Integrated Circuits, MOSFETs, OP-Amps and their Applications

Prof. Hardik J Pandya
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

Lecture – 07
Introduction to fabrication technology Contd.

Welcome to this module and these are class 6. So, let us quickly recall what we have done in the previous classes, right. What we have seen until now is how you can quickly know; what is the process flow for designing a sensor right? Whether it is an inter digitated electrodes within ASUA12 well or whether it is a gas sensor right? So, the idea was that you need or you learn; what are the process to finally, fabricate MOSFET, correct. So, until now what we have seen is that silicon dioxide right because if you take a silicon wafer the first step that we were performing was oxidation. So, and we have seen the application of oxidation or application of oxides at various stages for the MOSFET design for example, it is used the filled oxide it is used a gate oxide.

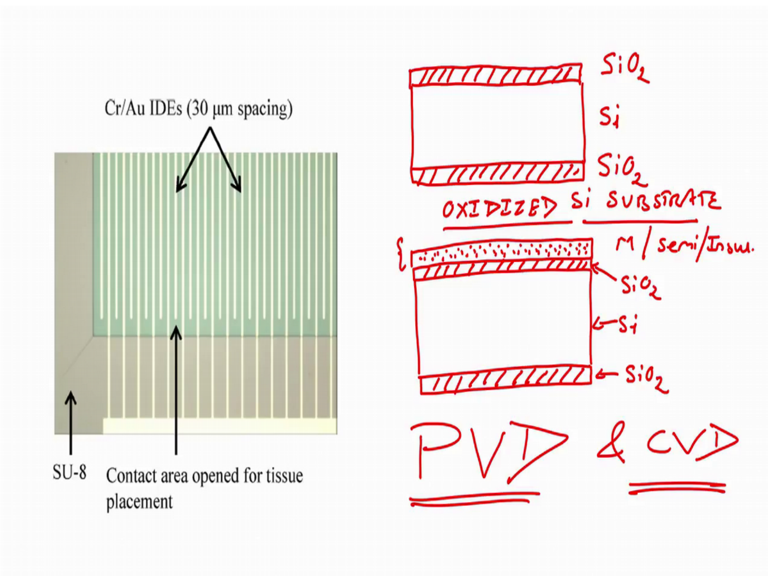
So, what are the techniques for growing the silicon dioxide, we have seen that one we have seen is lpcvd 1, we have seen is pecvd, lpcvd is nothing but low pressure Chemical Vapor Deposition PCVD is nothing but plasma enhanced Chemical Vapor Deposition. So, let us let us see today what are what are the Physical Vapor Depositions and what are the Chemical Vapor Depositions again. We are not going into depth, but we should know that these are the processes that are used to grow the grow the metal to grow the semiconductor to or deposit the metal deposit semiconductor deposit insulator and we have to understand that when we fabricate a MOSFET which technique we should use it right because what we are right now understanding is the process flow the process flow is a recipe. So, what kind of recipe you will recommend foundry.

So, that they can follow it and they can give you a device according to your choice your characteristics your metals, right? If you want to do a research by changing the by changing some different metals or by selling some different materials in a MOSFET, you have to tell your own recipe and that recipe should not be extremely different than the existing recipes in the foundry. So, how to understand this, what kind of recipes we can fib we can use it and for that we need to understand the equipment. So, right now what we understood is how we can grow silicon dioxide. Now let us see how we can deposit metal or how we can deposit semiconductor or how we can deposit insulator alright.

So, if you remember the what we have seen is the inter digitated electrodes right and in that we have used oxide oxidized silicon substrate, on which we have a metal which were which was patterned using photolithography to form inter digitated electrodes right? So, how this metal is deposited today we will learn that or how other semiconductors are deposit we will learn that alright. So, today's class is on understanding a very important equipment or a technique which is called Physical Vapour Deposition. And another technique which is as important as PVD is called Chemical Vapor Deposition right? We are focusing on integrated circuits we are focusing on integrated circuits. Now if you see the name physical right here you see the name chemical right; that means, that you are using a physical way of evaporating the material from met from metal to vapor semiconductor to vapor or insulator to vapor, but using some physical way of deposition.

In here you are using a chemical reactions to form a different vapors of the materials of your interest, right? So, let us see 1 by one what is Physical Vapor Deposition and then we will move on to what is Chemical Vapor Deposition alright.

(Refer Slide Time: 04:46)

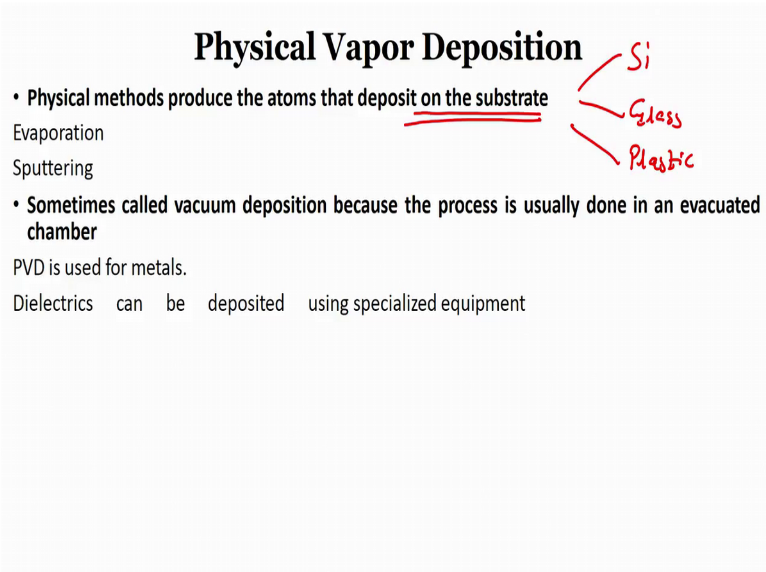


So, if you see the first slide this is what we have learned until now is that if I want to have a inter digitated electrodes right? Within an s u 8 what are the steps then we have also seen how we can fabricate a gas sensor right? The idea was that you understand the processes the processes. So, if you take this particular example which is on your screen the first step that we are we performed is we took a silicon wafer right? And then we have grown oxide we have grown oxideusing using thermal using thermal oxidation and this was done at this was done at 1200 degree centigrade using wet oxidation technique or dry oxidation technique, right? Until this we have seen.

Now, what we have to see is if I deposit or if I want to deposit a metal a metal or a semiconductor on this oxidized silicon substrate this is now what this is your oxidized o x I d I ze d oxidized silicon substrate we have seen what our substrates right. So now, it is oxidized silicon substrate. On this oxidized silicon substrate if I want to deposit if I want to deposit right a metal or an a semiconductor or a semiconductor I want to deposit a matter or I want to deposit semiconductor or I want to deposit insulator or insulated because this is see this is your insulating material, right? Silicon dioxide is insulator this is your semiconductor this is your insulator, right? So, if I want to deposit this particular layer that can be a metal that can be a semiconductor that can be an insulator what are the techniques that is our interest for today's lecture alright

So, like we see on the first slide there are 2 techniques one is Physical Vapor Deposition and another one is Chemical Vapour Deposition, right? Physical Vapor Deposition and Chemical Vapor Deposition. So, let us see what is first Physical Vapor Deposition alright let us see what is physical body motion.

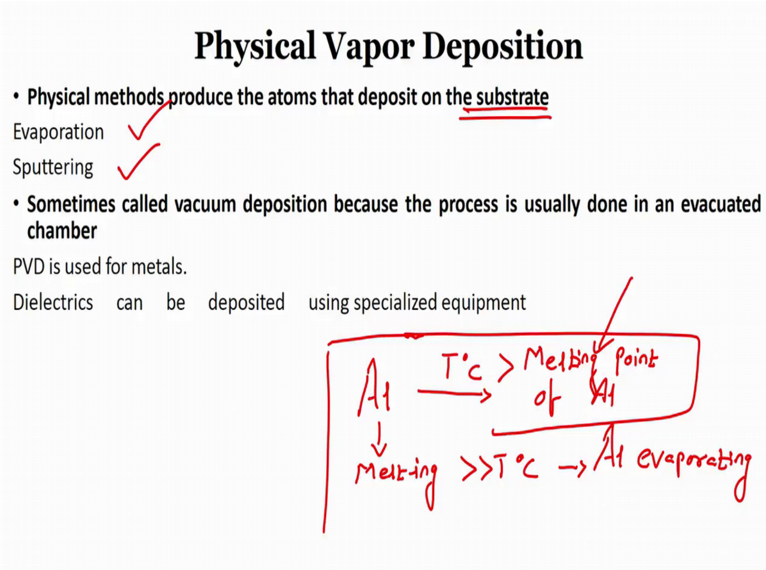
(Refer Slide Time: 07:41)



So, Physical Vapor Deposition or physical is a technique right in which physical methods produce the atoms that deposit on the substrate; that means, we have to physically dislodge the atoms right or vaporize the material. So, that we can deposit this material or the material of our interest onto the substrate onto the substrate can be silicon, substrate can be glass, substrate can be plastic, substrate can be any other material on which we want to grow or we want to fabricate our device alright.

So, What are these techniques? First is called Evaporation. Evaporation very easy right? So, what is evaporation right? What is the operation according to you? What is evaporation? So, let us see an example right if I one is evaporation one is sputtering. So, you evaporation is similar to changing a material to it is vaporized form vaporized form and finally, evaporating. So, if I keep on heating a metal let us say take an example of aluminum right? If I keep on heating the aluminum at

(Refer Slide Time: 09:12)

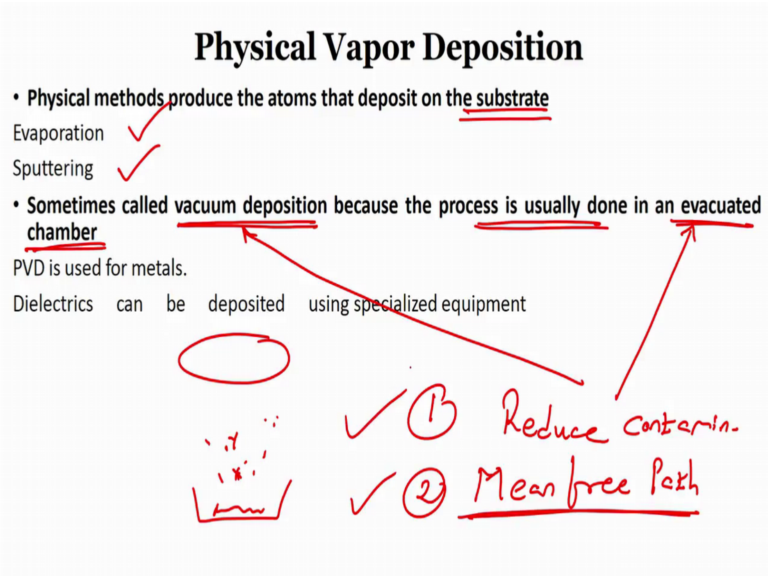


Some temperature, right? Greater than the melting point of aluminum greater than the melting point of aluminum. What will happen aluminum will first get melt it will start melting and if I still keep on increasing the temperature?

If I still keep on increasing the temperature then what will happen aluminum will start evaporating, evaporating alright. So, in evaporation we will see how we can heat the material how we can heat the material beyond it is melting point, beyond it is melting point. So, that it vaporizes it, vaporizes or it evaporates and it gets deposited or it gets deposit on the substrate on the substrate. Sputtering is another way of depositing the atoms on the substrate, it is a more of mechanical way we will see what exactly is sputtering does and how the system looks like that is our understanding this we are not really looking at the physics behind how these things are done alright, because there is not scope of our course scope is that we understand that these are the techniques that we can use in the process alright?

Now this physical body position are sometimes called vacuum deposition you see vacuum deposition because the process is usually done is usually done in an evacuated chamber in an evacuated; that means, the chamber in which there is a vacuum right?

(Refer Slide Time: 11:37)

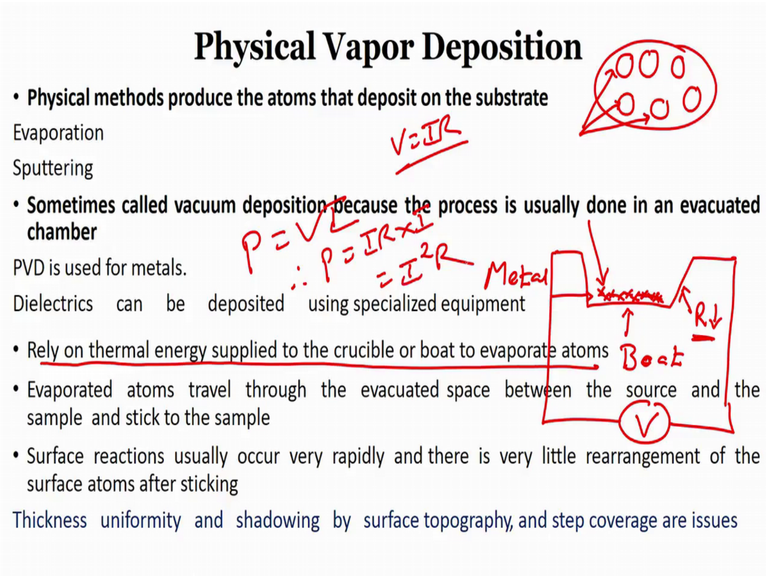


So, what is the advantage of evacuating or creating a vacuum? What is the advantage of doing this right? First is to reduce to reduce contamination conta me nation, right? Second is there is a concept called mean free path. See what is mean free path? Find it out number of collision between atoms right before.

So, thenif I deposit suppose this is a substrate if I evaporate the metal right then this atoms will get evaporated and the length right before which this atom will collide with some another atom this atom x will collide with some another atom y right this length this path is called mean free path. Mean free path should be as large as possible, as large as possible. So, 2 things that we understood is one is we have to increase the mean free path second is we have to reduce the contamination. To do that we have to create a vacuum we have to create a vacuum alright. So, sputtering or evaporation or in general thermal Physical Vapor

Deposition,Physical Vapor Deposition is usually done in a vacuum. Now most of the time Physical Vapor Depositions are used or this technique is used for metals right; however, dielectrics and some semiconductors can be deposited using some specialized equipment, using some specialized equipment. We will see how you can deposit dielectrics or semiconductors right using physical evaluation.

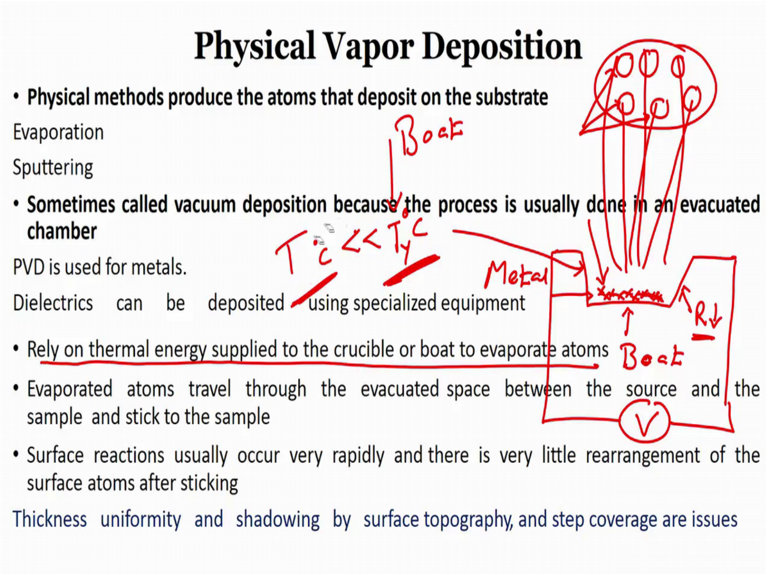
(Refer Slide Time: 13:54)



So, this thing is easy now, let us see further, let us see further, firther is it relies on the thermal energy supplied to the crucible or boat to evaporate atoms right, to evaporate atoms what does that mean? So, suppose I have this crucible or boat right I call this boat why I call this boat because it carries the material that you want to evaporate right? So, this is the metal let us say metal that we want to evaporate. Now how I can evaporate this metal because metal is solid right metal is solid. So, how can I evaporate this metal and deposit on the substrate which is on the top of this metal right are somewhere in the on the substrate holder. So, I will tell you what a substrate holders I will show it to you substrate holder is the is the equipment or a tool that can hold the substrate, that can hold the substrate right now I have to evaporate this metal right and deposit on this substrates on these substrates right?

So, how can do I do this by applying very high power by applying a high voltage a high voltage I said power, because the resistance of this is extremely small. So, if I apply voltage right high current will flow because the resistance is less and this one is generation of high power. Power is nothing but I square R right P equals to VI right V equal to IR that is therefore, P equals to IR into I which is nothing but I square RI square R right? So, this will cause the boat to heat to very high temperature the boat to heat at very high temperature because of the joule sitting, because of the joule sitting.

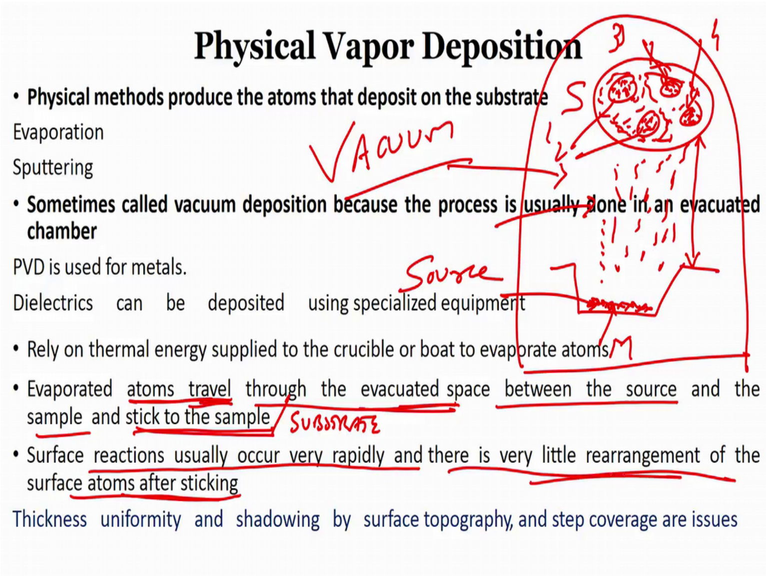
(Refer Slide Time: 16:14)



Now, if I heat this boat if I heat this boat at extremely high temperature right. So, let us say I call this temperature Y and the temperature for my metal, right? Temperature for my metal let me say TM this is TY, right? So, if my temperature this temperature which is the temperature of the boat is way sorry temperature of the boat, is way higher than the temperature of metal than the temperature of metal what will happen the metal will start melting right metal will start melting. And this melting will cause the matter if I keep on increasing this temperature of the boat the metal will start after melting evaporating, when starts evaporating it will get deposited on to the substrates, on to the substrates right? That is why what we say here, what we say here is that when you what we are, what we are saying in the state statement what we are saying is; when you have to use Physical Vapor Deposition it has to rely on the thermal energy supplied to the crucible or boat to evaporate atoms you got it to evaporate atoms, very easy extremely easy right super easy understanding electronics understanding any subject when you go down to it is basic becomes super easy.

Let us see the next sentence next sentence is evaporated atoms travel through the evoque you evacuated space between the source and the sample and stick to the sample, right?

(Refer Slide Time: 18:34)

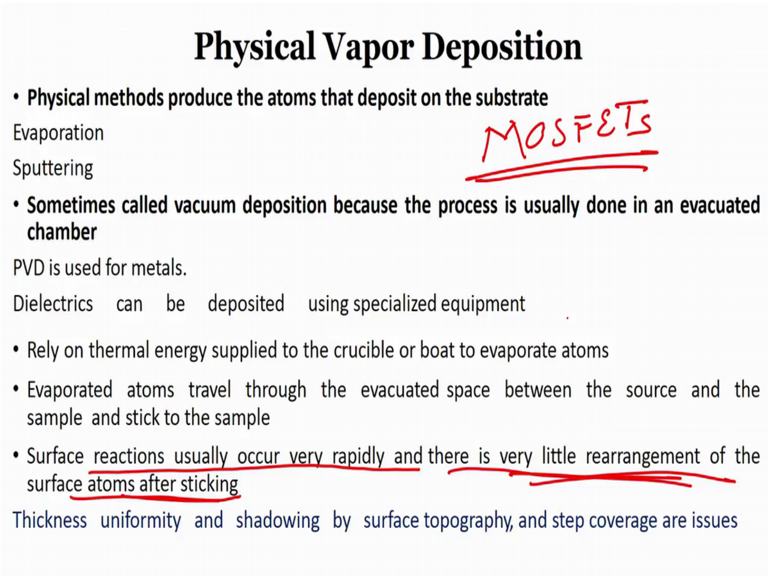


Or. So, what does that mean see if I take a boat if I have the substrate right if I have this sorry if I have this if I have the material metal and this is my substrate these are my substrates right? Then what it says that this everything is create everything is placed in a chamber in a chamber which is evacuated, which is evacuated right? Or there is a vacuum there is a vacuum. So, what I said evaporated, atoms evaporated atoms right? Travel through the evacuated space evacuated space vacuum between source and the sample this is our sample this is our source this is our source sample substrate it is one thing substrate. So, the atoms are traveling through this particular evacuated space these are atoms right and it is traveling between source and substrates, between source and substrate.

Now, surface reactions usually occur very rapidly and there is very little time for rearrangement of surface atoms after sticking you see when you deposit suddenly after the melting point is reached and when we increase greater than melting point this will start suddenly depositing very fast on the substrate, very fast on the substrate like this very fast on the substrate. Now it will deposit everywhere. It will deposit here, here, everywhere, everywhere it will deposit everywhere, but it would also deposit on the substrate because substrates are loaded on the substrate holder right these are our substrate one 2 3 4, 4 substrates are there.

So, when it is depositing rapidly we have very little time for the rearrangement of the atoms why the arrangement of atoms is required, because if you want to deposit a poly crystalline film if you want to deposit a poly crystalline film. Then the rearrangement of atoms are extremely important, but in case of PVD most of the time what you find is the films isnot polycrystalline. Not full extent now there are way of ways of making a poly crystalline, but right now we are not interested what we are interested is to understand the PVD understand the PVD such that we can use it

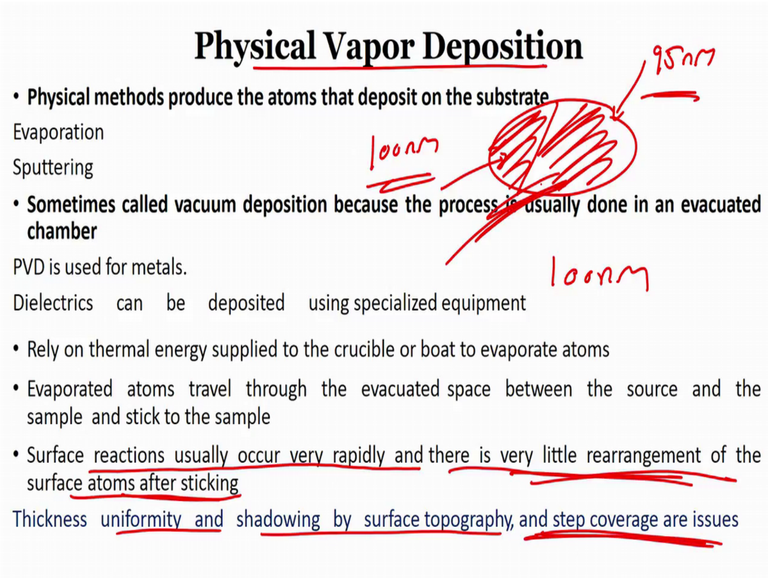
(Refer Slide Time: 21:28)



Or we can use it at several points in our MOSFET that is one time a 100 times 1000 times I am speaking same thing which is MOSFET, MOSFET, MOSFET why because we have to understand the process flow for how to preserve flow of how to fabricate a MOSFET alright. So, to understand the process of our MOSFET we had to understand Physical Vapor Deposition, we had to understand Chemical Vapor Deposition, we have to understand thermal oxidation, we have to understand photolithography alright. Then you will understand alright.

The surface reaction usually occur very rapidly there is very little time of rearrangement of surface atoms after sticking thickness uniformity and shadowing by surface topography and step coverage are issues alright. 3 things thickness uniformity.

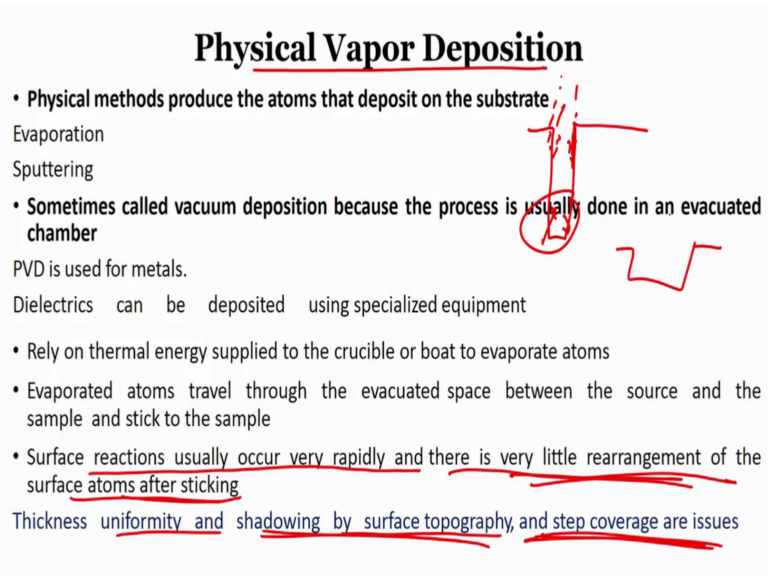
(Refer Slide Time: 22:17)



The uniformity across the substrate should be right? Because it should not be like half of the substrate here and half the substrate here. So, this is suppose I want to deposit 100 nanometer of film, right? I have here 95 nanometer I have here 100 nanometer. That is not I need to be have a uniform deposition everywhere uniform deposition everywhere. So, one is the deposition is not uniform is not uniform second is there is a shadowing by surface topography

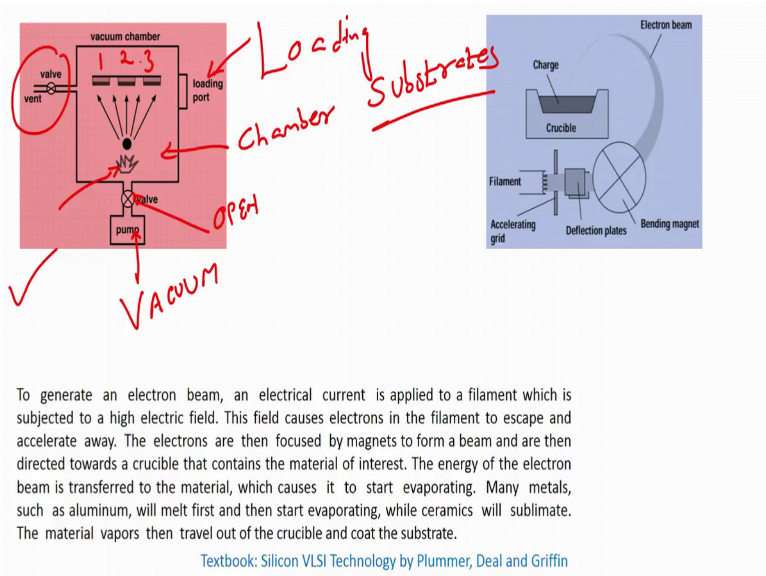
We will see what is shadowing effect and finally, step coverages are issues, step

(Refer Slide Time: 22:57)



Coverages issue means; if I have the step on which I want to evaporate the material and you will see only in this area the material is deposited this area it can not get deposited. This area cannot get deposited only this area gets deposited because of the shadow that is because of the step that is a shadow also because of the material that is deposited there is a shadow from the source right and from the sub and at the substrate side. And that will cause a problem in not covering the step coverage properly the step coverage is an issue we will see one example at the end of this particular lecture and then you will see that what is a step coverage what is the step coverage?

(Refer Slide Time: 23:37)



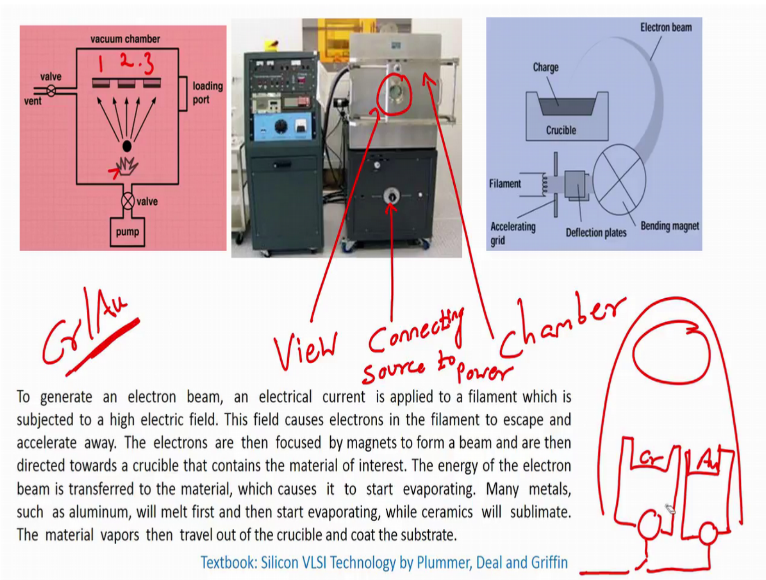
So, if I go to the next slide if I go to the next slide what I see here is first is I see a thermal oxidation. So, what I see on thermal oxidation if I see at the screen the left side of the screen the left side of the screen.

What does it show? It shows this one it shows there is a pump there is a pump that is created for that is there is there for creating vacuum, right? Because if I open this valve if I open this valve then my pump is connected to the chamber, my pump is connected to the chamber and; that means, whatever the air is there in the chamber will get evacuated with the help of this pump and I will be able to create a vacuum inside the chamber, right? Now you see there is a loading port loading port is for loading. Let me write it clearly loading port is used for loading substrates. These are substrate 1 2 and 3 these are 3 substrates and they are connected to the substrate holder.

Now, what we see here we see is that there is a boat this is the representative diagram representative diagram there is a boat which we have heated at high temperature and that is why the metal is getting deposited on to these 3 substrates. Now another question is why there is a vent valve why there is a valve for the vent. So, that when we want to after the position if I want to unload the wafers unload the substrate I had to open this valve. So, that the vacuum is broken and air from the outside can enter the vacuum can enter the chamber, right? Can enter the chamber.

So, this is how the thermal oxidation works. Again, I told you we are not interested in understanding the physics behind it we are not industry understanding the physics behind it because that is not the idea is said this is how it is done depositing off metal and you will see what is the advantage disadvantage that is it.

(Refer Slide Time: 25:59)

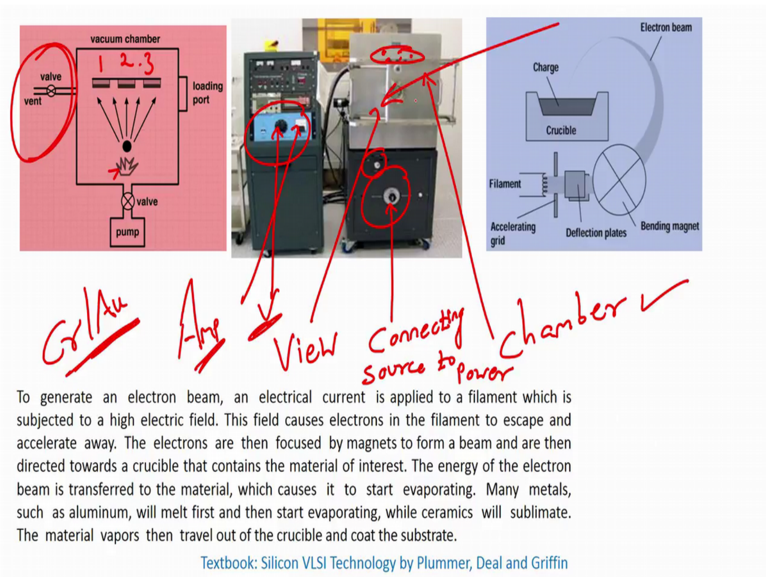


Now this is how it actually looks like, this is the thermal oxidation system this is the thermal oxidation system. So, here this one is to view right? Because we are to see whether it is melting or not then there is a viewing port alright there is a viewing point this is the chamber. This is the power to the boat. I m sorry this wrong this is for this for connecting the source connecting source to power.

What does that mean that if I have a chamber and if I have 2 boats right? I have 2 boats which bought to hit first because you see we have seen that we have deposited chrome gold chrome gold remember chrome is used to improve the addition of gold right. So, in that case I had to have chrome in one boat gold in one boat. So, I can only apply power I can only apply power at a time to one of this boat to one of this boat, right? I can apply power either to a or to chrome or I can apply power to gold. So, I should have some kind of switch some kind of switch right that will connect that will connect my power, my power to either cold or my power to either chrome right in this case I have 2 I have 2 boats chrome and gold or 2 sources chrome and gold in this case

What can I do? I have to connect the power either to chrome or to gold that is how this is the connecting port connecting port for source to the power this is the power this.

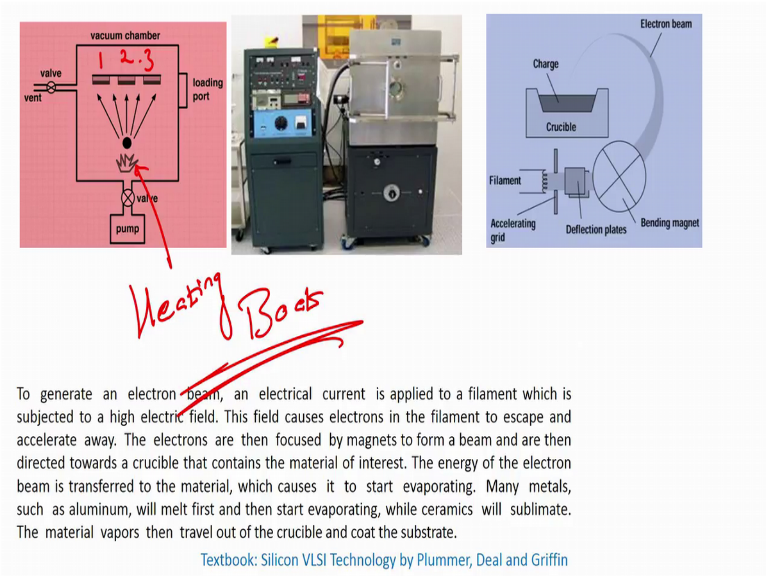
(Refer Slide Time: 28:22)



Is the power here you can see here you can see the amperes ampere how much ampere the boat is drawing alright? This is your this is your variable supply. You can change the voltage and you will see increase in current and that corresponding change in current will cause the board to heat within this chamber and the boat will stand here in the top within the chamber. There is a provision for holding your substrates. Once it is done you can give the you can open this particular chamber you can open this particular chamber by opening the vent valve, by opening the vent valve right?

So, this is how it actually looks like this is the handle you see this one is the handle to open the chamber alright? So, these of your Physical Vapor Deposition or thermal evaporator why thermal evaporator because we are using thermal energy we are using thermal energy to evaporate the material by thermal energy because we are heating

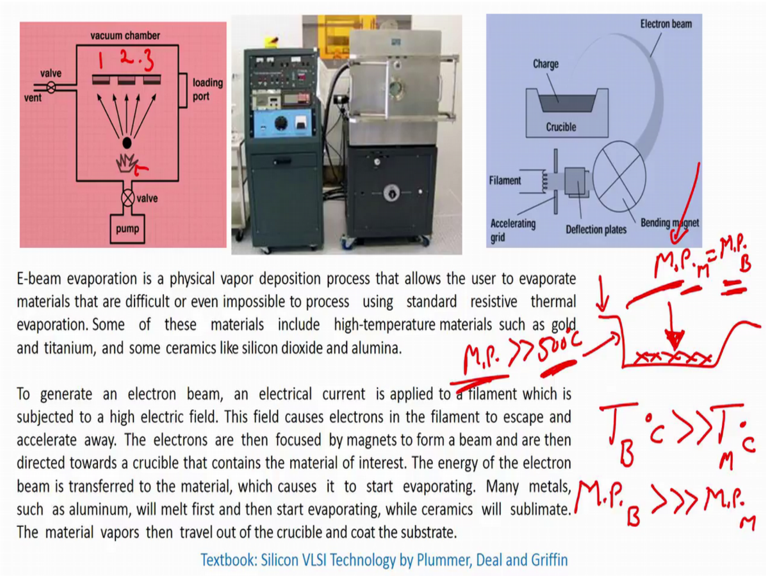
(Refer Slide Time: 29:41)



Right we are heating the boat. That is how we are applying or we are using thermal energy to evaporate the material cool alright excellent.

Now, once we understand what is thermal evaporator right we should go to another technique that is called electron beam evaporation. So now, from thermal operator why we have to go to her evaporate electron beam evaporation and how the electron beam evaporation would be used or how it will be used right or why we want to use it is there a problem with thermal evaporator right? So, first we should understand why we had to use electron beam operator instead of a thermal operator. So, let us see let us see on.

(Refer Slide Time: 30:38)



The screen now, what I told you is I have a boat I have some material right the temperature of the boat should be greater than temperature of the material right? Now another point is the melting point melting point of boat should be very higher than melting point of your metal correct right?

That means if I have a metal which has a melting point of let us say 500 degree centigrade my boat should have a melting point which is very higher than 500 degree centigrade. In this case my boat will not melt and only the material within the boat will melt easy. So, the point is here I have a material which is at which can be melted at 500 degree centigrade and beyond 500 degree centigrade you will get evaporate right? Now I have a boat which it is melting point is way higher than 500 degree centigrade; that means, when this boat will reach 550, 600 nothing will happen to the boat metal of the boat will not get deposited or evaporated, only the material within the boat will get melted and gets deposited or gets evaporated and finally, deposited onto the substrate correct?

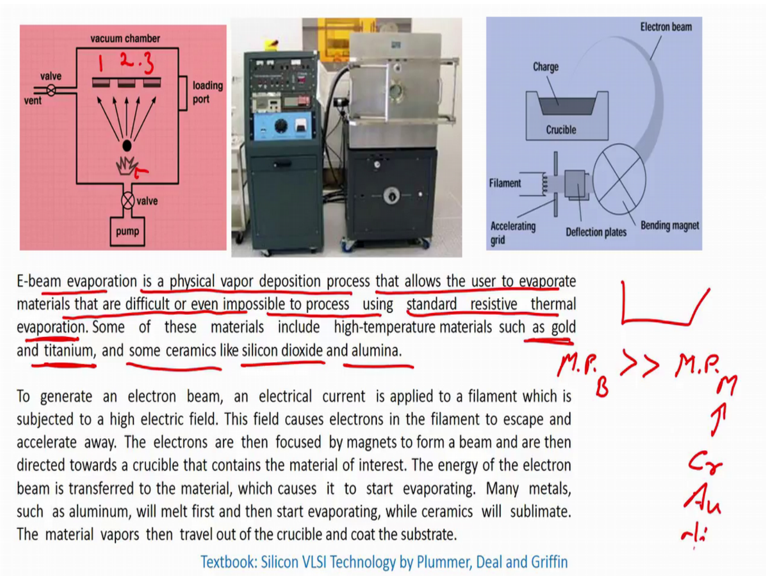
But what if the material inside this boat has a melting point has a melting point of metal similar to the melting point of boat. If my metal right within this boat has a melting point which is close to the melting point of the boat what is melting point of the boat melting point of the metal that is used to form this boat. In that case Icannot use thermal evaporater because I cannot deposit the metal which has a melting point similar to the melting point of boat.

Otherwise what will happen my boat will also start evaporating, my boat will also start evaporating. It will start melting the an and instead of getting a metal if my material is a metal I will get a alloy I get a alloy. 2 different metals I will get the I will be depositing right that is why in such cases where your melting point of the material loaded inside the boat is close to the melting point of the material from which boat is made we cannot use thermal evaporator, we cannot use thermal evaporator. In this case we have to go for electron beam evaporator alright electron beam operator. So, let us see quickly,

What is an electron beam evaporator? So, electron beam evaporation is a Physical Vapor Deposition process that allows the user to evaporate the materials that are difficult or impossible to process using standard resistive thermal evaporation right?

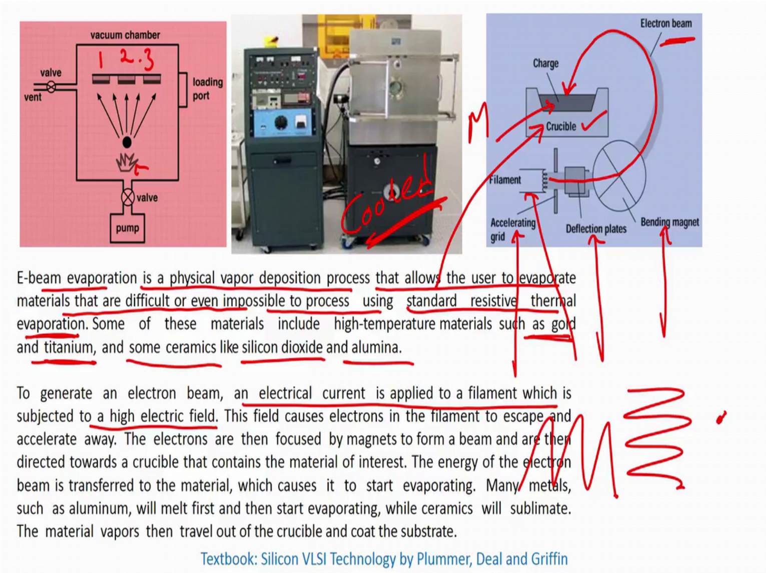
What we understood is that a e beam evaporation is a Physical Vapor Deposition that allows the user to evaporate materials that are difficult or impossible to process using resistive thermal evaporation, we are just seen an example some of these materials include material such as gold, titanium right some ceramics like silicon dioxide alumina, but if you generate if you find a material you find a boat

(Refer Slide Time: 34:37)



Which has a higher melting point of a boat is way higher than melting point of material and material can be grown, there material can be gold, that material can be nickel, that material can be any chrome right? Then I can use thermal evaporator, but in the cases where I cannot find a material of a boat which is greater than the material melting point of the metal, then in that case I cannot use thermal evaporator alright easy now to generate an electron beam an electrical current is applied to the filament which is subjected to high electric field if you see this one, if you see this particular diagram we have a filament right which is at high electric field.

(Refer Slide Time: 35:22)



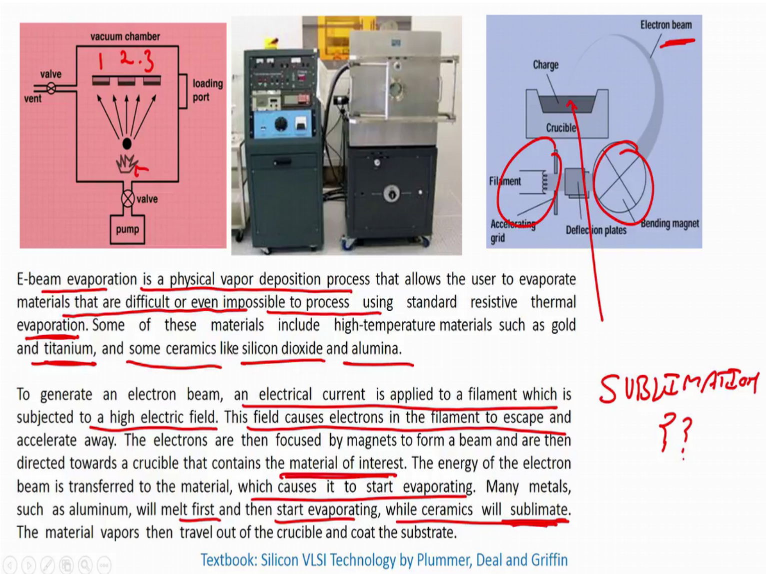
And then there is an accelerating gear grid then there is a deflecting plates and here is a bending magnet. So, electron generates from here will band and it will in we get incident on the crucible you see there is a crucible here and within the crucible. There is nothing but your material. So now, you are depositing this material by incident by incident thing the electron beam right by incident in the electron beam on the material which is loaded in the crucible and that is done with the help of filament accelerating gate deflection plates and the bending magnet. Here what will happen here the electron beam will electron beam will sweep or it will have a single point right all it will have a triangular sweep. And this is how it will sweep the material it will heat the material and materials gets deposited. The crucible is cooled down the crucible is cooled down alright?

So, that nothing happens to the crucible, crucible should not get disturbed because of the high electron beam damages and (Refer Time: 36:52) to electron beam again this is we are still using the thermal way of evaporating the material because finally, electron beam will heat this thing here heating the metal will cause it to melt melting the metal will finally, evaporate evaporation will cause the deposition, right? We are still using the thermal view of evaporating, but here it is not a resistive thermal evaporating, we are using a electron beam to generate the high temperature. So, in this case we can we can deposit a metal which is of higher temperature here we are not worried right?

So, if you see here if you see, here what we have written? We have written that;an electric current is applied to the filament which is subjected to high electric field, this field causes electrons in the filament to escape here, right? And accelerate away the electrons are then focused by magnets to form a beam, right? Here with the help of magnets these are used to form a beam and then a directed towards a crucible that contains the materials of material of interest is within your crucible within your crucible, right? Material of interest the high energy of electron beam is transferred to the material which causes is to start evaporation or evaporating. Many metals such as aluminum will melt first

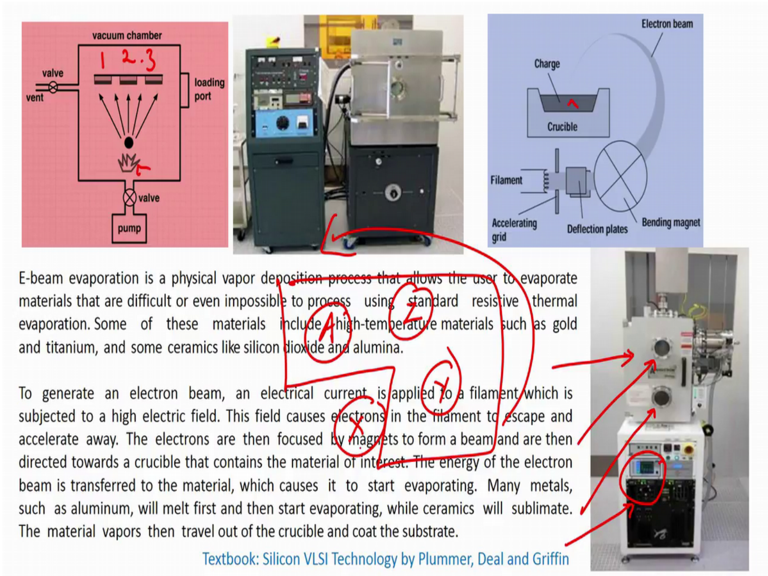
And then start evaporating while ceramics will sublimate first right will sublimate. In case of metal like aluminum it will melt, but in case of ceramics it will sublimate right find what is sublimation? Find what is sublimation.

(Refer Slide Time: 38:32)



What is sublimation? Find it out. Now the material vapors travels out to crucible and coat on the substrate and coat the substrate. So, in reality in reality how does an electron beam abrasion looks like?

(Refer Slide Time: 39:00)

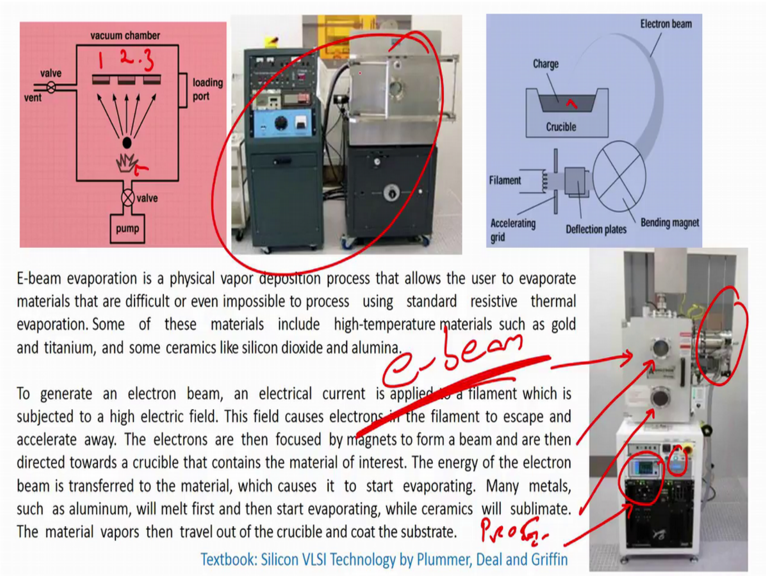


It looks like this and this is the chamber, right? This is the viewing port for the substrate, this is the viewing port for the source here using the program we can select a crucible because in electron beam evaporation there can be multiple crucibles as well like this.

And only one crucible is exposed rest of the crucibles are not; that means, you can deposit X material if you are done depositing X material then you have to turn this sub source holder turn the source holder right and this X will go to this position, let us say initially it was like this let us say let us say let us write X Y Z A alright initially first step, now once I am done by of depositing materials from substance, from the source X once I am done of depositing the material which is in X we have to deposit a material which is on A alright that is our process. Then in that case I will rotate the I rotate the source in such a way that now my A will be here, my X will go here,Y will go here Z will go here right. So, for rotating the source rotating the source.

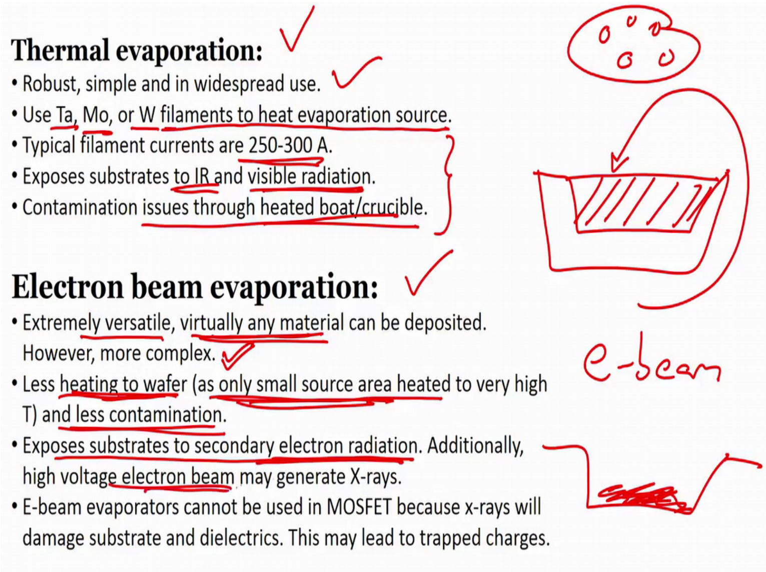
I have the source rotation facility which is which we can use using

(Refer Slide Time: 40:40)



Programming. Then I have this system or pump right that is called turbo molecular pump and is used to create a vacuum is reduced to create a vacuum and then I have this supply, I have various way of selecting which material, I have to deposit right? The point is that you can use E beam evaporation for the metals for the materials which are difficult to get which are difficult to be deposited using thermal evaporator using as a stiff heating alright. So, so

(Refer Slide Time: 41:35)



What we understood? We understood 2 things; first is we have seen thermal evaporator and second is we have seen E beam evaporator. What is the difference? Thermal evaporator is robust is simple and wide spread in use it uses several materials you can see here for filaments to heat evaporation source that is tantalum molybdenum tungsten filaments alright. To heat the evaporation source. So, this is the boat alright boat. Typical filament the currents are about 250 to 300 ampere exposes substrates to IR and visible radiation, contamination issues through heated boat or crucible. If the crucible or boat is contaminated that contamination will also get deposited on the substrate that is why there is a contamination issues right?

However, this is very simple to use it because we have to just lower the substrate and apply the power and boat will get heated up, when boat will get heated up, this of the material within the boat gets heated up, the material starts melting then it starts evaporating it will get deposited super simple to operate right; however, there are some of the drawbacks. What about E beam evaporation what about your electron beam evaporation right? Electron beam evaporation is extremely versatile virtually any material you see virtually any material can be deposited; however, it is little bit complex not only in design, but also in operation alright.

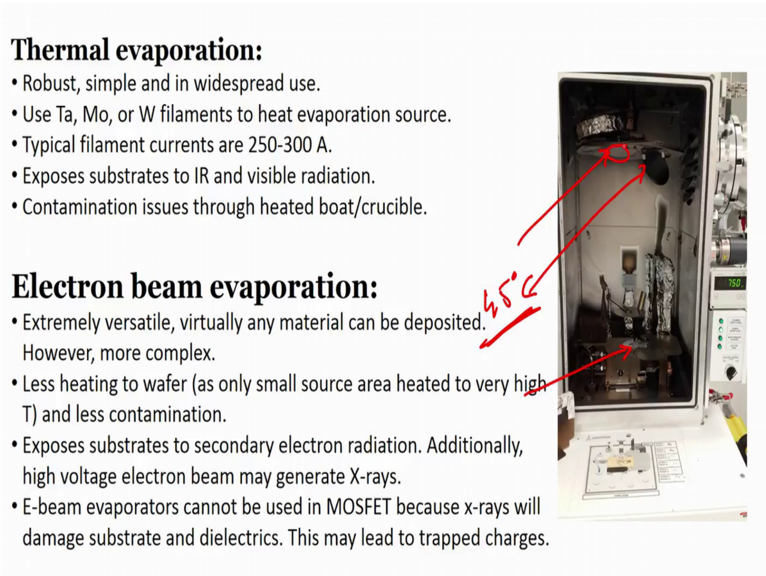
How to use it you have to get a properly trained to use E beam evaporator. Less heating to the wafer right has only small source area is heated to a very high temperature and less contamination. We have seen that in a crucible you have seen that you have loaded the material this is your material to get deposited right in case of E beam. Now the electron beam will come and only a particular area only a particular area at a time will get heated up, because only particular area gets heated up that is why the substrate also will not get heated up as much as in case of thermal evaporation where we were heating the entire material entire material at a time right?

So, in case of this E beam evaporation as only small source area is heated. There is very lar less contamination and less heating to the wafer. Next is exposes substrate to secondary electron radiation you see that there is a drawback. That it exposes substrate to secondary electron radiation.and high voltage electron may generate x rays high electron beams generates what x rays with this we have studied in physics right? That when we use this very high electron beam then there is a generation of x rays, now this generation of x rays are difficult because we have it will cause a problem in MOSFET.

So, what is that E beam evaporators cannot be used in MOSFET because x rays will damage the substrates and dielectric. And this will or this may cause the trap charges trap charges in

MOSFET. So, the point is that in case of E beam evaporators we cannot use unfortunately in MOSFET because this x rays will damage your dielectrics, this x ray will damage your substrate and this may lead to the trapped charges alright. So, what we have seen? We have seen 2 way of depositing the material one is using thermal evaporator one is using electron beam evaporator.

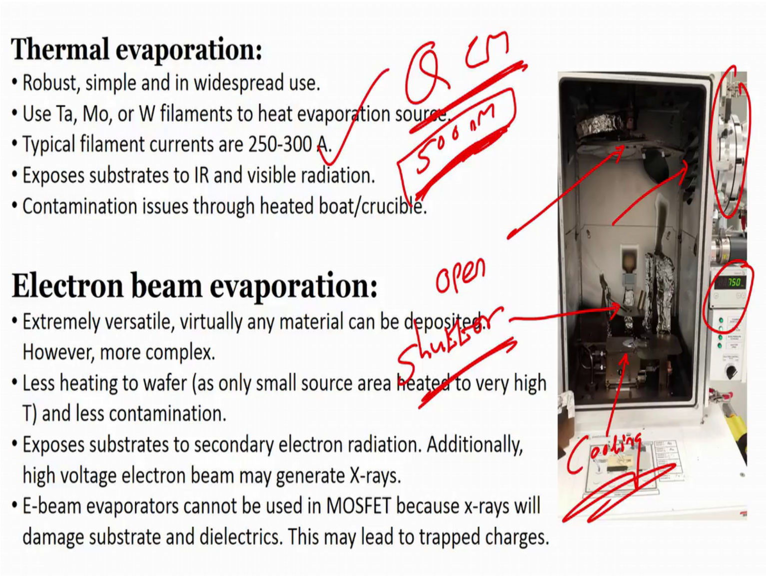
(Refer Slide Time: 45:36)



Right? This is how the electron beam evaporator from inside will look like from inside will look like. So, let us see let us see, how this chamber looks like you see this is similar to this is similar to this one alright, this is the closed chamber now what I am showing is when you open the chamber how it looks like alright.

So, here is your source alright here are your substrates here are your substrates alright. Now I have deliberately loaded this substrate at 45-degree angle, because one process needed the metal to get deposited at 45 degree. So, that is why otherwise substrates are loaded as I have shown here which is flat here like this alright you can see substrate which I have loaded like this. So, do not worry about this just understand that there is a substrate holder which looks like this alright, then there is a there is a shutter why we need shutter? Because until you are ready that this this has been melted you do not want to open the shutter or when

(Refer Slide Time: 46:52)



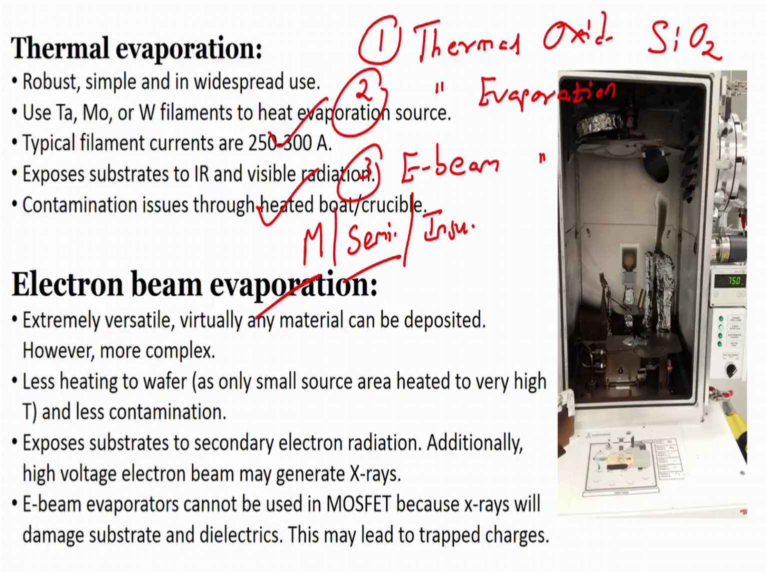
You reach let us say you one to deposit 500 nanometer when you reach 500 nanometer this shutter you should close it this is shutter right?

Shutter; that means, it will shut down it will stop the material to further deposit, because if I push the shutter the material will get deposited on the shutter it will not reach the it will not reach the substrate. If Iopen the shutter then only the materials will reach the substrate right? Sorry now what you see other things is that the e beam evaporation occurs from here there is a source there is a magnet and this magnet will cause the E beam to come from this particular area. So, let us let us see from here it will cause E beam from this particular area and it will oh sorry because E beam evaporation the particular area. And it will focus on this area focus on the source alright. And below this material below this here there is a cooling,cooling area right.

What you see here the amount of power that we are giving this is turbo molecular form see this connected if I if you see clearly the it is connected to the chamber. So, it will it will suck up the air and will create a vacuum to create a vacuum alright. So, when I open the door it looks like this when I open the door it looks like this there is a crystal over here which is called cross crystal microbalance used to understand how much the position has been done. Quartz crystal microbalance alright, quartz has a property it is called piezoelectric property; that means, when we apply pressure there is a change in voltage we can use this property to understand what is the thickness of the film and when the thickness is reached we can program the system such that the shutter will get closed when this particular film is film thickness is reach of or the film of our desired thickness is reached the shutter will get close right?

So, Q cm is extremely important tool used within the E beam evaporator or PVD in general to understand how much thickness of the film has been deposited alright. So, having said that having now you guys know physically vapor deposition, right? Physical vapour deposition. So, until now what we have seenwe have seen

(Refer Slide Time: 49:33)



One thermal oxidation, 2 thermal evaporation, right? 3E beam evaporation, evaporation, right? Using thermal evaporation and E beam evaporation, we can deposit metal, we can deposit semiconductor, we can deposit insulator there is some drawback of each technique of each technique that is technique 2 and technique 3 that we have seen with thermal oxidation we can grow silicon dioxide or SiO2 right? Silicon dioxide.

This much we have seen alright why we have seen this? Because at certain point in fabrication fabricating MOSFET we will we have to deposit metal we have to grow silicon dioxide we have to grow different insulators and that is why we are looking at several techniques that are available that we can use when we design the process for MOSFET, and when we had and if you know this equipment then we know what kind of recipes we can use it alright. So, that is the reason of teaching you what is Physical Vapor Deposition and how we can how we can use the physical body position for MOSFETs alright. So, I will complete the module at this particular time and in the next module for the same lecture what we will see? We will see one more Physical Vapor Deposition technique that is called sputtering and then we move to Chemical Vapor Veposition where we really understand how we can deposit the different materials using Chemical Vapor Deposition.

You have seen Chemical Vapor Deposition in a way that you have seen silicon reacting with water vapor right? SSi plus 2H2O gives SiO2 plus 2H2 right? That we have seen in the wet oxidation that is also LPCVD that is also low pressure Chemical Vapor Deposition. So, you understand this that it is not difficult to understand this technique the point is that we should know this technique. So, that we can use it in the actual fabricating or actual fabrication of the devices alright?

So, I will see you in the next class you read this particular things that I have told you today understand this lecture once again right? Understand there all the lectures once again and you ask me questions once we reach the lecture in which I can show it to you how the mass MOSFET is fabricated, after that if you do not understand you ask my questions alright, till then you take care once again look at the things that I have taught you today it is very important things which is your physical vapour deposition right? And as soon as we meet in the next class.

I will start showing you a mechanical way of depositing of material and that is your sputtering right what exactly a sputtering means alright is then you take care I will see you next class, bye.