Biomedical Ultrasound: Fundamentals of Imaging and Micromachined Transducers

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Lecture: 20

Thermal Evaporation lab demonstration

Hi welcome to this lab class and here we have recorded the thermal evaporation for you if you recall in thermal evaporation what we were doing we have a having a vacuum chamber and inside the chamber there was source holder we apply a voltage the current will pass through the source holder and the material inside the source holder will get heated melted and starts depositing right. So, now we will go through this lab class where a student will show you how the tool operates. During this thing you will also understand and see where a substrate is, where is a source, how to apply voltage, how to create vacuum, how to load the substrate and the possible internal mechanism of the vacuum chamber.

Welcome to the lab demo. Today we will see the operation of thermal evaporation system and overall view of how the PVD technique works and how we can deposit different type of metals using PVD techniques. PVD technique or the physical vapor deposition technique that we will be covering in this lab session is thermal evaporation.

As professor might have told you, there are three basic steps of microfabrication that is additive step, subtractive step or etching and patterning. In addition, step, we are adding a material or a thin film on our wafer or substrate. So, this thin film can be added or can be deposited onto our wafer or substrate with help of physical vapor deposition or chemical vapor deposition. In physical vapor deposition what happens is we are melting a material, or we are bombarding some ions onto a target material and this material will melt or either knocked out atoms will go and deposit on the substrate.

In CVD, there are two precursor which are precursor gases which comes inside the chamber. A chemical reaction happens on top of the substrate and film is grown or deposited in the CVD. In this lab session, we will be focusing on thermal evaporator which works on the principle of resistive heating. In resistive heating, we are having a very high resistance material that is a tungsten boat, or a tungsten basket and we are supplying a high amount of current. So, because of joule heating that is I square R heating the tungsten boat or basket will become red hot or the temperature will temperature of the basket or the boat will increase and whichever source material which is kept inside the basket will melt.

Once the source material has melted it will start evaporating and the vapors will go and settle down on the substrate. This is all about thermal evaporation. Now we'll have a closer look at the tool, and we'll see how we can operate or start operating the tool for the deposition. Now, we'll start by switching on the tool once I switch on the tool every time I press restart. This is a hardware reset that one must do after switch after we switch on the tool on the display, now you can see there are two options visible to me. One is start and another is vent. What starts is, it will start the turbo molecular pump which takes about 10 to 12 minutes of time to come to its maximum RPM speed.

To save time and to make the process faster, first I will just start my pumps. So meanwhile now you can see the status as turbo accelerating so that means the turbo has started gaining speed and meanwhile the turbo is ready, we can see what all other things are there on the panel. This Safety interlock tells me that my chamber is in a vacuum as well as all the doors of the tool are closed. Second is water cooling. This water cooling is a chiller unit which will supply cold water to all parts of the tool like chamber, turbo molecular pump or near to the thermal basket or the E beam crucible. So, this water cooling or the circulation of water, if it is happening properly, then this will be highlighted in green. This panel is for E-beam evaporation. So, this tool has the capability to go for E-beam as well as thermal. E-beam is not the scope of this lab session.

So, we'll be focusing on thermal. This panel is a common panel for E-beam as well as thermal. This is a digital thickness monitor wherein you can see the rate of deposition and the amount of deposition happened on this display panel. Coming to the controls for thermal evaporation, this is the display wherein you will see low tension current which will be used for deposition. This display is a high tension current.

So here a high amount of current we can supply to the chamber and whatever air molecules are present inside the chamber will turn into plasma and this can be used for chamber cleaning. This is a knob to switch on the DTM and this is the knob to open the shutter of the thermal evaporator. So basically, you have a basket on top of that there is a shutter. You will require up, you will need to do preheating of the basket so that whatever material is there inside the basket, example, in this class we will be depositing aluminum. So, I will be keeping some aluminum pellets inside my basket.

So, the aluminum pellets should melt before I start the deposition. So once I supply current to this basket, this basket will start getting heated up and it will be glowing after a point and the material inside the basket will start melting at the time I don't want any deposition to happen onto my substrate which is kept above for that reason I have kept a shutter till my material is melting I'll keep the shutter off once the material is melted I'll open the shutter and the vapors coming out of this basket will settle down onto my substrate This is a socket breaker. This tool has two options, either to go for E-beam or thermal. So, this will switch the supply voltage to thermal basket. And this is the knob to switch on the display for the LT current.

And this is a knob wherein I'll increase my current for preheating as well as to a point where I'll see some deposition or that the deposition rate is increasing, and I'll stop at that current and I'll open the shutter to start my deposition. Same goes for a high tension current this is a knob to switch on the display for high tension and this this is a knob for the rotary drive because I want a uniform deposition on my substrate so I want my substrate holder to rotate in at low rpm speed so this is a knob to switch on the rotation and we can set how much rotation we want using this knob the most important part of this tool is this emergency stop whenever you feel like there is a smoke or there is some fire hazard or you are seeing some smoke or fire from the tool Then you should press this EMO button so that this tool will go into emergency situation position or emergency situation and there will be no harm to the user as well as the tool. Now as you can see the status turbo pump is ready and as you have seen the safety interlock is green that means my chamber is in vacuum condition. And because I need to bring it to atmospheric pressure, I will press vent and after that we will load the sample inside the chamber to start the deposition process. So, I will press vent and wait for couple of minutes because now the atmospheric air is coming inside the chamber, and it will take couple of minutes for the chamber to come to atmospheric pressure. Once the chamber is under atmospheric pressure, we will open the chamber and load the substrate. Hissing sound has stopped and now we can open the chamber. This is the substrate holder where we will load our sample. Just to show how the substrate holder rotates, I will just switch on the rotation, and you will be able to see the substrate holder is rotating with the help of the spindle.

Now, I will unload the substrate holder and keep it aside for sample loading. Now let's have a closer look inside the chamber. Water components are there for thermal evaporation. We'll have a closer look. Now we will have the closer look inside the chamber.

The most important part of thermal evaporator is the tungsten basket and where it is connected. So, as you can see here, this is my tungsten basket and the two terminals are connected to this, two points of the basket are connected to these two terminals. and you can see some material, or the source material is already loaded inside this tungsten basket. You might feel that once this material melts, it will come out of the basket because there is a gap in the basket. But what will happen is because of the surface tension and wettability with the tungsten, the material will not fall down, and it will just stick to the walls or the wires or coil of the basket.

Now this is done. We'll see the DTM which is here. So, it is a quartz crystal monitor. It has a quartz crystal inside it which has its frequency. resonant frequency, once some mass gets deposited on that quartz crystal, its frequency will change and the change in frequency will be converted to the amount of thickness deposited in that run. This is the shutter which I was telling you which will be covering this tungsten basket like before the time of deposition or at the time of deposition this shutter will come to this position and the vapors from the vapor of this source material will come and settle down on the substrate holder which is kept here.

Now we will load our sample. We will go for sample preparation, and we will load the substrate holder onto the spindle. This is a glass slide on which we will be depositing aluminum. I have cleaned this glass slide using acetone, IPA and DI water and gave a nitrogen blow so that the top surface of the glass is very clean for the deposition. I will place the glass slide onto the substrate holder, and these are the clamps through which using which I will be securing the glass slide so that when we are placing this substrate holder upside down so the clamps will make sure that the sample or the substrate will not fall into the chamber.

I will make sure that the glass slide is not moving, and I will tighten it properly in such a way that it is not pressurizing the glass slide. At the same time the glass slide is secured. So, this is the glass slide secured with the help of these clamps. Now we will place a substrate holder inside the chamber, and we will start evacuating the chamber and we will wait for the chamber pressure to reach 10 to the power minus 6 millibar before we start the deposition. So this is the sample holder and the glass slide which I have secured just now already the chamber is in a vent condition or the atmospheric pressure I can easily open the chamber and will load the sample by flipping it upside down and there are the holdings for this substrate holder for a secure fitting so I have just secure the substrate holder onto this spindle and now I can close the chamber door and I can go for cycling so what cycling will do it will start evacuating the chamber and will take the chamber pressure to 10 to the power minus 6 Millibar of pressure which is desired for the process to happen. A quick view or the quick point to the safety interlock because the chamber is in atmospheric pressure, this is not green. Once the chamber goes into vacuum condition, this will turn green automatically. Now this is the sound of rotary pump or the roughing pump which will take the chamber pressure to 10 to the power minus 3 Millibar and already the turbo is running and once the chamber pressure reaches to 10 to the power minus 3 Millibar there will be the backing valve will open and the chamber will be connected to turbo molecular pump. So further vacuuming or further evacuation will be done by turbo molecular pump.

After this we will wait for around one and a half hours for the vacuum to reach the desired pressure value and we will see the rest of the process after the desired vacuum, or the pressure is reached. Meanwhile the pressure has started decreasing. We can take a closer look of the mimic diagram which is the schematic of the whole system to understand what is happening when we are pumping down the chamber. So, for that I will go to system view and the mimic diagram. so here this is the turbo molecular pump this is the rotary pump when we press start what happens is this is the backing wall which will open and there will be evacuation from of this line and the turbo molecular pump will start gaining speed and will come to at maximum rpm speed When we press cycle at the time the chamber is directly connected to the rotary pump using the roughing wall and after the chamber pressure reaches to 10 to the power minus 3 Millibar.

The high vacuum valve which is open right now will open and the evacuation will happen through the high vacuum valve, turbo molecular pump and then the roughing pump. These are two gauges, pressure gauges which will measure the pressure inside the chamber. This is the vent valve. So, whenever we are pressing vent, this valve will open and the atmospheric air will start gushing inside the chamber. We'll go back to the systems page and see, and we are seeing that still the vacuum hasn't reached.

So, we'll wait for the vacuum to reach and then we'll look at how we will start or how we'll proceed with the deposition. As we have waited for one and a half hours for the vacuum generation, and we have already loaded one glass side onto the substrate holder, and you can see now the vacuum has reached 3-6 Millibar and now we can start our deposition process. This time we will be doing thermal evaporation. So, the main knobs or the main points to focus on is the circuit breaker. Circuit breaker will change the supply from the electron beam to my thermal evaporation circuit.

Then this knob will switch on the display. This is a low-tension secondary current that means this low tension means from 1 to 30 Amperes we will able to supply the current to the tungsten basket and we can see a discharge or a glow inside the chamber. Through this knob we will increase the current and we will switch on the DTM using this and the rotary knob rotation through this knob. So first I will switch on the DTM and as you can see there is a P fail that means power fail.

So first I will press stop. It has reset and because there is no deposition happening right now so we are getting zero values, and I will start the rotation as well and now the rotation rpm is kept at three. Now I'll using the circuit breaker as I have given the supply to my thermal evaporation circuit, and I'll switch on display of my current and I'll ensure that my current knob is set to zero Slowly and one more thing this is the shutter control for our thermal. Now slowly I increase the current to 10. So first I'll give, do the preheating of my element.

That is the aluminum. We have kept aluminum in tungsten basket. So, I'll preheat it to 10 or 12 amperes. And you can see, you will see a close-up view of the viewport wherein you will see the basket glowing. Now I'm increasing the current. So, this has a very precise control, so I have to rotate a lot more to get the desired current and I have set it to 12.

And I will just look at once whether my basket is glowing or not. It is not. So I will further increase my current to 15 or 16 or something like that. I can further go to 17 or 18. I am just checking from the viewport whether there is a glow on the tungsten basket or not.

Now we will have a closer look from the viewport to see the tungsten basket glowing. Now the preheating was carried out for around 1 minute 30 seconds and now I will start my DTM so that whatever deposition will happen that way we can monitor using the DTM. Now I will increase my current to around 22. Yes, and as, you can see now there is some change in the DTM so that means the material has started melting so I will go till 25 or 26, 27 is also fine and I will open the shutter. To increase the deposition rate, I can increase my current furthermore to 25.

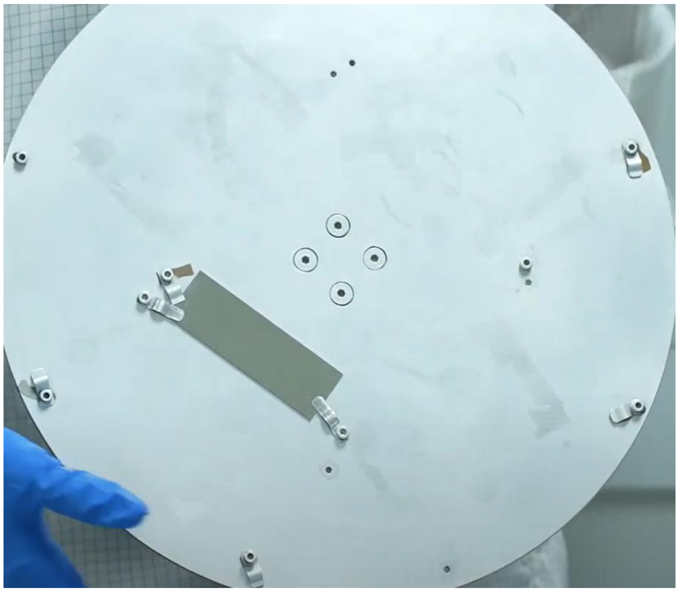
It was already there. I can go on the 27 and 28. As you can see the deposition rate has increased, and I'll just wait for one minute or so to get a good quality good film thickness. The thickness depends on our application how much thick, thicker film you want so right now it is seven nanometers. We can go to 50 nanometers. I can increase the current a little bit so that the rate of deposition will increase. 25 nanometers also is a good amount to see how the deposition has come up.

So, I can stop at 25. I'll just take it to 30. No issues. So, the first thing which I will do is I will close the shutter then slowly I will decrease the current which I am applying to the basket and slowly the glow discharge or the glow which was there it will reduce, and the temperature will come down. I have made sure that this current knob is completely at the zero position, and I will close the display, and I will again break the circuit breaker so that the ideal or the default voltage connection should be to E beam.

And I will switch off the DTM as well. I will stop the rotation as well. And now we want to see how the deposition is. So, we need to vent the chamber, or we need to increase the pressure inside the chamber. For that I have two options.

One is seal and one is vent. Now if I press vent, what will happen? My pumps will also start decelerating. I don't want to do that. So first I do seal. The seal will isolate my chambers with the pump and now I can press vent. So, now you will see, now you will hear a sound, a hissing sound.

That means atmospheric air is coming inside the chamber and bringing it to atmospheric pressure. We will just wait for couple of minutes and then we will be ready to open the chamber. The hissing sound has stopped, and it is safe to open the chamber. I will open the chamber, and I will take out the substrate holder. So, you can see the transparent glass light has converted to a reflective surface.



This is the aluminum which we deposited a while ago. and it is an ideal practice to again keep the chamber into vacuum condition or evacuated condition. So, I will again press cycle so that the chamber will go to lower atmospheric pressure and then finally we can stop the system as a whole.

So that's it for today's lab demo. Thank you.

Okay so now you have seen the lab right and what you understood from the lab class is how to operate the thermal evaporation tool. This is one of the tools of many different companies makes a similar kind of tool what you have seen is a tool from Hind Hivec but you have tools from different companies from Indian manufacturers and from manufacturers outside India. But again, depending on the application you can have only a single source, or you can have multiple source for depositing the different kinds of materials. Here what you have seen is a single source that means only one material you can deposit part for one time. We can have the advantage of this tool because it is very simple to operate, just you have to control the power, and you can heat the metal so that you can deposit different films.

So, in the next class you will see the EB operation and following classes you can see the sputtering as well to cover up the PVD tactics. Thank you.