Lec 05 - Neural Implant Fabrication: PVD - II

Welcome to this class ah now we will continue ah E- Beam evaporation. So, in the last class what we have learned? We have learned about thermal evaporation and its limitation as well. So, in the E- Beam evaporation how we overcome the limitation of thermal evaporation? So, if you recall right ah in thermal evaporation the limitation was that when you heat the material so, that the the source material if the melting point of the source material is more than the melting point of the source holder then we cannot use thermal evaporation because the source holder will melt first before the material itself. So, ah how to overcome that particular limitation? Then the answer to that ah limitation or overcoming the limitation is electron beam evaporation. So, if you see the slide right what you will see is that ah let us ah understand this particular schematic. Before we go to this schematic first understand E- Beam evaporation or electron beam evaporation is a physical vapor deposition ah ah process that allows the user to evaporate materials that are difficult or even impossible to process using standard resistive thermal evaporation right, that is first thing.

And we say that why? How it will be ah useful and how it works is is a second question, but first thing is that the role of E Beam is that it can deposit materials that are difficult to deposit using thermal evaporation one thing ok. Some of these materials include high temperature materials and some ceramics we also understand this thing because those melting point of those materials would be extremely high. Now how this works right? So, let us understand this particular ah figure I will say figure 1 like this ok. So, what you see here is that there is a source holder which we call crucible C R U C I B L E crucible ok, then there is source right.

So, this this here this is source ok, then we have here in the back side we cool the ah crucible all right because it gets too heated up. Now how the electrons are generated? So, the from the filament from the filament the electron beam is generated and this beam is accelerated by the accelerating electrode. So, this is a filament right I will say f the electrons are generated and electron beam is further accelerated with the help of accelerating electrode A E ok. So, you can see here the electron beam right that is generated and accelerated. Once it accelerates there is a deflecting magnets. This deflecting magnets will deflect the E beam and will the E beam will get incident on the source which is loaded into the crucible or onto the crucible right.

So, the electron from the filament travels to accelerating electrodes through and bends through the help of magnetic field or deflecting magnet ah and then it gets incident on the source when it is incident on the source the source will start heating and melting and that is why you have it we we can see here something written molten source molten source ok. And then you know ah when the source melts what will happen? It will start evaporating when it is evaporating what will happen? It will start depositing onto the substrate. So, either you can have point source or you can you can sweep this electron beam right in a raster scanning mechanism or in a triangular form mechanism. So, there are different way of controlling this electron beam. But the idea is that in this case the E beam will be used to heat the ah source that is loaded under the crucible and when it melts it gets deposited you can see here the shield you can see here.

So, let us let me just erase the other things. So, the circle that is left here is the shield that we were talking about correct? Now, this shield will protect or not allow the material that gets evaporated through here because this shield here right will block the material as give you ok. So, we have to remove this shield from the path. So, deposition starts. Before deposition starts what is important that the source is melted properly.

Now ah here you can see the source loaded onto the source holder or crucible right source is loaded onto the crucible and the electron beam is generated it comes from the bottom from here and it gets deposited like this like it it is incident on this source ok. So, this comes from this and then bends it here and you can see the E beam ok. So, the same thing is written more or less here is that the generate to generate the electron beam an electrical current is applied to a filament which is subject to a high electric field. This field causes the electrons in the filament to escape and accelerate away. Electrons are focused by magnets to form a beam which is directed towards the crucible that contains the materials or a source and the energy of electron beam is transferred the material to start evaporation.

Many materials will either melt or evaporate or sublimate. So, you can see here there is a deposition monitor right you can see very clearly what is it, is a QCM we talked about quartz crystal monitor right people use different terms we say deposition monitor fine. There is an electron beam filament, there is an electrical supply, there is a hearth, there is a water cooling and you can see that the the crucible is loaded here and then E beam will come and is directed towards the source in the crucible so, that it melts and start evaporating. So, now, if you understand a bit more thermal evaporation suffers from contamination by evaporation of the crucible materials and this process is not efficient to evaporate high melting point materials. But, E beam evaporation in contrast is used to overcome these problems.

It uses water water-cooled crucible or in the depression of a water-cooled copper earth. The electrons are thermionically emitted from heated filaments that we have seen in the last slide right and are shielded from direct line of sight of the evaporation charge and substrate. The filament cathode assembly potential is biased negatively with respect to the ground in a node to accelerate the electrons which we can understand very easily. And finally, the magnetic field is generated by the deflecting magnets and the electron is deflected in a 270 degree circular arc and then it is focused onto the earth and evaporation charge at a ground potential. This is a video that will help you to understand the E beam evaporation.

So, let me play the video. So, now, what are the power requirements? So, the power requirements for E beam evaporation is approximately 10 kilowatts per centimeter square and dielectric requires only 1 to 2 kilowatts per centimeter square. The contamination level of deposited film using E beam evaporation is less than other PVD methods. Very important to understand that the E beam evaporation contaminates comparatively lesser than other PVD methods. The electron density leaving the hot filament due to thermodynamic emission right can be expressed by Richardson equation which is given in here right and if where A is what it has a constant Q is the in coulombs and then we have work function of the material as well.

So, near to evaporant surface evaporant flux shows a laminar flow there is a laminar and turbulent flow right. So, laminar flow is a smooth flow, turbulent flow is uneven flow right turbulent flow. So, let me give an example if you have ever taken a flight right you may have experienced turbulence, ok forget about the flight. If the river is calm right is smoothly flowing versus river which is flowing during the monsoons right. So, that is turbulent all right in nature while smooth river is a laminar.

Just giving a very kind of simple example so that most of you understand ok. So, the turbulence versus laminar. So, in the in the evaporant near to the evaporant surface, the evaporant flux shows a laminar flow and uniformity of thickness can be described with the help of the cosine law right. So, in the case of the E-beam evaporation how uniform the deposition will be there it can be based on the cosine law. Now, let us understand different kind of evaporation sources.

So, one is single pocket, one is rotary pocket and finally, third one is a linear pocket. So, what is the single pocket versus rotary pocket versus linear pocket. So, water cooled copper block is bored out to have a pocket which is which is right now you can see here right in shape of an inverted truncated cone, isn't it. Now, source material is placed within this pocket. So, within this particular pocket the crucible is placed right and then or the source material is placed or within the crucible whose exterior fits squarely within this pocket.

So, you can have a crucible and then that crucible fits here and within the crucible. So, crucible is like this right and within the crucible you can load the material. The crucible has smaller similar pocket within it a magnetic structure consisting of permanent magnet and two pole extensions are located around the block such that the field lines are parallelly to one side of the block right and the E-beam will come here and will ah incident a directed here. On the same side of the block below this primary fields ah lines is a filament which produce electron by thermodynamic emissions and is formed into a beam which we already know it from 270 degree arc which we already know ah an additional electromagnetic coil known as sweep coil. This is important sweep coil is employed to effectively raster the beam around the surface of the contents of the pocket to evenly heat the source material.

Because continuously if you point use a point source like say this is a crucible right and then you use only electron beam in the center like a point source then what will happen that the other material will not get deposited. Only that area which is where the electron is focused that will get deposited. So, have a uniform deposition uniform melting of the material we can use ah a raster beam, but for raster beam ah we have to have a sweep coil. So, sweep coil is also employed to effectively use the raster scanning and that will evenly heat the source ah which is a part of the operation and typically referred to as XY sweep sweeping. Ah As I told you that there is there are different kind of sweeping ah methods ah and we can use a control program ah ah for the electromagnetic coil.

Materials with lower melting points melt readily within and the field the crucible and they do not require XY sweep. So, for example, if I deposit aluminum with E-beam operation I do not require XY sweep, but there is a material which is having higher melting point you require a XY sweep. Materials with high melting point require XY sweep. So, to prevent the E-beam from boring a hole into the metal and subsequently spitting which creates large modules of the source material in growing thin film which is undesirable. That means, if you continuously point only electron beam in one area then ah it will create a hole and and a bigger chunk of the material will be ah melted and faster such that in the thin film instead of having a uniform ah grains right which are the atoms in a way that you will find a ah larger modules which is not desirable.

Now, this is only for one source what if I want to deposit multiple source and that is why we have a rotary pocket and we have a linear pocket. As you can see in the rotary pocket the other other ah crucibles are shielded by this particular shield ok. It is behind that the circle that I have drawn here know it is behind the shield ok or below the shield in a in a right way is below the shield. So, whichever material you want to deposit you just bring that one into the ah site of the electron beam. So, first if this is the material ah you have to deposit you you can open this one and all the other would be shielded by the shield.

Then you rotate this one and bring the another material or the source holder or the crucible in the site of the electron beam. So, you can rotate it well because you can rotate different ah blocks right or pockets is called rotary pocket mechanism. A rotary pocket electron beam source has all the same parts a single pocket you need except that the water-cooled copper block has a turret of multiple pockets each of which can be indexed into a position. With this design a number of different material can be operated ah sequentially from a common magnet emitter sweep coil structure right. Obviously, this is a include additional shielding to prevent cross-contamination which is here I like I said this is a shield right ah and the pocket position is chosen via motorized or rotary indexer.

So, what happens is the linear one? Linear one also has 4, 1 2 3 and 4 whichever you want you just bring it here ok. This is where the electron beam would be there. So, you can bring first second third or fourth right ah pocket in the site of the electron beam. Earlier pocket electron beam source is similar to rotary pocket source. Exterior pockets are arranged in line and are indexed into a position in a linear fashion with common magnet sweep magnet emitter sweep coil structures you got it.

So, there are electron beam evaporation sources as you can see in this particular slide ok. We will stop here in the next class ah we will talk about ah another PVD technique which we call as a sputtering. So, thermal evaporation, E-beam evaporation and thermal is sputtering ok. So, till then you take care I will see you in next class bye.