Fabrication Techniques and Mems-based Sensors: Clinical Perspective
Prof. Hardik J Pandya
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

Lecture - 15
Scalable Data Science

Hi, welcome to this last module of this particular class, or you can say lecture. And this is on Micro Machining way. So, along with micro machining we are also looking at CVD in particular, which is your chemical vapour deposition.

Now we have taken few examples of sensors, how you can fabricate sensors using bulk micro machining or bulk plus surface micro machining, or if it is a actuator that can actuate the mirror or it can be a cantilever how can we use this bulk and surface micro machining right? We also seen the advantages and disadvantages of dry and wet etching.

Now, in the thin film deposition when you want to grow or deposit the thin film, there are 2 techniques we have already discussed PVD, which is plasma which is a physical vapour deposition. And in this PVD there is again sub division, one is evaporation another one is sputtering. So, when you talk about evaporation you have thermal evaporation and you have E beam evaporation. And when we talk about sputtering; sputtering is a mechanical way of dislodging the atoms from the target and deposit the film on the substrate right.

So, when talk about chemical vapour deposition the chemical vapour deposition have inherently better or few advantages over PVD. And those advantages are: it can have it will have a better step coverage, the quality of the film is better. And it is generally used to deposit silicon and insulators. So, depositing growing a silicon or Si O 2 or Si 3 N 4 silicon dioxide or silicon nitride with CVD is better. Also the purity of the film is better in case of chemical vapour deposition.

So, having said that let us see what kind of chemical vapour deposition are there, and what exactly the chemical vapour deposition means.

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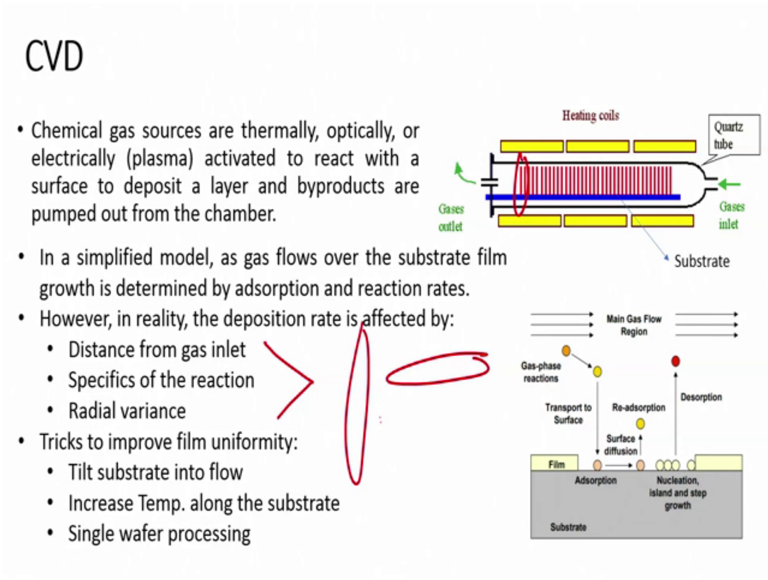

If you recall we have seen this kind of arrangement, sometime when we were discussing about wet etching wet oxidation and dry oxidation right, wet oxidation and dry oxidation. So, chemical gas sources are thermally, optically or electrically plasma activated to react with a surface to deposit a layer and by-products are pumped out from the chamber. So, we were introducing o 2 right it very high temperature about 1100 degree centigrade right. And the by-product was out of this particular Furness.

Similarly, 1100 similarly in case of vapour right H 2 O right. The vapour of what water vapour were carried out carry inside this particular Furness and it reacts with the with the silicon 2 from Si O 2 plus 2 H 2 O right, which was the by-product and that would come out of the chamber right of the Furness. So, point is the by-product will come out after re etching that is what is it, by-products are pumped out from the chamber. In a simplified model as a gas flows over the substrate film growth is determined by it absorption, adsorption and reaction rates correct.

So, you can see here the gas is flowing main gas flow region. Gas phase interaction right transport to the surface there is a surface diffusion in a reabsorption right. Same way there is a desorption and this is how the film starts growing. So, when it is a adsorption or if it is a desorption, then desorption occurs, because of the as a first of nucleation island and step growth occurs, which we can see there is a nucleation. And then slowly island will form following by the step growth. And of course, as a desorption which have the, not which have the by-products and there can be pumped out of the chamber.

So, the point is that using CVD we can deposit several films in particular insulator and silicon. So, when we say several; that means, just limited to insulators and silicon right. Now, in reality the deposition rate is affected by distance from the gas inlet right. These are the factors specifics of the reaction and radial variance. How to improve the uniformity then right? So, you can tilt the substrate into flow right, you can see here we have tilted the substrate; instead of placing substrate like this we have substrate place in a this particular position right. So, we have tilted the substrate increase temperature along the substrate and single wafer processing right. These are tricks to improve the uniformity of the film.

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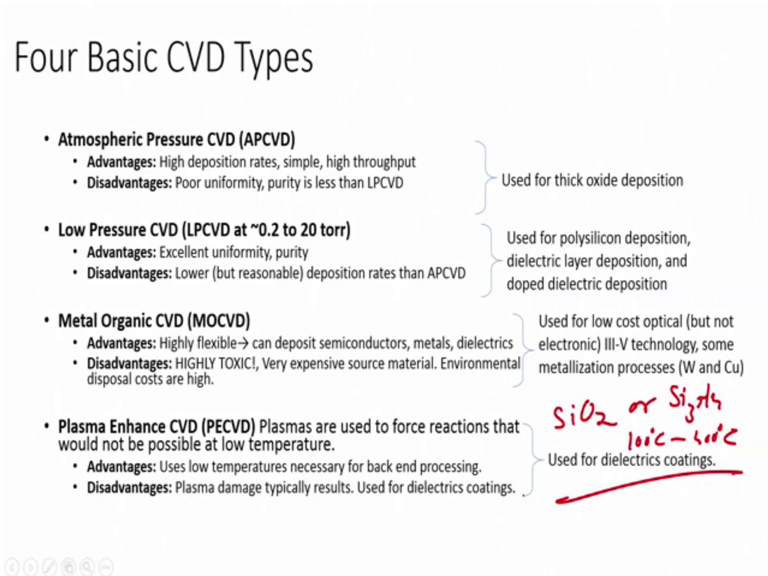

So, when you talk about CVD, how many types of CVD are available right? So, we have 4 basic type of CVD that will be talking about. First one is atmospheric pressure CVD it is also called APCVD, the advantages of this CVD are high deposition rate, simple and high throughput. Disadvantages are poor uniformity and purity is less than LPCVD right. So, what is the use for APCVD? APCVD is use for thick oxide deposition right. The when you talk about LPCVD, LPCVD can be used at 0.2 to 20 torr advantages excellent uniformity purity disadvantages is lower, but reasonable deposition rate than APCVD right; is used for polysilicon deposition, dielectric layer deposition and doped dielectric deposition.

Now, when you talk about metal organic CVD which is also called MOCVD it is advantages are it is highly flexible can deposit semiconductors metals and dielectrics right in PECVD or LPCVD or APCVD, either generally oxides are used or oxides are deposited or polysilicon deposited. But in case of MOCVD we can also deposit semiconductors and metals. The disadvantages being highly toxic and extremely expensive and environmental disposal costs are also very high.

However, MOCVD is used for low cost optical 3 4 technology right, some metallization processes which includes tungsten and copper. When you talk about plasma enhance CVD which is your PECVD, plasmas are used to force reaction that would not be possible at low temperature right. Advantages being uses: low temperatures necessary for back end processing. Disadvantages being plasma damage typically results and used for dielectrics coatings right.

So, these are the advantages disadvantages and generally it is used for dielectric coatings, what is PECVD. Also we can grow the advantages are low temperatures you see. So, we can we can deposit silicon dioxide or silicon nitride right at relatively low temperature like from 100 degree centigrade to 400 degree centigrade. It is a relatively low temperature that plasma enhance CVD chemical vapour deposition uses and that is why it is used in MEMS application, MEMS based sensor fabrication which we have just seen like we can group silicon dioxide with PECVD.

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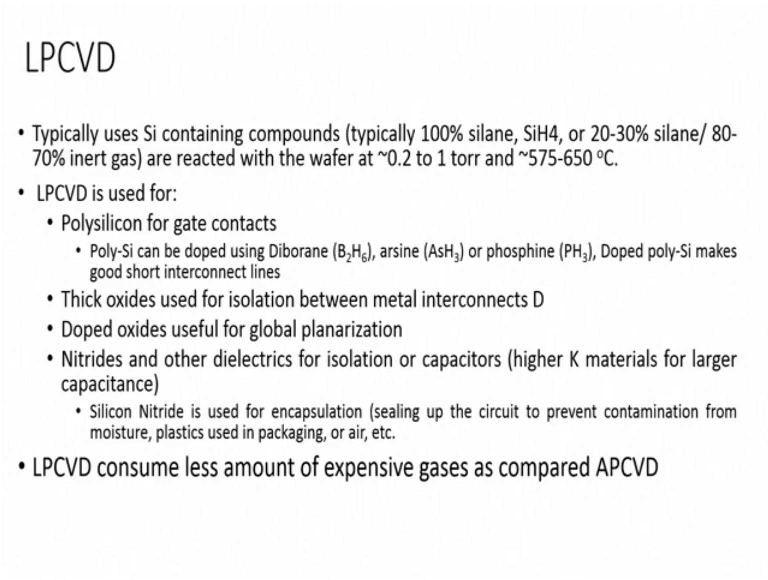

So, when you talk about LPCVD, LPCVD typically uses silicon containing compounds typically 100 percent silane, Si H 4, or 20 30 percent silane, or 80 70 inert gas. And which are reacted with the wafer at 0.2 to 1 torr and about 575 to 650 degree centigrade right. LPCVD is used for polysilicon for gate contacts, polysilicon can be doped using diborane or arsine at B 2 H 6, A s H 3 or phosphine this is P H 3. Doped polyslicon makes good short interconnect lines right we know it. Thick oxide used for isolation between metal interconnects right, these are also used with LPCVD right.

Doped: sorry boys, doped oxide uses is useful for global planarization, as well as nitrides and other dielectrics for isolation or capacitors like higher K materials for large capacitance right. So, LPCVD is useful as well, since silicon nitride is used for encapsulation there is sealing up the circuit to prevent contamination from moisture plastics used in packaging or air. So, LPCVD is used in these particular processes; however, LPCVD consume less amount of expansive gases as compared to APCVD.

So, then how APCVD works right, another question towards would be how APCVD works. So, we will see that APCVD later on let us first that see MOCVD.

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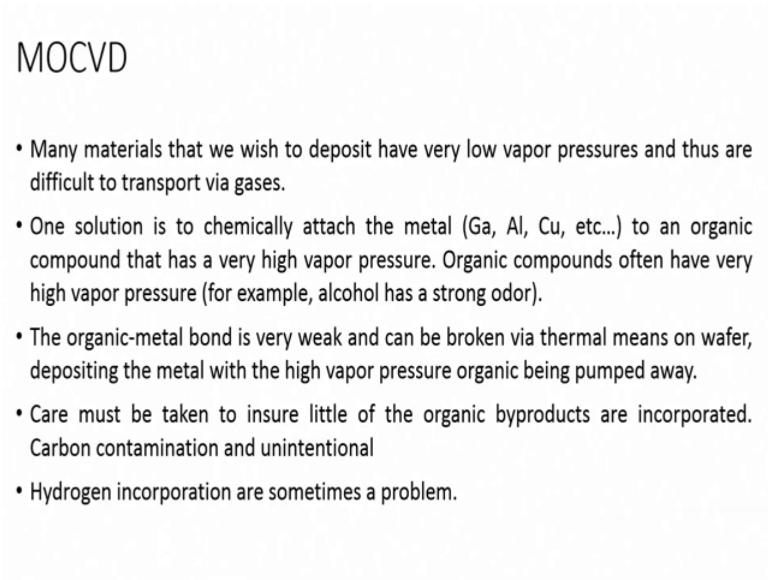

So, MOCVD many materials that we wish to deposit have very low vapour pressures and thus are difficult to transport via gases right. So, what is the solution? The solution is to use MOCVD. If you look at this screen one solution is to chemically attach the metal right that is Galion, Aluminum, Copper etcetera to an organic compound that has a very high vapour pressure. Organic compounds often have very high vapour pressure. For example: alcohol has a strong odor right. The organic metal bond is very weak and can be broken via thermal means on wafer. Depositing the metal with the high vapour pressure organic being pumped away right.

So, care must be taken to insure little of the organic by-products are incorporated and carbon contamination and unintentional. Hydrogen incorporation are sometimes a problem, so these about MOCVD.

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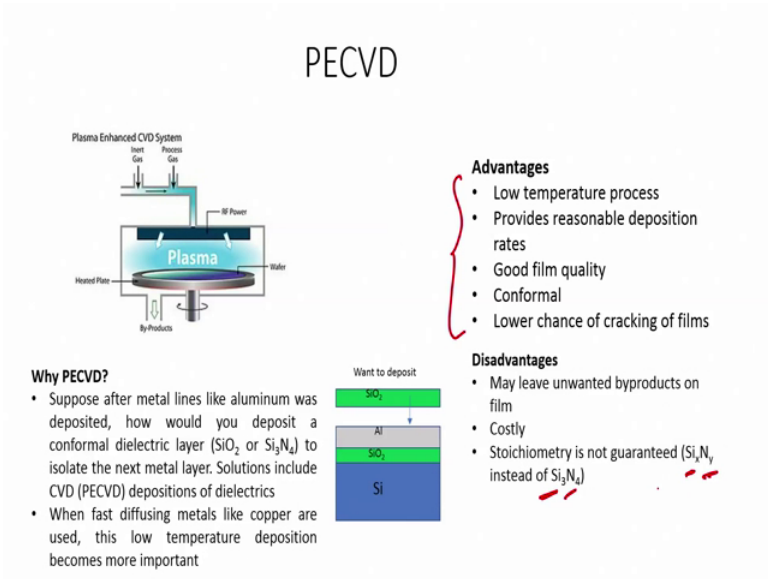

When we talk about PECVD so as we can see a system here is a heated plate there is a inert gas and process gas that we can inside in the system, is a R F power between there will be creation of plasma. And when the gas is reacts which is it will get deposited the film will get deposited on the wafer.

So, what have what is exactly why we are used PECVD, PECVD so let us take an example here, which is shown right over here. If you have a oxide silicon wafer with aluminum metal coated on the wafer or deposited on the wafer. And on this if I want to grow silicon dioxide, we want to deposits silicon dioxide. Now all that the methods they have extremely high temperature, but in case of PECVD this can be grown or deposited at a lower temperature about 100 to 400 degree centigrade. There is a advantage of PECVD. So, suppose after metal lines like aluminum was deposited how would you deposit a conformal dielectric Si O 2 or Si 3 N 4 to isolate the next metal layer right.

So, if I want to have another metal layer I have to have a silicon dioxide in between these 2 metal right. This is another metal, this is one metal right, this one would be my insulating material correct. This silicon dioxide would be an insular we have just taken example of we have taken example of gas inert right when we were depositing a silicon dioxide between the heater and interdigitated electrodes.

So, solution includes PECVD deposition of dielectric and fast diffusion metal like copper are used this low temperature deposition becomes more important. So, what are the advantages of PECVD advantages of PECVD are first it is a low temperature process right. Second provides reasonable deposition rates. Third advantage being good film quality the quality of the film is excellent. Next advantage would be conformal finally they have lower chance of cracking of films right. These are the advantages of PECVD.

While when we talk about disadvantages of PECVD, it may leave may leave unwanted by-products on films, costlier while this stoichiometry is not guaranteed. For example, Si N Si X N Y instead of Si 3 N 4. So, this we do not know exactly it is Si 3 N 4 or we cannot really guarantee this stoichiometry right these are the disadvantages or limitations of PECVD.

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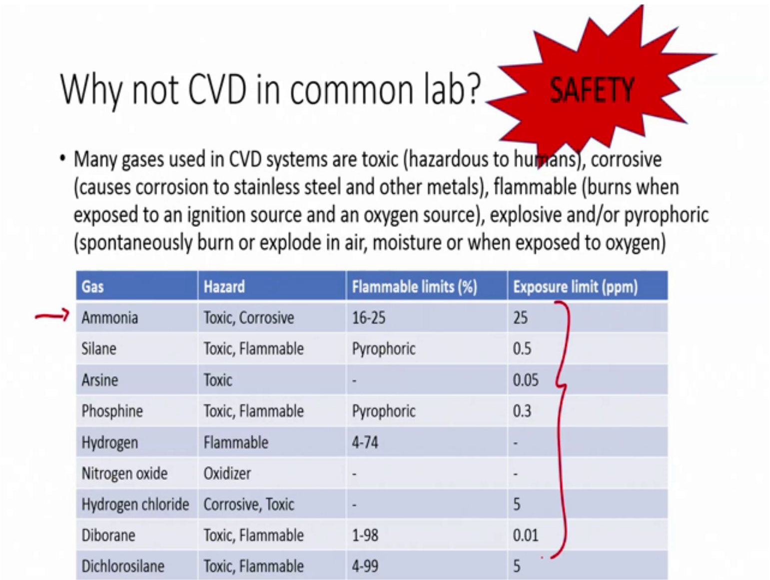

So, why not CVD is commonly used in lab? When you see except few bigger fab labs generally CVDs are not commonly used and the reason is because of the safety factor. Many gases that we used in CVD many gases that we used in CVD are toxic; that is hazardous to humans it is corrosive and it causes corrosion to stainless steel and other metals. And it is flammable it burns when exposed to an ignition source, and an oxygen source is also explosive and or pyrophoric there is spontaneously burn or explode in air at it is spontaneously burns or explodes in air moisture or when exposed to oxygen.

So, these are the reasons why you will not find CVD very common in laboratory. If you x, if you see sorry. If you see gas is hazardous effect flammable limits and exposure limit then you will see that ammonia is a toxic and corrosive gas, flammable limits about 16 to 25 percent, while exposure limit is just 25 ppm; seemly talk about silane 0.5 ppm arsine 0.05, phosphine

0.3, hydrogen chloride 5, diborane 0.01, dichlorosilane 5. So, the exposure limit is extremely small right. You need to be extremely careful when you are using CVD.

Again you see the flammable limits also that it is pyrophoric when it is silane and first film while hydrogen is between 4 and 74, the diborane 198 the dichlorosilane about 4 to 99. And most of the gases are either toxic or corrosive or flammable right. For example, if the corrosion has comes then ammonia and hydrogen chloride are corrosive, if it is toxicity then all the gases like ammonia, silane, arsine, phosphine, nitrogen, diborane as well as dichlorosilane is all are toxic. And when we talk about flammable gases then silane, phosphine and diborane, and dichlorosilane these are toxic gases these are flammable gases not toxic they are flammable gases right.

So, in short what we understand is CVD can be used for depositing insulator or an oxide layer, insulator is oxide or silicon nitride layer. It can also be used to deposit silicon and it has and it has advantages over PVD, in terms of it is film quality, in terms of better step coverage.

And there are several kinds of CVD and what is interesting to us is one that we used for growing wet oxidation, where growing oxide at high temperature, but another one that is that is also interesting to us for this particular MEMS based sensor is PECVD, why PECVD; because PECVD can grow insulating material at a lower temperature. Lot of fabrication we require insulator between 2 metals and we can take help of PECVD right.

So, this would be the end of this particular lecture, which consisted of several modules. And I wish and I will urge you guys to that you guys would read again. The first is I wish that you guys read again second is I will urge you to read again because it is very important to understand how to use micro machining. And then it is an also important to understand what kind of a device is you can fabricate using micromachining also what kind of chemical vapour deposition techniques are used.

And understanding this is very important because when we actually go to a FAB Lab and see how the things are executed, you will understand because you have already covered this thing in theory right. When we talk about photo resist positive photo resist negative photo resist lithography we talk about BHF or we talk about silicon etching right we talk about deposition of gold or chrome or other their metal.

So, in all these thing all these things we are talking about photo resist development right. So, when we know it on theory when we know the process flow, then it will be easier for us to understand when in one of the course that I may be taking in a following semester; where you where the students will be shown. How the device is fabricated in a FAB Lab environment? So, all this things would be useful when you want to understand from FAB Lab perspective right.

So, till then you guys go through this lecture have fun right enjoy your life it is a not so difficult things, but it is important to thoroughly understand this subject. And I am sure you will do well and use this knowledge to create novel devices. Bye.