessel unless it has a lid.

•Finally if the steam is given immense more energy, the single molecules themselves break apart into their constituent elements. This is known as the plasma state.

So; that means, if we explain this thing, if it gets heated off which one ice, the molecule gets some energy; obviously, the ice melts and become water. It can be held in a open top container; that means, the lid is not closed, you need not to use a lid for keeping water, it is not a vapour for vapour you have to put some lid. Otherwise, it will what will happen it will go away from that container, but for water it can be held in an open top container; that means, there are some structures do not rigid, but there is some bonding of the molecules that is why, it can be kept in an open top container.

So, the molecules still have some connection to each other giving it some structure. If the water is placed in a kettle and heated again it will turn into steam which is gas, the molecules has lots of energy and break away from each other, the stem cannot be contained in a vessel unless it has a lid.

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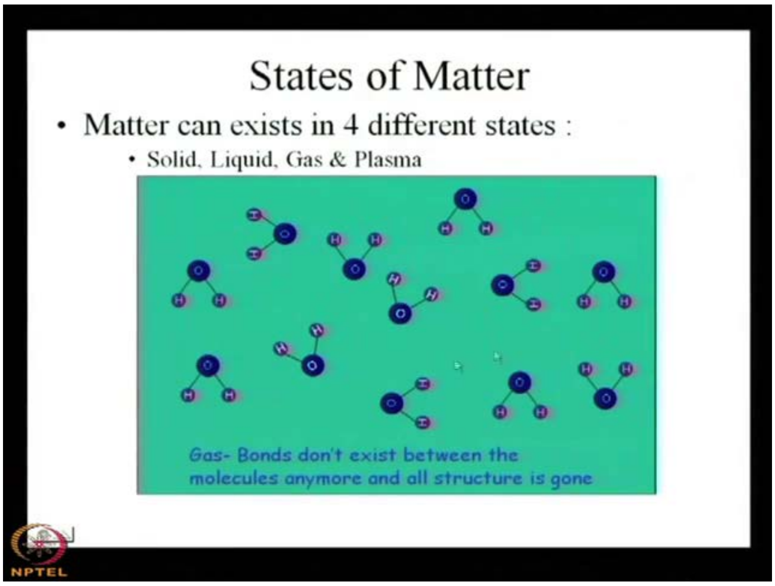

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- Matter can exists in 4 different states :
  - Solid, Liquid, Gas & Plasma

Gas- Bonds don't exist between the molecules anymore and all structure is gone

So, that means, it is completely it is completely, randomly it is moving. You see that in gas bounds do not exists between the molecules anymore and all structure is gone right. So, from solid ice to gas we find that, it is basically the game with the structures, there is no rigidity, there is no specific structure. So, they can move anywhere.

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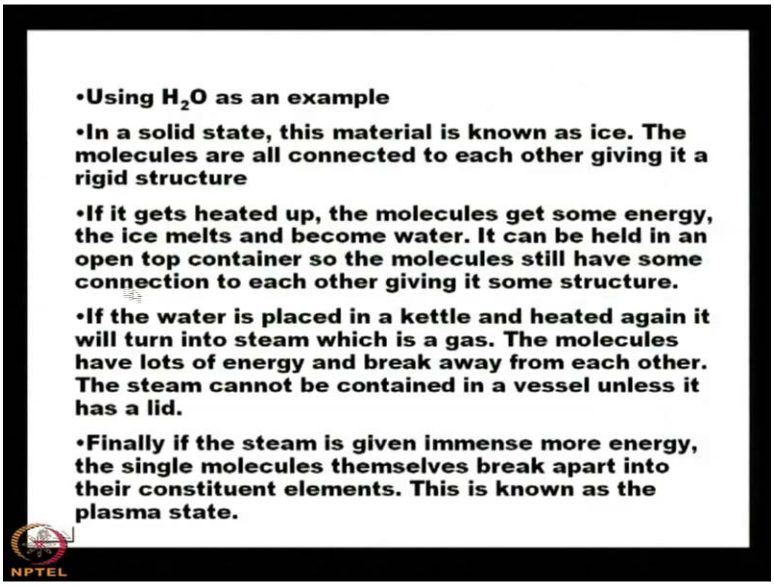

- Using H_2O as an example
- In a solid state, this material is known as ice. The molecules are all connected to each other giving it a rigid structure
- If it gets heated up, the molecules get some energy, the ice melts and become water. It can be held in an open top container so the molecules still have some connection to each other giving it some structure.
- If the water is placed in a kettle and heated again it will turn into steam which is a gas. The molecules have lots of energy and break away from each other. The steam cannot be contained in a vessel unless it has a lid.
- Finally if the steam is given immense more energy, the single molecules themselves break apart into their constituent elements. This is known as the plasma state.

Then the next part is the plasma finally, if the steam is given immense more energy, the steam which you have done earlier out of the your heated water. The single molecules themselves break apart into their constituent elements, this is known as the plasma state.

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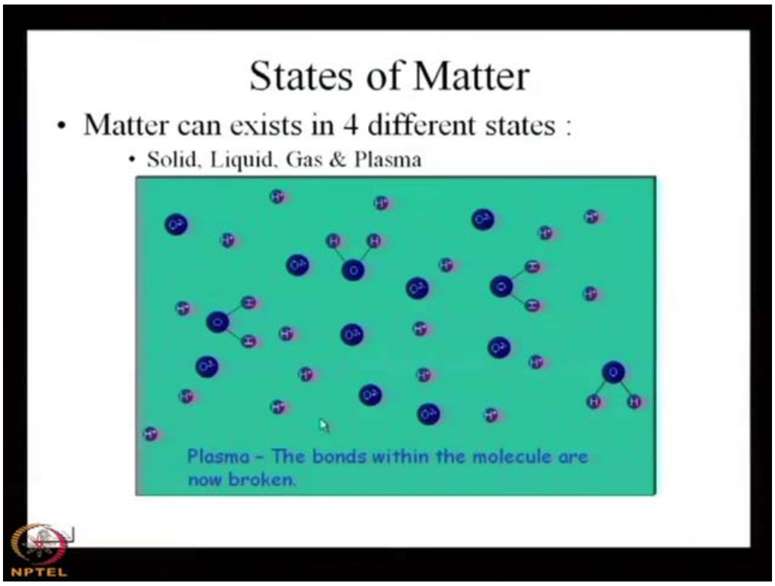

States of Matter

- Matter can exists in 4 different states :
  - Solid, Liquid, Gas & Plasma

Plasma - The bonds within the molecule are now broken.

So, you see that in this case the bounds within the molecules are now broken. Here, you see the difference between these thing is in gas H 2 O teams were there, oxygen and hydrogen were steel bounding, in case of plasma the oxygen and hydrogen molecules are part apart, there is no bounding right. So, similarly in normal PECVD plasma enhanced chemical vapour deposition, argon is used as gas right. So, if you use some RF power supply high voltage, then what will happen the argon plasma will be there; that means, there will be argon ion and electrons.

Argon ion and electrons it is not water that it will break into hydrogen and oxygen, in argon what will happen, there will be electrons and there will be positively charged ions, that positively charged ions will collide with the say aluminum. So, if it collides with the aluminum then it will remove some parts of the aluminum because, of it is energy and what will the electrons will do, the electrons will no no no there is no oxygen because, it is under compete back warm fast, back warm heat then you send some argons that argon there is no oxygen etcetera.

So, you make the argon plasma then you make the whole thing, so there is no scope for oxidation the electrons are very energetic. So, the electrons will again bombard the argon ions argon, argon atoms basically and it will ionize more and more argons gas into ions. So, that is fundamental principle of the plasma enhanced CVD, the efficiency will be very, very high because, your making plasma then, your breaking the target large chunk of the material can be removed from the target because, the impact will be higher.

And then you can deposit and, to some substrate the chunk of aluminum will fall on the substrate, the substrate is kept in the in a platform below the target, the target is at the higher end.

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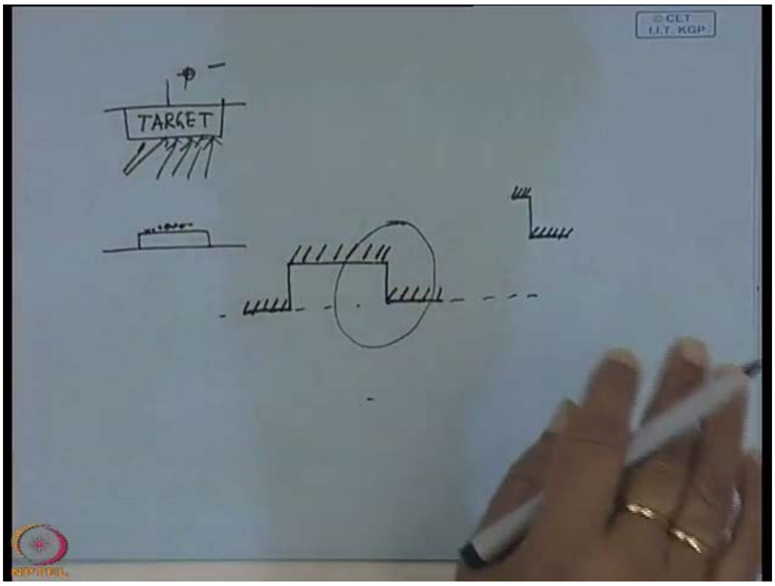

So, the structure is like this say this is your target, target means the material which you would like to deposit, it can be any material, it can be oxides also, it can be aluminum oxide, it can be zinc oxide, it can be silicon, it can be aluminum if you want to make some metal film. So, what you do you have to use some metal target suppose, you want to make gold platted something; that means, you want to make gold film. Then your target will be gold high purity gold suppose, you want to make say barium titanet frame.

So, what you will do your target will be barium titanet, pure barium titanet and here on the platform there will be your substrate, on which you would like to make the film. So, as the ion bombards will be on the target, chunks of target will fall on it and finally, a film will be deposited right. Now, you can ask me, sir why the argons ions will move towards the target, why the argons ions will move towards the target because, of the potential yes, it is always kept in a positive potential sorry negative potential.

So, the neutral or the positively charged particles will move towards that end. So, it will collide with that and large chunk of the material will be, removed from the target and will fall on the substrate to give a film type of appearance. So, this is the.

Student: (( ))

That you can because, because that is the you see that it depends on the material, argon is a normal example not for that in cases we have to use the argon. Generally for metal film argon is used, but if you want to make some new type of film, says silicon nitride you want to grow. So, you have to use ammonium you can, but for making the plasma some tricks are there, so plasma you have to grow and it is reactivity that is the whole thing, why you can use nitrogen also posi if it it it is possible to make the plasma out of nitrogen with greater efficiency then ammonium, with greater reactivity then ammonium.

Because, for cost effectiveness and easy handling (( )) you have to use some optimization technique. Theoretically you can do anything, but for optimization you have to use some specific gasses and specific chemicals.

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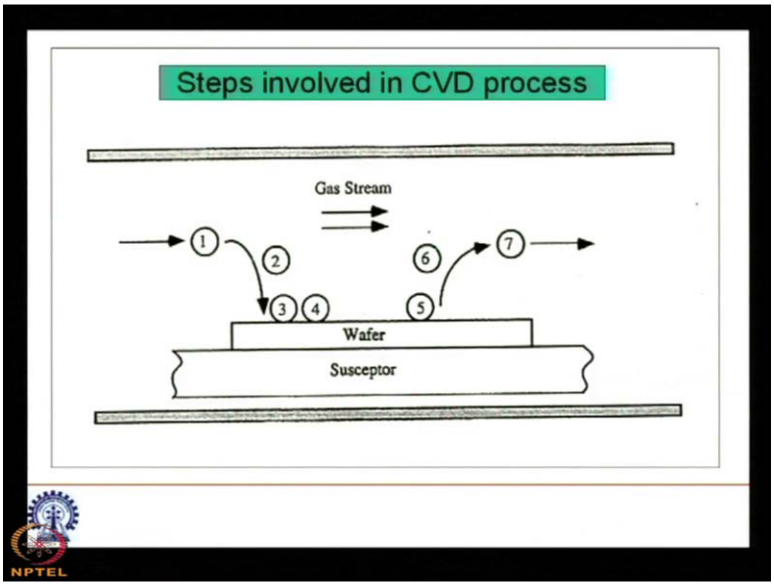

Steps involved in CVD process

So, now you see that for this CVD I have seen some I have shown some steps involved in CVD process. This is the subsector, this is the wafer 1, 2, 3, 4, 5, 6, 7 I shall explain all those seven steps in the next slide.

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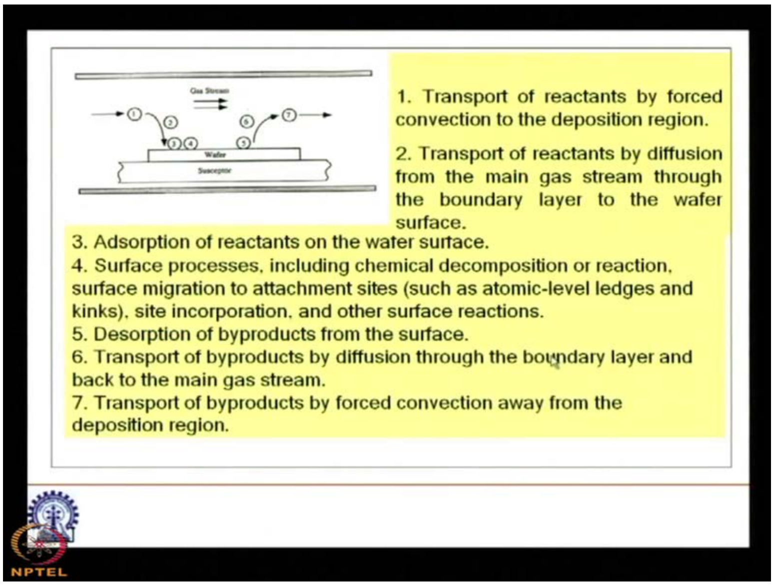

1. Transport of reactants by forced convection to the deposition region.
2. Transport of reactants by diffusion from the main gas stream through the boundary layer to the wafer surface.
3. Adsorption of reactants on the wafer surface.
4. Surface processes, including chemical decomposition or reaction, surface migration to attachment sites (such as atomic-level ledges and kinks), site incorporation, and other surface reactions.
5. Desorption of byproducts from the surface.
6. Transport of byproducts by diffusion through the boundary layer and back to the main gas stream.
7. Transport of byproducts by forced convection away from the deposition region.

Process one, this arrow means it is a gas stream gas stream, gas stream means the vapour containing the chemicals which are required for the fabrication of the film. 1 is transport of reactants by forced convection to the deposition region, number 2 transport of reactant by diffusion from the main gas stream, through the boundary layer to the wafer surface.

Number 3, adsorption of reactants on the water surface, number 4, surface processes including chemical decomposition or reaction surface migration to attachment sites, site incorporation and other surface reactions.

So, number 4 is basically related to the surface processes there are many surface processes which are involved for fabrication or making of the film. Then what is 5, 5 is the desorption of byproducts from the surface, number 6, transport of byproducts by diffusion through the boundary layer and back to the main gas stream. Number 7, transport of byproducts by forced convection away from the deposition region. So, this 7 steps are involved in any CVD process.

So, let us start from 1, transport of reactants by forced convection to the deposition region. Suppose, you have to use some silane for silicon deposition, so; that means, in one some silane is involved with some high purity gasses, say with hydrogen because, there must be some carrier gasses. So, one is the transport of reactant in this case, it is the saline the reactant gas is the saline, who is transporting hydrogen or you can use saline itself, if it has sufficient quantity with you.

But, saline you know that is very dangerous gas and very costly also. So, generally we use some hydro gen mixing, then number 2, is the transport of reactant by diffusion from the main gas stream, main gas stream means main gas stream means is hydrogen plus saline, from the main gas stream diffusion of what diffusion of saline on the silicon surface. So, diffusion from the main gas stream through the boundary layer to the wafer surface, then adsorption; that means, the molecules or the atoms are resting on the surface of the wafer.

Then number 4, is the surface processes this is very complicated process and it include what is surfaces processes, is includes many things, one is the chemical decomposition or reaction because, the temperature of the wafer is higher then any part of the reactor. Then any part of the reactor because, you see that the heating is done from the subsector just below the subsector. So, the temperature is higher in that region compare to the other parts of the reactor.

So, it will be chemical decomposition or reaction surface migration; that means, from migration means moving from one part to the another part, movement site incorporation and other surface reactions. So, the whole thing is basically four, four gives you the safe of the thin film on the wafer. Number 5 is the deposition desorption by of by byproducts from the surface, byproducts means when saline is converted into silicon. So, there may be some byproducts, I shall show you some reactions in the next class, the what are the byproducts for a particular type of thing that I shall give you some example in the next class.

So, those byproducts will be desorption from the surface then, it will be transported to the main gas stream, what is the main gas stream, main gas stream is hydrogen plus. So, here also there will be hydrogen plus saline here, also hydrogen plus saline. So, only some parts of the saline will be diffused onto the surface and many parts of the saline will be, go away from the reaction chamber to the vent or the vast. And number 7, is the transport of byproducts by forced convection away from the deposition region.

So, this is the inside view and different process related to the chemical wafer deposition of any material, only thing is that your gas will be different, your reactants will be different, your byproducts will be different, but the process is same and the main main process is process four; that means, the surface process, which actually will make the film and give you the safe of the film.

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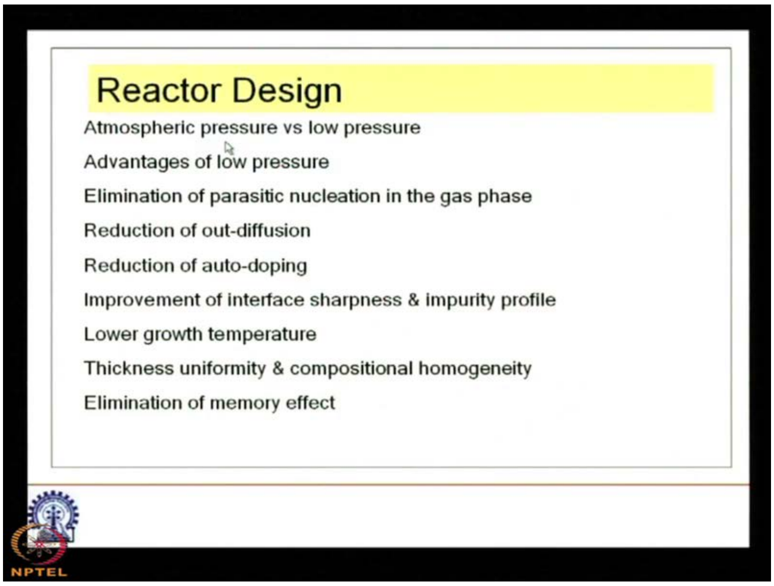

Reactor Design

Atmospheric pressure vs low pressure

Advantages of low pressure

Elimination of parasitic nucleation in the gas phase

Reduction of out-diffusion

Reduction of auto-doping

Improvement of interface sharpness & impurity profile

Lower growth temperature

Thickness uniformity & compositional homogeneity

Elimination of memory effect

So, now there will be different kinds of reactant design, one is say the atmospheric pressure verses low pressure. What are the advantages of low pressure you see that we have discussed something, but some more discussion we can make, like this the elimination of parasitic nucleation in the gas phase. What is parasitic nucleation in the gas phase, parasitic nucleation in the gas phase means before coming to this reaction reaction site.

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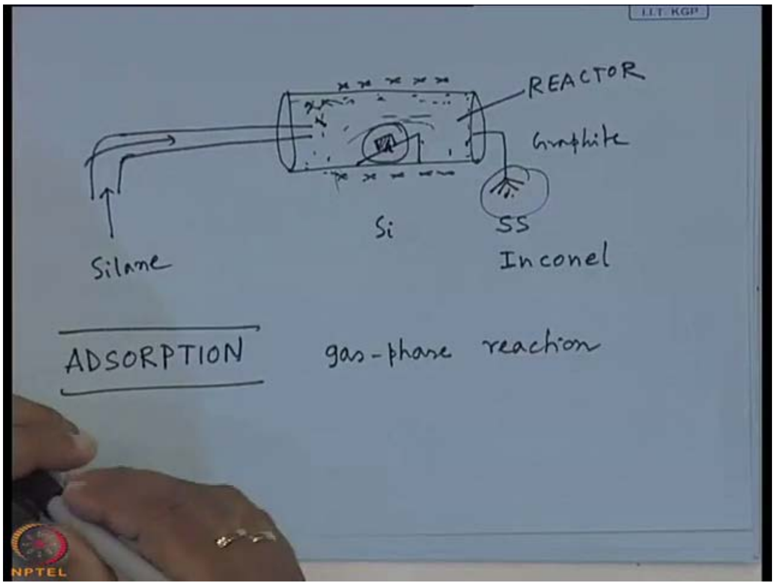

This is the site of the reaction, on the surface of the substrate there will be reaction; that means, take four; that means, take four before making some reaction in the step four there may be some reaction here and there, that is the parasitic nucleation. We want that the whole nucleation takes place on the surface on the substrate.

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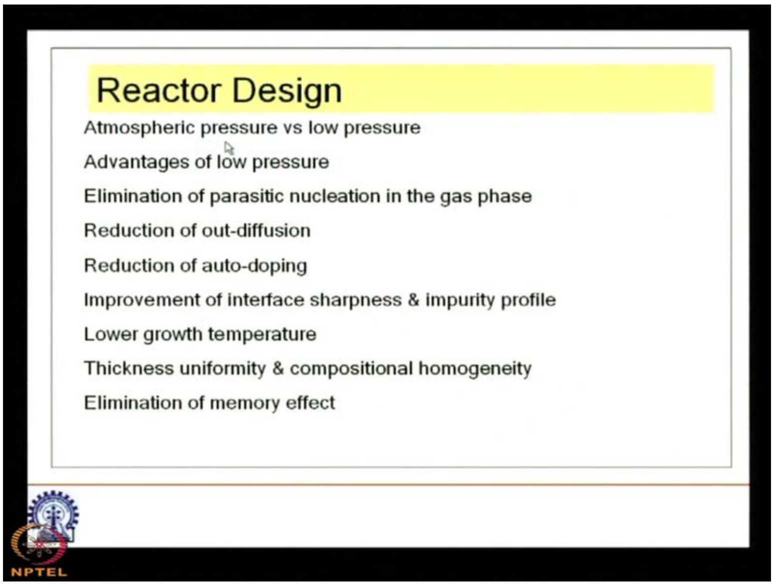

Reactor Design

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Lower growth temperature

Thickness uniformity & compositional homogeneity

Elimination of memory effect

So, if you use low pressure then it will eliminate parasitic nucleation in the gas phase. Reduction of out diffusion, out diffusion means what is out diffusion, out diffusion means something from the substrate, diffusion something from the substrate. So, you you use gallium or arsenic. So, diffusion of arsenic from gallium or arsenic to the gas stream that is out diffusion.

Reduction of auto doping, improvement of interface sharpness and impurity profile, lower growth temperature, thickness uniformity compositional homogeneity, elimination of memory effect those are the important thing that one must, take into consideration before designing of a reactor CVD I shall come to the point also what is memory effect.

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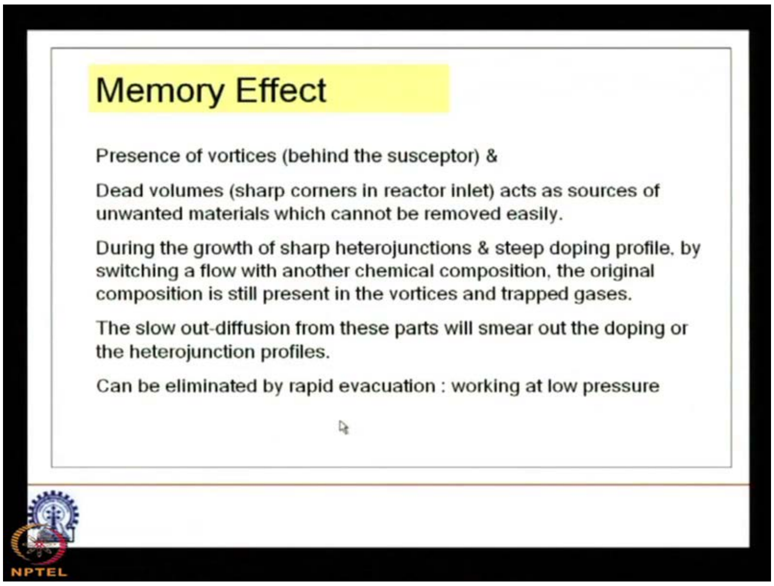

Memory Effect

Presence of vortices (behind the susceptor) &

Dead volumes (sharp corners in reactor inlet) acts as sources of unwanted materials which cannot be removed easily.

During the growth of sharp heterojunctions & steep doping profile, by switching a flow with another chemical composition, the original composition is still present in the vortices and trapped gases.

The slow out-diffusion from these parts will smear out the doping or the heterojunction profiles.

Can be eliminated by rapid evacuation : working at low pressure

What is memory effect, memory effect is the presence of vortices; that means, behind the subsector and dead volume, sub corners in reactors inlet acts as sources of unwanted materials which cannot be removed easily. One is the behind the subsector; that means, you see that this is the subsector behind the subsector means in this region in this region and another is the dead volumes; that means, sub corners in reactor in let.

So, this is the inlet that in in inlet there will be some sub corner like that, I can show you one reactor of a CVD how it looks like, if you come to my laboratory I can show you that it is a quartz type of reactor and there are many dead volumes, that means; there are many sub corners in the reactors in let. So, where the unwanted materials cannot be removed easily, it cannot be removed easily from the space behind the subsector and also at the side phases of the reactor. During the growth of sharp hetero junctions and steep doping profile, by switching a flow with another chemical composition.

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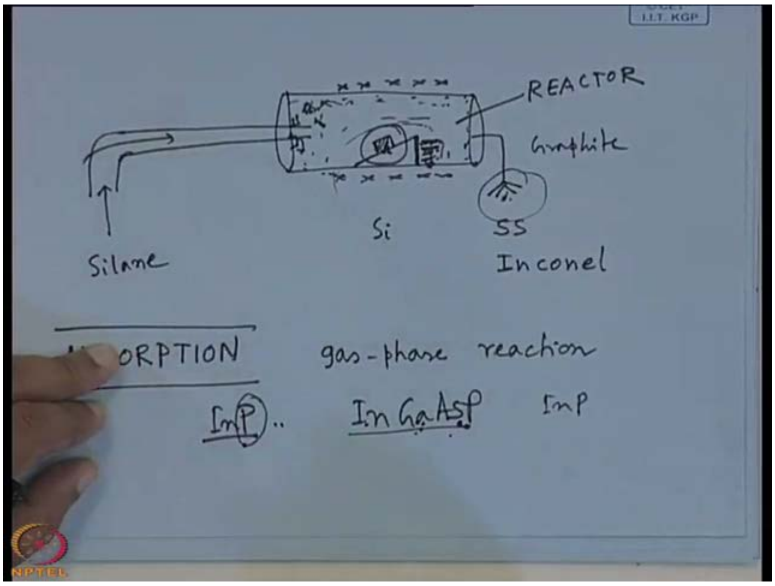

The original composition is still present in the vertices and trapped gases; that means. Suppose, you want to make Indium Gallium Arsenic on indium phosphate. So, first you grow indium phosphate; that means, when you grow indium phosphate, indium and phosphorus are coming inside the reactor chamber. Then as soon as you like to grow indium gallium arsenic, what is the next step the next step is that switching over from phosphorus to gallium and arsenic; that means, phosphorus will be stopped and at the same time gallium and arsenic will make the input.

So, this is switching again you want to grow indium phosphate then what will happen gallium and arsenic will be stopped phosphorus will be on. So, this is the changing or switching and if there is a dead space or dead volume inside the material, thou you switch a phosphorus, there will be some trace amount of phosphorus inside those places. So; that means, here the material will be indium gallium arsenic phosphate.

Because, there will be some phosphorus that is the memory effect, you cannot remove the phosphorus instantly that is known as the memory effect and the slow out diffusion these parts will near out the doping or the hetero junction profiles.

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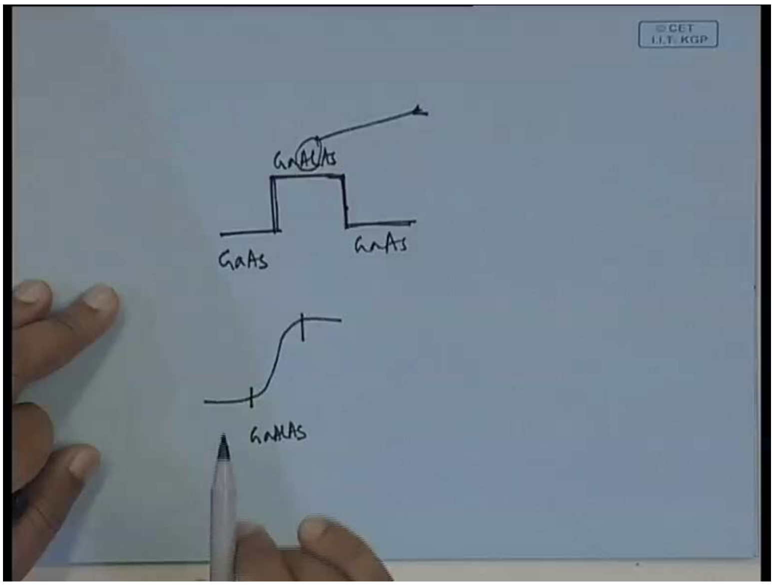

That means, now the profile can be like this you want sub profile, say this is gallium arsenic, this is gallium aluminum arsenic, then again it is gallium arsenic and, so on, this is the step profile. Now, if you switch of arsenic and make an input of aluminum, if it is instantaneous it is otherwise what will happen, there will be like this these thing is not solved right.

There will be gallium aluminum arsenic, here also there will be aluminum because, if you remove the aluminum because, of the memory effect some aluminum will be there. So, that is the memory effect and this can be eliminated by rapid evacuation; that means, working at low pressure. So, that is the memory effect, so this is the advantage of LPCVD.

Thank you.