Sensors and Actuators
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Lecture – 32
Introduction to Cleanroom facilities for biomedical application

Hi. This is lab class number 12, extremely important lab class, because now we will be showing you how the actual Cleanroom class 1000 slash 10000 looks like ok. Now, this particular lab class we are just focusing in introducing it to you how the cleanroom looks like, what kind of wet benches are there, where there is only acid or you can use only solvent, then we will be looking at the biosafety hood, then we will be looking at how the lithography room looks like ok, then we will be looking at what kind of HEPA filters are there and we will be looking at the incubator.

So, it is important for you to know laboratory component for you to understand and slowly and gradually we will also teach you how can you actually use a electron beam slash thermal evaporator and will be demonstrate you how it can be used in detail. We will be also showing it to you how can you use oxygen plasma system for bonding PDMS with glass all right.

So, not only just expose giving exposure for the actual or conventional cleanroom facility, but also showing it to you the equipment within the cleanroom that is my idea right, but for this particular lab we will be taking you or giving you a tour that how the lab looks like more or less. And you will see that lithography lab in particular will be of yellow colour compare to other part of the laboratory the reason is that because the in lithography section we will be using a photoresist and photoresist is sensitive to the UV light.

So, even you the tube light will expose the photoresist and to avoid that we will be using the yellow colour light. If you have seen in old movies right there is a red light the room with red light and the photographer is like exposing or curing the negative you know this photo so as to develop it present it. So, why there was red colour light? Because the photosensitive material that was used for capturing or developing the photograph right should not be exposed to UV and that was the reason. So, similar concept, but now we are using at a micro level or a nano level and that is why we had to use a yellow room.

So, we will be showing you about for around half an hour. So, please look at it thoroughly right and like I said slowly and gradually we will also show it to you the equipment within the clip all right. So, till then you have if you have any questions always feel free to ask. You can also simultaneously look at the Youtube videos you see you will have lot of information about how the cleanroom looks like, now whatever the class of cleanroom right and etcetera ok. So, that will be the end of this particular in a lab class after he shows this particular facility and I will request my teaching assistant Anil to give you the lab tool and I will see you in the next lab class. Bye.

Hi welcome to this course this module covers something very interesting in as you know this course is discusses about sensors and actuators. You would have covered or you will be covering as part of this course, design of sensors. The fabrication techniques involved in making such sensors, what is the difference between sensors and actuators, how these are interfaced with electronic systems to make interesting systems that can be used for real world applications, how biological applications can be implemented using this and let such vibrant ways in which sensors and actuators interact with the real world you would have covered.

In this module we are going to see one very core aspect of sensors and actuators, which is fabrication of sensors correct. Now, for sensor fabrication as you would have understood by now it is very important to have a very clean environment to avoid contamination of the fabricated sensor.

For this people use cleanrooms throughout the world in all fabrication facilities. Cleanrooms are classified as based on the number of particles of size greater than 5 microns per cubic feet. So, if that number is less than 1 it is called a class one cleanroom. If that number is less than 10,000 it is called a class 10,000 cleanroom. Most of the time in India we usually have class 1000 cleanrooms or class 10,000 cleanrooms.

For big companies like Intel TSMC, Taiwan Semiconductor Manufacturing Company, they even have class one cleanrooms where they make high end processor chips as you would be aware all of you would be aware of Intel core I7 I5 I3 and all these are chipsets that are fabricated from such facilities and depending on the criticality of the process that is involved they might even use a class one cleanroom. Today we are seeing one such cleanroom that is being developed here at IISc in department of electronic systems engineering.

So, what I will do as part of this module is show you how overall a cleanroom looks like, what are the protocols followed in going into such a cleanroom that will eventually fabricate the sensors that you have covered ok. So, as and when you enter this is what you call the governing area or the entry area into the cleanroom.

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So, here in this cupboard which is used to keep the gowns cleanroom gowns. So, right now what I am wearing is just a lab coat with a head mask, face mask, and gloves. Now, right now we have not we are not operating the cleanroom and we have not fully maintained the class of the cleanroom. So, for that reason right now it is to go in to the cleanroom in this way, but once it is fully operational we are doing this so that you understand how small things come together form to form a good establishment.

So, as you enter cleanroom gowns will be housed in this cupboard. So, here the display it is just like another cupboard, but just that the material and all is made for a clean environment. So, you can keep the gowns here and other things like head mask, face mask also will be kept next to it. So, this is the gowning area.

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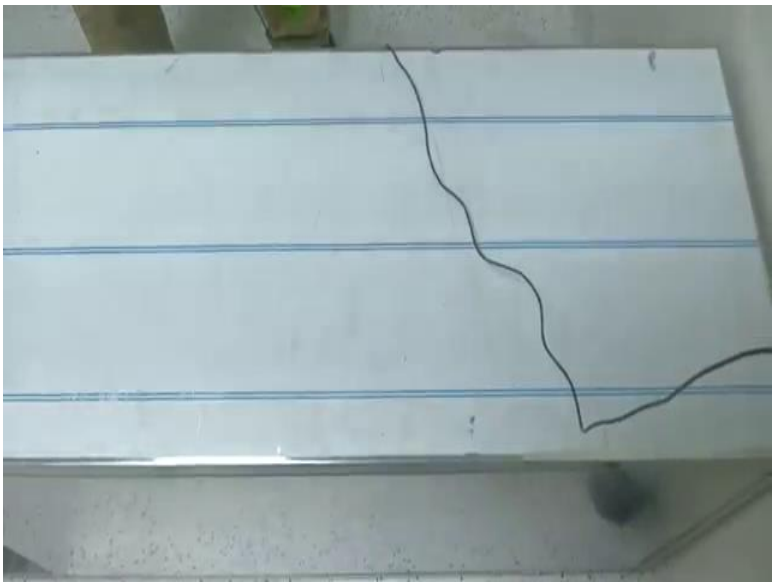

So, if you can see yeah, so this is a separation which you can see that separates the gowned person from the ungowned person. So, when you are not gowned you stay here and after you finish once you have completed you come here

So, the protocol is the protocol is that you enter the area, first you will put your head mask, face mask, gloves, and then you put your shoe cleanroom shoes and come in into this separation and then you can may or may not choose to wear the gloves, but head mask and face first is compulsory before you come into this. Then you come in you take your cleanroom gowns from here put it on then you are ready to enter the cleanroom.

So, this there will be for you to hear properly we have switched off the circulation here it will create a lot of sound that circulation is what maintains the particle count in the cleanroom ok. Then this is the door through which we will enter. So, this once you are ready you can go in like this. So, now, you have seen how you gown and you enter the cleanroom right, but now you are going to do a scientific research work there.

It is very rare that you want you will go inside a cleanroom without carrying anything either you will have samples or you will have some notebook to write down things. Here two things are there one is samples that you carry you should make sure it is your own responsibility as a person who is working in the scientific field to ensure that your samples meet the cleanliness requirements of the cleanroom to which it is taken. So, you should make sure that your sample is thoroughly cleaned should not have any contaminating particles, no dust particles and all as

much as possible that is regarding samples. Now, about notebooks, in cleanrooms usually special type of papers and notebooks are used they are called cleanroom notebooks. I will show the cleanroom notebook in another session.

So, cleanroom notebooks where and you should not use gel pens usually you should use ball pens to write on that notebook because gel pens also add contamination to the devices ok. They will enter the air and cause contamination or ink pens also for that matter are not allowed, only ball pens and cleanroom notebooks.

So, now, the point is that you cannot simply enter the cleanroom like this carrying your device and your cleanroom notebook that is this is because you there needs to be a proper separation between the inside of the cleanroom and the outside of the cleanroom as much as possible because we do not know what foreign particle might be there in the stuff that you bring. So, for that we have a separation chamber it is called a pass through chamber which we will see shortly.

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Now, you can see the pass through chamber ok. So, this is where what it happens is you keep the items that you want to bring in you keep them inside ok. So, the thing is you press the button and you open the door and then you can keep your things inside and then you close the door. So, the thing is why you when you look at it you might seeing that this is simple what is it is this just a door why do you want so much sophistication for this. So, the idea behind is this door has a door on the other side correct, the other side is the proper cleanroom environment. This door has a protection that it can only be opened from one side at a given time. So, the

moment you press this key the moment you press this key and open it the other side get locked. So, you keep your item inside then you close it then only can you open it there.

So, this way if it is a normal cupboard if both these doors are opened on either side simply dust from the entrance will simply go inside. So, this is the protection for that. So, that is why it is called static pass-through chamber that will reduce the contamination that might enter the cleanroom. So, these are the things these are small small things which you may not come across, which you may not hear about that are also a part of a fabrication process.

You might be making extremely mind blowing designs very innovative structures, but then if you cannot fabricate it with that cleanliness or that finish it will not be useful to use a sensor. So, that is why we are going through each of these small small things. So, that being a scientist you also work as a responsible scientist. You have to be responsible for your work and you also have to be responsible that you do not affect other people who work in a cleanroom.

This is like a shared facility, it is not your own property. You are coming in to do your work, but when you do your work you should make sure that you do not affect others that is why these protocols and mechanisms are in place across the world. So, this is the overall way in which you enter the cleanroom you bring stuff inside now we will go inside.

We have now entered the cleanroom ok. This cleanroom is something special it is little bit unique compared to other cleanrooms in that this in this cleanroom we also have a biology section which you use to immediately test the sensors that we have built with biological specimen ok. So, there is a main room which is where main area this is where I am standing right now, there is a bio section which we will see shortly and there is a litho room with yellow light which also we will see shortly, these are the three main areas ok.

So, litho room is for the optical lithography which you might have covered in the course where the litho machine or the mask aligner machine is kept and this room is where we do other processes ok. When we come to other processes I need to tell you how very in a simplistic manner you can look at micro fabrication. As you know this course covers micro fabrication for making sensors and actuators correct.

Micro fabrication can fundamentally be broken down to three processes, one is an addition step where you deposit material be it metals insulators anything. Next the second step is a patterning step where you make or imprint some kind of pattern on this deposited material which is in

turn on a substrate that does the patterning. Third is the removal step or the etching step where you remove the unpatterned or the pattern depending on the photoresist that you have used material from the substrate.

So, these are the main three processes in micro fabrication, but for each of these processes you use different techniques ok. For addition which is the deposition of material you can do sputtering sputter deposition, you can do E-beam evaporation or e-beam deposition you can do thermal evaporation. So, these are different techniques to deposit material.

There is chemical vapour deposition, physical vapour deposition android. In this main area we will have E-beam evaporator and thermal evaporator systems and that is the addition part of the addition process and behind me you can see wet benches which are used for fit etching of pattern substrates ok. These are the two main equipments or systems that are there in this main bay. In further modules you will actually see the operation of these videos if time permits operation of these systems which is the thermal evaporator a beam evaporator if time permits in this course. This is one section next we will see what does this wet benches do in a short video as part of this module.

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So, as I have told you that wet benches for wet etching and for cleaning processes happen in this main room. So, these are two wet benches that we have this is acids only bench as you can see written on the wet bench. And it is you can see that wet benches are written this is a wet bench and this is solvents only bench ok. As per safety protocols acids and solvents must never

come in contact with each other because that is dangerous, that is why we have separate benches for acids and solvents.

So, now, what happens in these benches? These benches are primarily used for two things one is wafer cleaning when you take a substrate which forms the wafer when you take the wafer that is the first substrate for a device fabrication. So, that wafer first before you use has to be cleaned thoroughly. There are different types of cleaning which is piranha cleaning RCA cleaning RCA 1, RCA 2. So, these are standard cleaning procedures that are usually carried out ok. They have their own fixed concentration proportions etcetera which will be covered or would have been covered already in this course.

So acid bench and solvent bench has to be separated. One use is the cleaning of the substrate which is the wafer; wafer can be silicon wafer, silicon on insulator wafer, glass wafer it can be lot of different wafers it can even be a gallium nitride wafer different types of wafers are there. Now, cleaning is one thing another thing is etching, etching in the sense suppose you deposited gold on top of your substrate then you have patterned it in lithography. There was a pattern formed and then you want to take the pattern out. So, only lithography only forms the pattern it does not remove material from where the pattern is not formed you bring that wafer here then you etch the gold.

So, gold etchings are there standard etchings like gold and chrome and gold will not be deposited as just gold gold will be deposited as chrome gold. First a thin layer of chrome let us say 30 nanometer of chrome will be deposited on top of that the your required thickness of gold which is usually around 200 nanometer to 400 nanometer gold will be deposited onto your substrate. Why chrome is deposited? It is for sticktion or a better addition of the gold onto the substrate. Gold alone will not stick properly onto your substrate. There is why chrome gold is used.

Now that we have used chrome gold on the substrate you have patterned it you need to remove the gold and chrome from where the pattern is not formed right. So, first you remove gold because chrome is below it remove gold with gold etchant which is usually potassium iodide KI and you remove chrome with a chrome etchant.

So, these two etchants will be kept here ok. Likewise there are etchants for different things or you might even use a lift off process which does not require a etchant for a specific material, but requires only acetone and IPA that removes the photoresist. There is separately a lift off

process which will which will be covered. So, for lift off processes or for etching also these benches can be used and you understood why so acids say for silicon dioxide etching you use HF ok.

So, for a hydrofluoric acid buffered hydrofluoric acid is also used for cleaning the wafer a lot of things are there. So, if the wafer you take silicon wafer you take it will have a small layer of oxide on top of it. Suppose you want to remove that use HF; HF is a highly heavily dangerous chemical to handle. So, there are specific operation protocols for using HF itself. So, HF is an acid hydrofluoric acid. So, that will be stored here. So, these acids will be stored below in these areas which will be labelled properly.

So, you might not have seen it, but there is a container below where the acids will be stored. So, the chemicals will be stored just below the bench itself and this bench is right now not switched on. So, as you know you are handling chemicals right. So, when you add multiple chemicals the chemicals will react there might be fumes ok, water vapour might get greater. So, you have to be careful you need to wear face shield and all and lapel and everything to work on this bench. Right now we are not directly working on the bench that is why I have not worn the PPE. What is PPE? Personal Protection Equipment you need to wear personal protection equipment before you work with these benches ok. Now, I told you that fumes might get formed when you work with this benches. So, these benches also come with an inbuilt HEPA filter or a filter that sucks in air at a high pressure.

So, that inside as small high pressure is maintained. So, that that the fumes are sucked in. So, it does not escape this side. So, that if you are working like this the fumes go that way and does not come this way ok. So, there is switch for light. So, you can see light has come and the next button will switch on the filter. When I switch on the filter you will hear the sound with the filter switching on. This is the sound of the filter switching on.

We also have a meter which we which I will show you shortly there is a meter on top of this bench which starts with 0 pressure and as and when the filter starts operating and reaches a stable point it re goes to a higher pressure and stabilizes there that change we also we will see shortly. So, this is how the filter the wet bench works. So, now, when you have to work you lift the glass light only up to when how much you require maybe around this much and there are outlets for the discard and these holes are there through which all the liquid will go in that is the overall operation. Let us see how the meter works.

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So, you can see the meter here, right now it is in 0 position ok. So, I am going to switch on the filter and as I switch on the filter you can observe that the pink or the orange indicator will change. So, it is moving slowly moving. The pressure is in millimetres of water ok. It is going and it stabilizers at around 9.8 ok. So, that is how this works. So, this shows that there is a positive pressure inside and the wet bench is operational. This is how you use a wet bench. So, we have seen the wet bench which is next to me here.

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And now we have seen. So, this is a module filter module HEPA filter module apart from the overhead filter modules that are there for maintaining the clean environment of this room. We have a separate filter modules also dispersed throughout this room for maintaining the air quality ok. So, I have connected with the power. So, this is a filter there is filtering mechanism inside it is a very sophisticated equipment which needs to be maintained thoroughly.

So, if I when I switch on you will hear the filter turning on as you can see it is creating lot of sound. So, that is why I am just switching it off that is why we are recording presently with things switched off. So, that you can hear me properly imagine around 10 of this switched on parallely so; that means, sound will be there. So, that is why we have switched on for a short time for us to show you this facility. So, this is HEPA filter. What is HEPA filter? High Efficiency Particulate Air, HEPA filter.

Now, we have seen the HEPA filter. We will go to the biology section which I told you before of this cleanroom. So, we will go inside the biology section we have entered the biological section within the cleanroom. The main equipment that will be there in such a biology section will be usually an incubator for growing the cells and maintaining cells and a hood, what good biosafety hood biosafety cabinet that is used for processing the cells tissues etcetera ok. I think you have already covered in detail how a biosafety cabinet generally works and you have seen one biosafety cabinet in the other lab this is another biosafety cabinet the operating principle is everything is same before you use you need to switch on the UV light. I am switching on the UV light now.

So, now UV light this was done before you use you have to switch on the UV light and leave it for like 15 to 20 minutes for sterilizing and killing all bacteria inside ok. Once that is done once you before you start work you switch off the UV light. You cannot work inside the UV light because it is carcinogenic then you switch on the light lights are switched on ok. Now, lights are switched on. So, you can see inside there are these vents that is for air circulation what happens is air gets sucked in and gets recirculated through this top filter again another HEPA filter is there.

So, I am starting on the air you can see the air being circulated. So, if I lift it up you can see this. So, it is actually circulation is from inside it is sucking. Now you have to work with the air on and you can see the mark here with I think you have covered already this glass should

always be at or below this mark ok. You can see the lights are there inside. Now how to work the? I will also talk to you about the protection that is there in this equipment.

Let us say I have told you that let me switch on the air now I have told you that the UV has to be on correct before using and you have to switch it off before you start working. So, the light is on, the UV light is off the filter is on as you can hear the sound then you know you are ready to learn how you will work you have to lift it the bare minimum that you need it to be lifted put your hands inside and with minimum movement you have to operate all the equipment and samples that are inside. This is the way you should work and once it is over you have to wipe your hands with ethanol that is a disinfectant and then close the hood and switch off the light and fan.

So, now, I have shown the light to you. So, that you it is visible for you. So, this is how a hood works by a safety cabinet for processing tissue cells and all why we are having such a facility inside a cleanroom is as and when we make the sensors we can do a preliminary testing here itself. This is something very unique about this lab because most of the cleanrooms across the world have strict protocols, but they are used for VLSI fabrication what we work on is mems fabrication and sensors and actuator fabrication where we very often have to deal with biological samples for testing.

So, mems fabrication and VLSI fabrication are a two different separate streams though the processes involved are same. So, VLSI most often would not have to interface with biological samples, but mems devices constantly interact. So, there should be a facility where we can quickly test our fabricated sensor in the most cleanest environment and test it out preliminary testing then you can take it out and test it in other labs because finally, it has to be used in a normal setting right, but then you need few for you to characterize your sensor you need to test it in the environment where it was made for that we have made a biological section like this ok.

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Next we will see and yellow room we have seen the biology section of the cleanroom here next we are going to a very important heart actually if you can look at it of the cleanroom which is a yellow room. Why we are using yellow room? This yellow room is used for optical lithography before I go let me switch on the yellow lights. You can see the glass inside there is a yellow light before we go in. Let me introduce you why this is required.

So, optical lithography is what we perform to pattern correct I have told you optical lithography is fundamentally done using a material called photoresist which is a photosensitive material that is coated on top of the deposited material. The photosensitive material is spin coated then hardened and then exposed to ultraviolet light. The photosensitive material is sensitive to ultraviolet light and under the influence of ultraviolet light it changes its properties depending on where the mask is exposed or not exposed correct. Through the mask the ultraviolet light will fall on the photoresist.

So, some parts of the photoresist will get exposed to ultraviolet light some parts do not. So, after we spin coat before we use a mask and a UV light source you need to be able to handle the photoresist light. So, what do we need for such an environment? Yes we do not need ultraviolet light; light in that environment because the photoresist will get blanket exposed for that we use yellow light which does not affect the photoresist. So, you coat the photoresist use the photoresist everything in a yellow light environment, then you take it into the lithography machine which is usually called a mask aligner and then you expose it to UV light ok.

Next we will just quickly go in we will have a separate session on mask aligner is possible in this course otherwise we will just see the yellow room inside now. So, I have endured the yellow room and so, you can see everything is yellow. Yellow light is falling on me I am sitting inside the yellow room and another video we will try to show you the equipment here if time permits, but generally what are the two main three main equipment that will be there in any yellow room.

The beasts in the room the main guy in the room is the mask aligner or the mask aligner system which is the lithography machine which will have a ports to input the wafer one port to put in the mask plate and then UV light source and laser source to expose the wafer through the mask that is the mask aligner system. What does it do? It aligns the mask along with the wafer or the substrate and then exposes it ok, but before we do that we have to spin coat the photoresist right.

So, you will use a spin coater machine that does that rotates at unique RPMs fixed RPMs like 4000 RPM, 5000 RPM, 6000 RPM and then you spin coat after dropping the putting the photoresist on your substrate and then you switch on the spin coater it will rotate and uniformly spread the photoresist on your substrate. So, spin coater is required then you need to work with the spin coater you need a workstation pathology workstation.

It is just like the hood that we saw, but just that it will not be that sophisticated. It will have basic protection and a fume hood. So, the floor dresses and all are lot of they have unique smell and many times many chemicals are little bit carcinogenic and all, so the fumes you should not breathe in. So, it will have a fume hood to take out unnecessary fumes that are formed inside.

So, it is always advisable to work with photoresist material and other materials inside a foam fume hood, you stand in like the one we saw before you stand inside the fume hood and then work with it. So, that the fumes get sucked in and you are not affected much. So, that is required. So, you use the fume hood you put the photoresist you take the wafer which is having the photoresist drop put it on the spin coater or you put it on the spin coater and then drop the photoresist, switch on the spin coater it will uniformly deposit the photoresist on the substrate then you take it out you have to do a lot of heat treatments before and after you do photoresist coating. So, let us say you bring in the wafer you need to first dehydrate it. So, that there are no water particles or water molecules on your substrate.

So, first you keep it on a hot plate on the wafer on a hot plate. So, that for like 130 degree 120 degree depending on what is your process parameter. So, that it will have a dehydration that is called dehydration bake then you put it on the spin coater you put your photoresist and then you spin coat it then you heat it also again for a 1 by 4 minute it is called a pre exposure bake because before you expose ah. So, the there will a small bake it is called baking of the photoresist then you take that into the mask aligner system.

You align it expose it to UV take it out and then you have to develop it. So, development is just like olden days you people use to develop photo films right. It is just like that then UV light falls on the photo material some part where the light falls on the material gets developed other parts material gets changed chemical property changes, other parts it will not it will remain same.

So, when you develop the photoresist depending on the type of photoresist there is positive photoresist and negative photoresist. Depending on the type of photoresist the part that was exposed to the UV light remains or gets removed by the development process. This development again involves chemicals like Emma's 26 a which are usual developers that are used. There are a lot of photoresist like S1813 and S4562. These are all standard photoresists the numbers denote the number that micron of thickness of photoresist that gets formed when you coat it.

Let us say AZ4562 is a type of photoresist in that 4562 means that 6.2 micron the last 6 2 is 6.2 micron will be the photoresist thickness when it is rotated at around 4500 RPM that is 4 5 6 2 and say like that we have S1813. So, like that lot of photoresists are there for each of the photoresist you have different types of developers. So, use a developer solution and then you develop it. So, this development will also be carried out in a hood like I told before. After you develop you again have to use a hot plate where you hard bake it, it is like whatever photoresist remains that will be hardened on top of it. So, that it can be used for further processes like itching ok.

So, what are the main equipment that will be required in a yellow room you need a workstation or a workbench or a fume hood you can call for your photoresist coating baking like dehydration bake, pre exposure bake, etcetera and then you need a spin coater machine a hot plate as I told then you want the mask aligner system. And then a bench for development which can be the same bench and this much is required for you to do the lithography process.

Now, why we need to do a hard baking of the photoresist? This is because let us say there is a subsequent process I am having a gold deposited again I am removing after the photoresist exposure I will use gold etchant. So, wherever the photoresist hardens and remains that part below that gold will get protected everywhere else the gold and chrome gets removed.

So, once that process is over you can remove your photoresist through like a acetone dip acetone IAP dip the photoresist will go and wherever below that photoresist only the golden chrome will remain that is your last process of micro fabrication, which is a subtractive process. I hope this overall view of a small visit to the cleanroom and overall view of equipment was useful to you I mean in further modules if time permits we will try to show you individual equipments and that I think would be more interesting to you in this course on sensors and actuators**.**