Advanced Neural Science for Engineers
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Lecture: 05
Developed Systems At A Glance

Hello everyone. So, this is the third lecture in the series. Now, in the last lecture what we have seen is what are the different kinds of sensors and devices you can say chips that we can fabricate either it is a flexible material or it is a silicon based or you have seen a force sensors, micro heaters.

Then we have seen implantable devices for recording electrical signals, that is the ECOG we talk about little bit about what is ECG, EEG and ECOG, just I told you the full form of those terms, and Electrocorticography is something that you should remember, because we are going to talk a lot about acquiring the signals from the brain.

Now, we will talk about how to implant these devices into the brain and record the signals in detail at some point in time. However, the last 2-3 minutes of my previous lecture, what I said is that we cannot use sensor alone, we had to integrate sensor along with an electronic system, and overall the system should also have the encasing.

So, there should be some kind of casing that should be used with like 3-D printing, which is additive manufacturing, or subtractive manufacturing techniques. So, when we say that sensors cannot be used alone, what does that mean? That means you need to make a system, what kind of systems one can make, with little bit understanding about mechanical or electronics or software, and so on.

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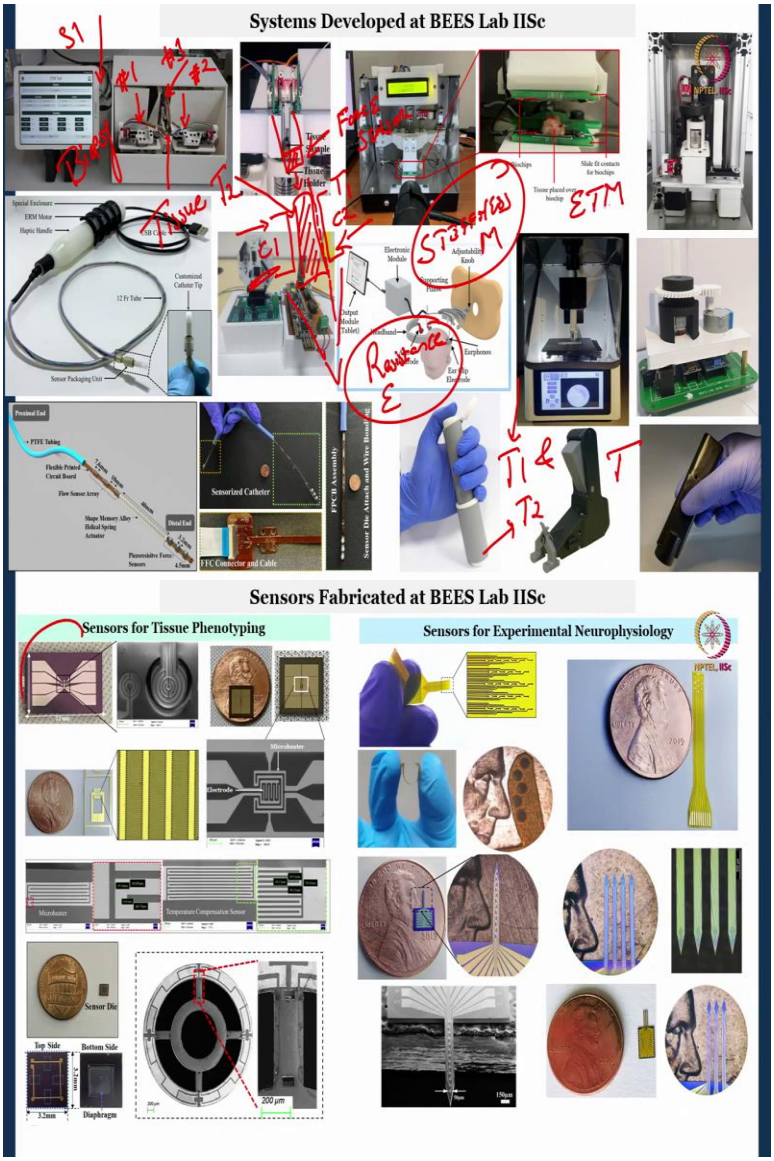
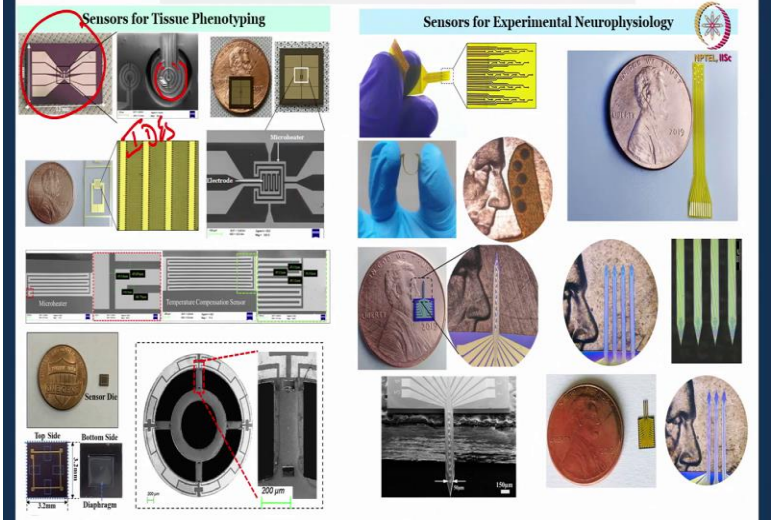


Sensors Fabricated at BEES Lab IISc



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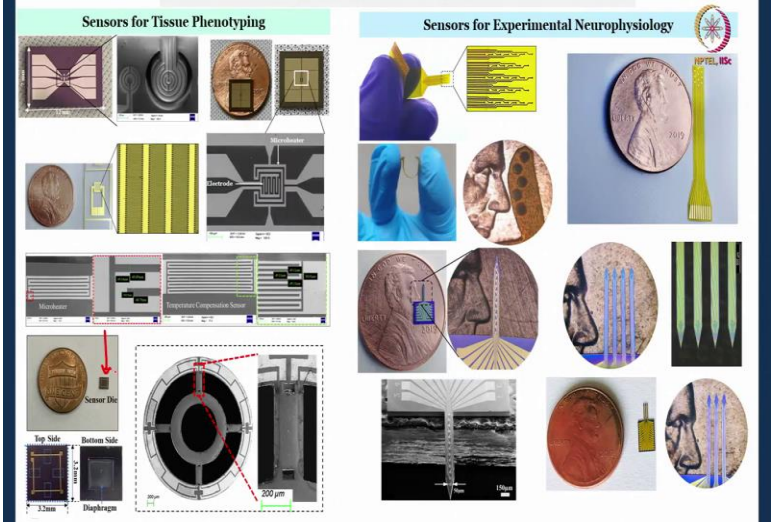

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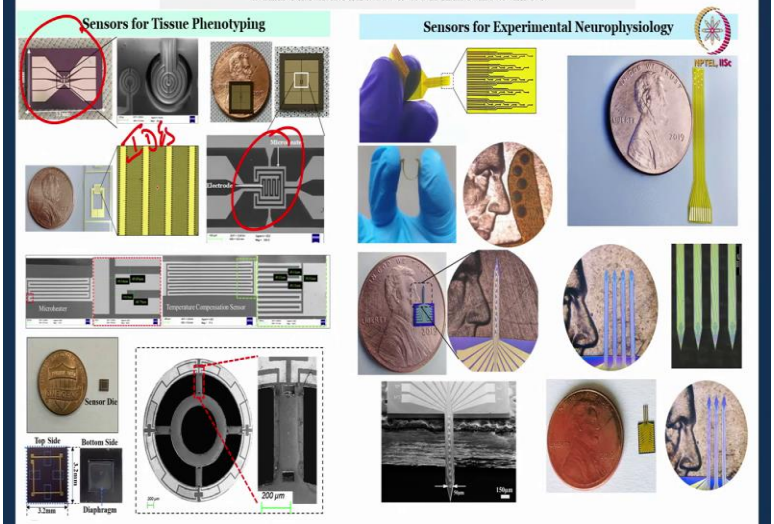

So, if you see the slide we will be talking about, I will just show it some of the systems that we have developed and we will take few examples in detail in this course, the first system that you see here, I will just play a video of lot of systems. So, that you understand, but the first system that I have placed arrow now is a system that can be used to understand the change in the tissue property biopsy tissues, I told about biopsy, biopsy tissues, and the tissue can be placed in the center and then there are two robotic arms, arm 1 and arm 2 and then a third arm which is right over here.

So, these arms arm 1, arm 2 are loaded or integrated with this chip, which one this one and this chip has what it has a interdigitated electrodes like this one not like exactly like this, let me just correct you can see here 1 line, 2nd line like this, these are interdigitated electrodes and it has a micro heater and thermistor. So, this chip is loaded on to the 1 and 2 arms of the robot transducer.

Now, the third one which is this one is integrated with a force sensor, force sensor is this sensor. So, this third sensor or third arm is loaded or integrated with the force sensor. Now, what will happen? In the center what we have tissue on 1 and 2 what you have you have the chip, so, when this chip touches the tissue.

So, if you have a tissue here and chip 1 and chip 2, C2, C1 and that is third one which is integrated here this is the force sensor. So, when this force sensor presses this tissue, you have stiffness, you can measure stiffness. Chip 1 and chip 2 you apply a voltage between these two chips. Then the corresponding current will flow through this tissue and the current that flows into this particular tissue depends on the resistance of the tissue.. Why you can apply, how can apply voltage? You can apply voltage with the help of the interdigitated electrodes that are integrated onto these chips.

Now, you can measure stiffness with force sensor, then measure resistance with the applying voltage across the tissue and you can heat the tissue from one side let us say here there is heat T1 then on the second side, what do you have on the chips what you have? You have temperature sensor, you have a micro heater and temperature sensors.

So, if I heat the tissue, this side, this side of the chip 1 or chip 2, this is chip 1 this is chip 2. So, if I hit this area, this one. Then the heat will transfer through this tissue and I can measure the

change in the temperature in this region, T2, with the help of the temperature sensor. So, what I have? I have T1 and T2 (Temperature that is given to the tissue and temperature that has conducted, the issue has conducted through it).

If I have T1 and T2 what I can measure I can measure thermal conductivity of the tissue. Thus, the system that you see here let us say S1, the system can be used to understand this stiffness, resistance, electrical stiffness, mechanical and thermal conductivity which is thermal. So, ETM (Electrical, Thermal and Mechanical) properties of tissue from onset to disease progression.

This is how the system one can use you have two arms of the robot chip 1 chip 2 and third arm. So, when there is a tissue in between let us assume that this is a tissue and if I have two chips like this apply voltage current will flow the tissue and this black pen is a tissue biopsy tissue. Now, depending on the resistance of the tissue the current will flow and I can measure the resistance count. Apply a force tissue and there is a hard substrate on which the tissue is placed, apply a force.

I can measure the change in resistance of the piezo resistor, from that I can measure this stiffness of the tissue, apply it heat on one side and measure the heat on another side, I have T1 and T2, I can measure thermal conductivity. So, three different modalities electrical, mechanical and thermal modality, we can integrate onto a platform to study tissue properties and what kind of tissue we can have, we can have adjacent normal, from where we have when we do the biopsy not entire tissue is cancerous.

There will be some tissue which will be normal as well. So, normal tissue next to the cancer is called adjacent normal. So, we have adjacent normal tissues and we have a tumor tissues and we can understand the change in the tissue property as cancer progresses, that is the idea about that particular platform. Now, let me go to the next platform, which is a next system S1 we have seen this system S2 we have NIR and ultrasound, NIR stands for near infrared rays and ultrasound transducer we use it. So, with that, again we use the biopsy tissue.

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So, here you can see the tissue is here tissue sample is in the center, this is the tissue. And then you have NIR source and detector, NIR sources and there is a photo detector. So, we use LED as NIR source instead of laser and that will cut down the system cost significantly, you have multi wavelength LED, we use 850 nanometers, 950 nanometers and 1050 nanometer LED wavelengths. These are all NIR (Near Infrared Rays).

So, we can buy or we can use a commercial LED which has multiple wavelengths, 850, 950, 1050 all three in one single LED. Now we have a corresponding photo detector. So, the light will

pass through this tissue and the photo detector will see the change in the voltage corresponding the light that is passed to the tissue.

This way, we can use the NIR to understand the change in the tissue properties, we also use ultrasound. So, with ultrasound what we do is we apply a certain voltage to create the corresponding acoustic waves and through that we can know what is the absorption coefficient, what is the reflectant coefficient and then how the acoustic signals passes through the tissue.

Depending on the type of the tissue we can say scattering coefficient μ_s or we can say absorption coefficient μ_a, how much tissue as absorbed. So, we can have different kind of ultrasound frequency we can use it. We have tried 1 megahertz but we can increase the frequency to higher frequency depending on the kind of ultrasound sensor we use.

This is a commercial ultrasound sensor that we used, but we will talk in detail of ultrasound sensor in the array of those sensors, in the course when I teach you the fabrication part of it. Now, we talk about these breast tissues because one was used for ETM properties and second S2 is used for the NIR and ultrasound.

This third one is for the electrical property you have two chips, chip 1, and chip 2 these are nothing but just interdigitated electrode. What are the interdigitated electrodes? So, you see these are called interdigitated electrodes. So, now, between these electrodes if I I am going to measure resistance, what will be the resistance? Almost infinite.

Because these are not touching. These are all metal electrodes, this are all metals. Metal electrodes. These are called interdigitated, I-N-T-E-R, inter, digitated electrodes IDEs, interdigitated electrodes in short form is called IDEs. So, there is IDE on chip 1, IDE on chip 2 you place a tissue apply a voltage and you can measure the resistance but if the tissue is a fresh tissue. And if you place the tissue along with some solution, this resistance would not be a good idea to measure but what we can measure, we can measure impedance.

So, as your homework what you should learn is what is the difference between resistance, impedance, reactance, sheet resistance and how these terms would help and how we can measure resistivity? Very simple formulas are there. Just go back and brush up your knowledge if you do

not know. If you know, its great. Just understand, What is the difference between resistors? What is the difference between resistance and impedance?

What is the unit of resistance? unit of impedance, unit of reactance, sheet resistance, ohm centimeter, what is ohm centimeter? It is your resistivity, sheet resistance in ohms per square that is the unit of sheet resistance. So, why it is called sheet resistance? So, you need to understand all this terminology. In this case, we are measuring the impedance, Z, unit is ohms.

So, we place a fresh tissue this is a brain tissue and we measure the normal tissues through the tissue bank for the people who donate their brain, and the fresh tissues these are from the cancer tissues cancer patients. When the surgeon is operating that tissue, will take the tissue and understand the tissue properly.

Now will go into the detail, because it is part of our advanced neural science for engineer course. So, I am not spending a lot of time on that particular system, but will move to the next system. So, the next system that you see on the slide so, this is system number 3.

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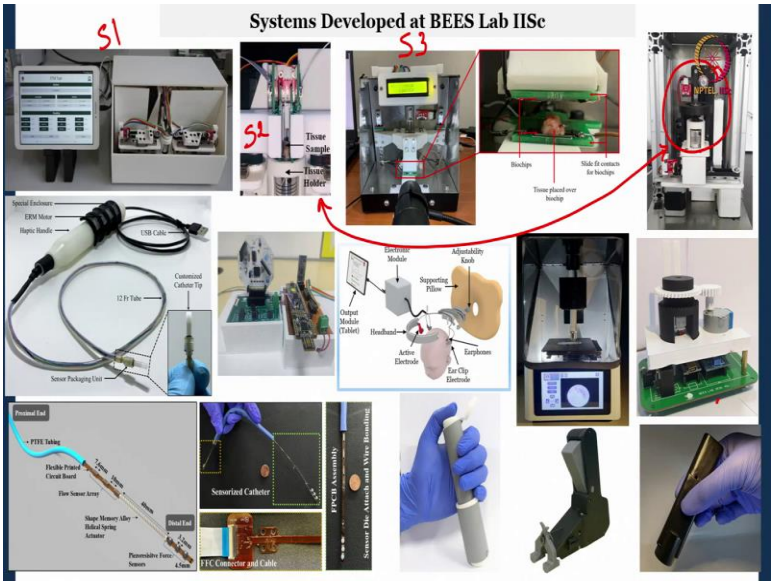

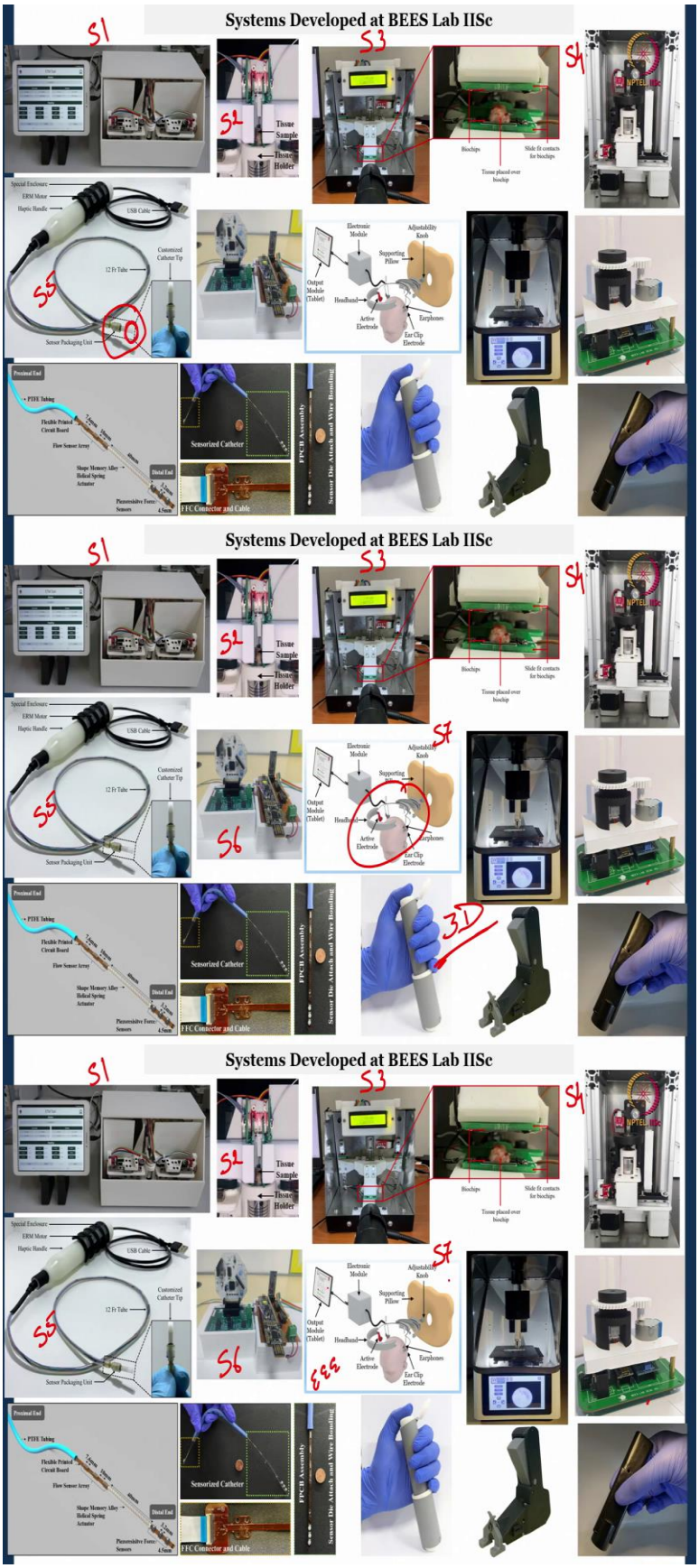
Systems Developed at BEES Lab IISc
S1
S2
Tissue Sample
Tissue Holder
S3
Biochips
Slide fit contacts for biochips
Tissue placed over biochip
S4
S5
Special Enclosure
ERM Motor
Haptic Handle
USB Cable
Customized Catheter Tip
12 Fr Tube
Sensor Packaging Unit
Electronic Module
Adjustability Knob
Supporting Pillow
Output Module (Tablet)
Headband
Active Electrode
Earphones
Ear Clip Electrode
S6
S7
Proximal End
PTFE Tubing
Flexible Printed Circuit Board
Flow Sensor Array
Shape Memory Alloy Helical Spring Actuator
Distal End
Piezoresistive Force Sensors
Sensorized Catheter
FFC Connector and Cable
FPCB Assembly
Sensor Die Attach and Wire Bonding
3D
Systems Developed at BEES Lab IISc
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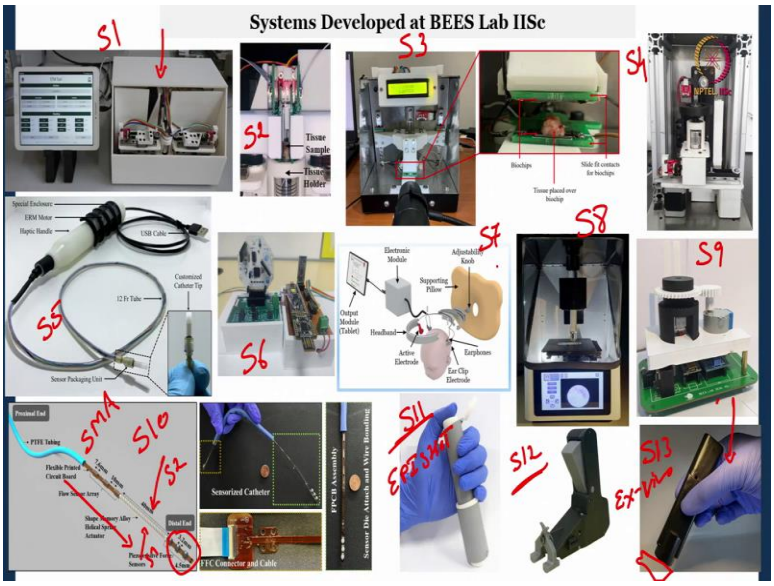

System 1, this is system 1, this is system 2, this is system 3, now, this is system 4, it is a part of this system. So, in a way you see this one . This is just a zoomed in image. S2 is zoomed in image of this particular part. Actually what happened is, we wanted to keep two different, now the holder, the tissue holder one with ultrasound and one with NIR. We have the system same but the holder and the mechanism different.

So, that way it is different, but I already have discussed about the ultrasound. So, this is S4, S2 with NIR, S4 with ultrasound and the system remains same there is a tissue older there is a motor which can rotate the tissue. Because tissue is anisotropic, so we have to measure different regions of the tissue and that is the reason of having this motorized stage.

Now this next one which is a system number 5 or you can say tool or system that we have developed is a catheter. You can see the catheter here, on the tip of the catheter. This tip of the catheter has the force sensor that we are talking about which force sensor, this force sensor, this force sensor is integrated onto the tip of the catheter here.

So, we are not here exactly, this tip is right here, this is the sensor here. And all the packaging is done within the same thing and then you have this entire electronics fitted within this particular probe or handle and there is ERM motors which will give it Haptic feedback. So, this is for the catheter, RF catheter ablation, we discussed about atrial fibrillation and the catheter, this is the device for that.

Next one, this is S6. This is electrical stimulation and neural signal data acquisition system, we use Inovio and open BCI and for acquiring the signal and we have developed the electronic module for applying the electrical stimulation to the surface of the brain and to the deep brain structures, we will discuss this thing in a lot of detail in this course.

Next one is S7. Again S7 we will discuss in detail but just to give you a brief this is for neonatal hearing screening, we will show you the band how we have created the band then you can see this entire thing which is casing most of the things have been created using 3D printing. So, what I thought is even though we will look at the science part of the syllabus we will also look into the engineering part in detail, particularly when it comes to 3D printing because 3D printing is exclusively used for prototype development.

So, will be taking a experiment class on 3D printing. Right now, what you see is there are electrodes as an active electrode which is in red color here, and then there is a supporting pillow there are ear clips for reference and ground, you can see that, one is here and one is here. Then there are earphones. Earphones are used to apply the ABR (Auditory Brainstem Response) and also for the AEP (Auditory Evoked Potentials) and MMN (Mismatch Negativity) we will talk about what are these terms.

From a active electrode, we record the EEG signals, here we record EEG signal, and the signal can be transferred to a tablet either via Bluetooth or wired version. So, this system can be used for neonatal hearing screening and we will be talking about it at a later stage. This is system number 8. And here I was talking about the cytology scanning if you remember in oral cancer, there is a swab, the cells are taken to the pathologist, the pathologist will smell the glass slide and look at the morphology we told we discuss about that, but, what about a system at the remote place?

And so that the ASHA worker or semi skilled personnel can use the same technique right over there, press a button and task that is scan only the data or the image that looks like there is a change in morphology, the image of the cell. That will be shared with a pathologist to get a quicker diagnosis.

So, that is this system that you see on the screen is a one that we have made in the lab and now it is with MSMF (Mazumdar Shaw Medical Foundation). This system S9 is used for understanding

the heart tissues, human heart tissues, and this is based on the degree of linear polarization and degree of circular polarization.

So, light will pass through the tissue in linear fashion, degree of linear polarization(DLOP), degree of circular polarization (DCOP). So, we want to measure the degree of circular and degree of linear polarization based on that, whether we can delineate the type of the tissue whether the tissue is normal or it has a diseased tissue or the tissue is from LV region or RV region, we can differentiate that will be helpful.

Once we understand the ex-vivo property of the tissue, we will go for the invivo probe. Next system is theS10. Here you can see the catheter we have talked about the tracheal inflammation, in tracheal inflammation what happens, the trachea tackle has inflammated and you can place this catheter, the entire catheter into the trachea and see which part is inflammated.

And then you can maneuver the catheter, you can touch the tissues to understand the elasticity of the tissue. There is a force sensor, the tip of the catheter, as I have told you here you can see as well, and then there is a spring here, two side S1 and S2, these two springs are made up of Nitinol or smart actuators called SMAs. And for your understanding, I will just record these videos. And we will show it to you so that you understand that how the system actually works, how the catheter works, how it placed. How it is maneuvered.

So, just for understanding, you do not have to worry about it. I will not question from this systems thing. But do you understand that once you understand these fabrication, sensors, how to integrate those things onto a platform for certain applications? What are the next tools? We have S11, if you see the image on the screen, this is what we called as the EPISHOT. Now we have learnt about the EPIPEN.

So, if you see this screen, we call this as a EPISHOT. Now the advantage of this EPISHOT is, it is single hand operated, it is a single hand operated, we can reuse it. And there are multiple degrees of safety so that it can be used by anyone. We just do not want people to have allergy. But for people who already have allergy against certain pollens or milk or peanuts or something else, they can immediately use this tool.

That is our idea and that is why we designed this tool. Then this is S12. This is tool for epidermal shot. Epidermal. And then finally we have this S13, this S13 is a probe that can be used for Ex vivo tissue characteristics. Ex vivo.

And then this probe can be used we just place a tissue here, and we will tell you what kind of tissue it is, it is a normal tissue or it is a cancerous tissue. So, right from the system, which is right over here to the probe that is here.

So, over a period of last six years, several systems has been developed. So, when you look at that into this kind of, different kinds of systems do not get overwhelmed, it is a work from many, many, many students many postdocs, scientists, clinicians, PhD students, M Tech students, project assistants, even interns.

So, everyone together have done all this stuff that I am showing you today, and in this stage. Now, we will go for the next part of the course, which is on understanding what is a clean room and when you understand what is a clean room then it will be easier for you to appreciate that what is the requirement what kind of infrastructure is required to develop the systems and the sensors that we are talking about. So, let us understand what exactly clean room means?

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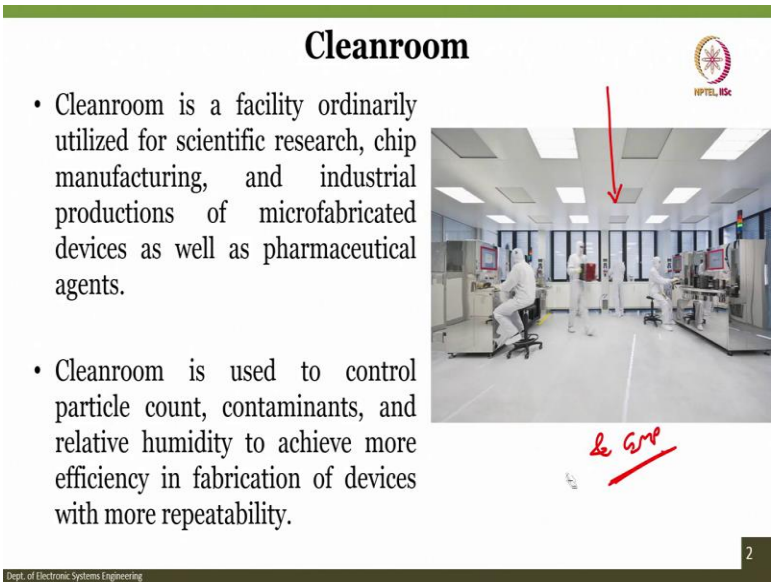

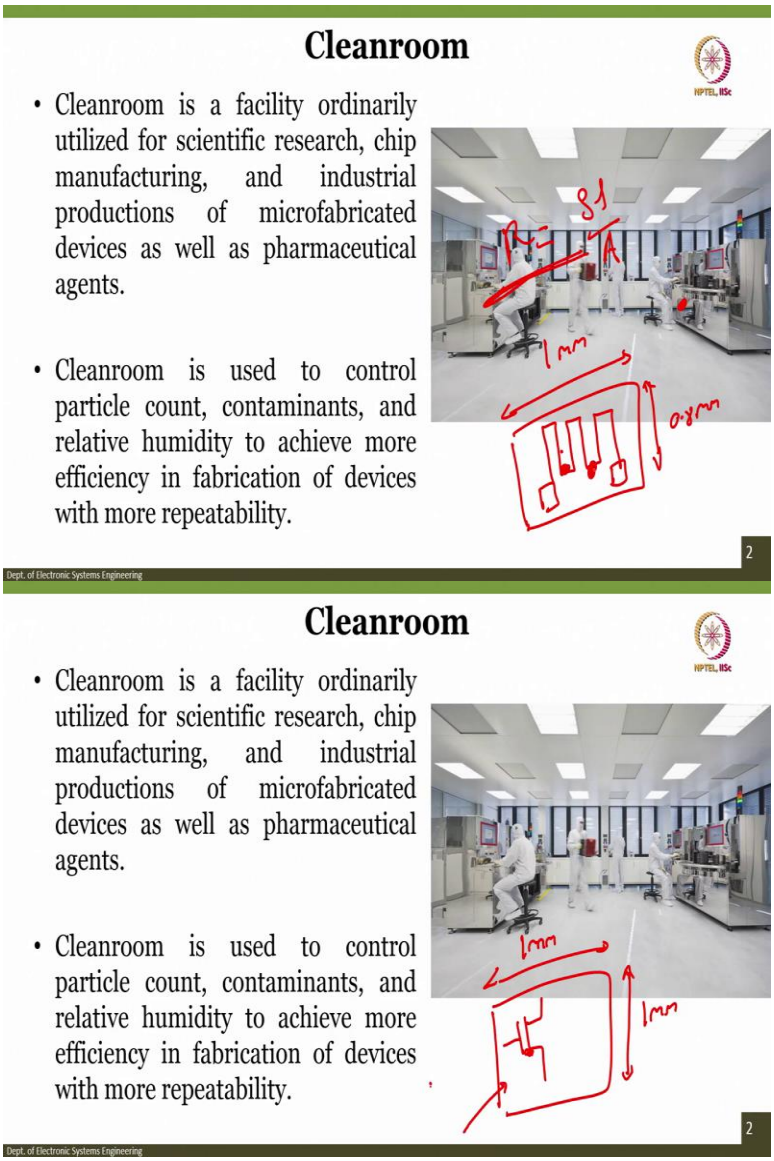

So, if you see the slide, you have, you see this image, this image is similar to what I have been showing on the slide one, on Lecture 1, Lecture 2 probably, where I was showing it, the facilities that we have in our department. So, this is what we call is a clean room. And here if you see the clean room is a facility that is ordinarily utilized for scientific research, so there is a clean room for pharmaceuticals as well, the industrial production as well.

And you can see here that lot of pharmacies; they would require the clean room facility to develop the drugs. There is something called GLP, GLP and GMP, Good Laboratory Practices and Good Manufacturing Practices, just look into that what are those practices so you will understand more.

Now, what I wanted to tell you more about it is that clean room is used to control the particle counts, contaminants and humidity. So, what happens is that let us say you have I will just give you a simple example so it is easier for you let us say that is an example of a heater. So, you want to have a heater that is nothing but a resistor. And if I have a particle, so let us say this whole chip is 1 millimeter by 0.8 millimeter.

And you have a particle which is let us say this big, so it will sit somewhere here, another particle will sit somewhere here like this, what will happen? What will happen? The calculation of your resistor itself depends on:

$$\rho l/A$$

But here because of this particle either you cannot develop the metal or the resistance value would be different. So, this will affect the overall properties of the device.

Now, when we talk about such a big device, we do not care, we really had to care but let us say we still understand the role of particles. But that it may not affect the device, but what about your transistors in one small 1 millimeter by 1 millimeter chip you have billions of transistors, billions of transistors, what will happen, what will happen? If you have 1000s and 1000s of transistors in this area and a small particle will kill the entire chip, entire chip will be destroyed.

So, even the smallest amount of dust or contaminant is not allowed in the clean room and the biggest source of contaminants is or are humans and that is why all these gowning mechanism. So, clean room is used to control particle count, contaminants and the relative humidity to achieve more efficiency in fabrication of devices and repeatability, because one time your heater like I give an example, it will give you different resistance, different heater give different resistance. So, the class of the clean room is very important.

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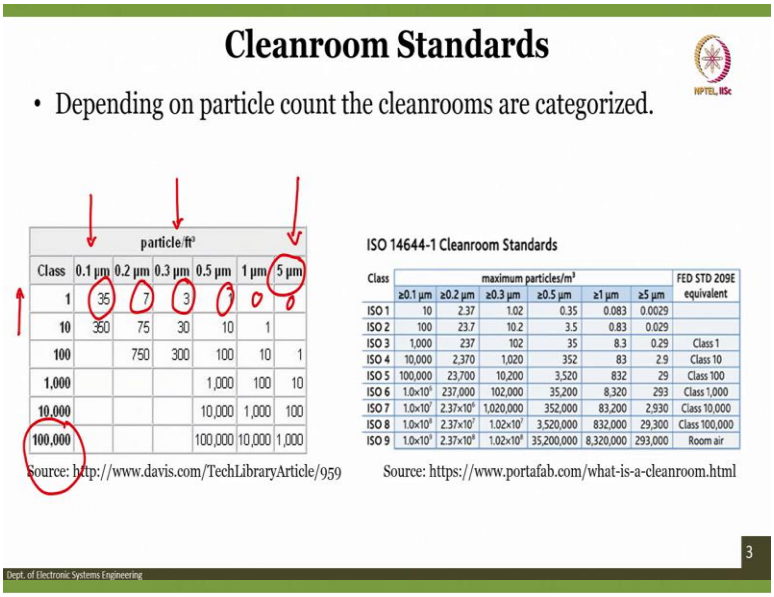

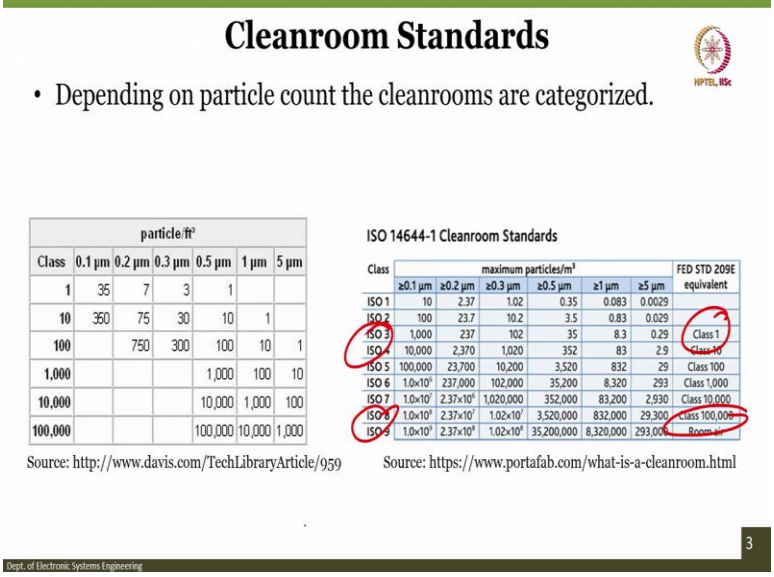

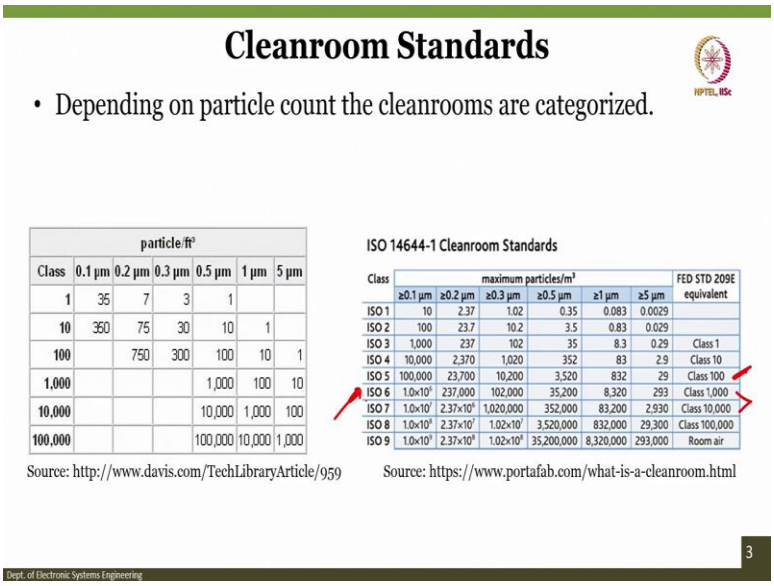

So, depending on the particle count the clean rooms are categorized into several class, the class 10,000 or 100,000 we say from here would have particles per cubic feet, you can see here. So, right from 0.1 microns to 5 microns particle is what we see, even 5 microns particle can kill many, many, many transistors on a chip.

So, we have both 1000, 10,000 and 100,000, 0.5 microns particle. When we talk about class 10,000 clean room, the particles count is little bit less which is 100, 1000 and 10,000 ; 0.5 microns. 1 micron is 1000 and 5 micron is 100 particles. You go in the class 1000, 100, 10 and 1 you will see that the particle size from 5 microns there is non (zero). s0.5 micron is 1 and 0.3 micron only 3, 0.2 micron only 7 and 0.1 micrometer only 35.

But as you go towards, class 1 the cost increases by manifolds. So, but also the quality of the clean room also increases manifolds. So, these are the different classes of the clean room also we can be classified as per the ISO 14644 - 1 clean room standards as ISO 1 to ISO 9 and depending on that you can have maximum particles per cubic meter is cubic feet particle per cubic feet here is a particles per meter cube.

So, we have 0.1 micron greater than 0.2 micron greater than 0.3 micron so on still greater than 0.5 microns. And how many number of particles should be there to qualified in ISO 1, 2, 3 to 9. So, class 1 falls in ISO 3 category, where class 100,000 falls in ISO 8 category. What we have in this fab in our department is 1000, 100 and some area is class 100. So, we fall somewhere in ISO

6 kind of category. Now, this is good for like I said for devices, but may not be used for the transistors.

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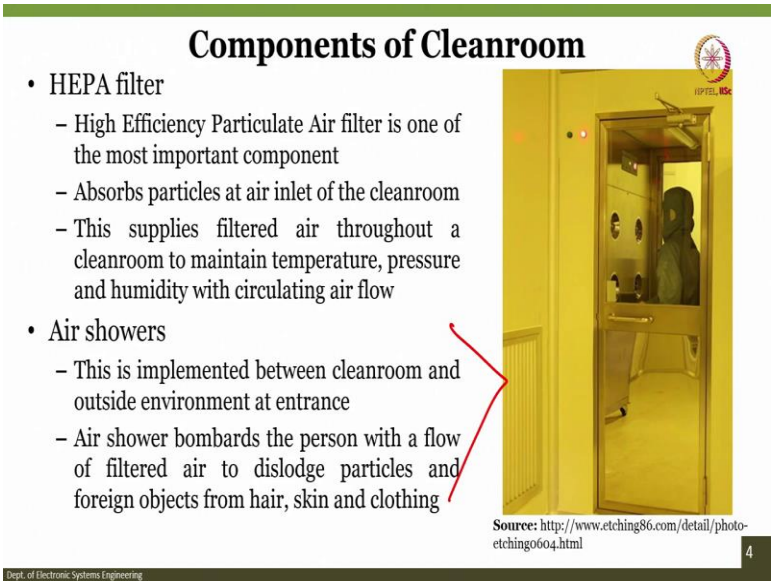

But what keeps this clean room clean, in a way. How can you say that this many numbers of particles should be there, this many number of particles should not be there. So, there is something called HEPA filters, and HEPA full form is High Efficiency Particulate Air filter, this is one of the most important component in the clean room, it absorbs particle at air inlet of the clean room and some of the so HEPA filter is kept here.

Then there is air shower through which you have to pass and then you can enter that clean room. Now, this supplies filtered air throughout a clean room to maintain temperature, pressure and humidity. Air showers, like I said, this is implemented between clean room and outside environment at the entrance. Air shower bombards the person with the flow of filtered air to dislodge particles and foreign objects from hair, skin and clothing. So, nothing should enter the clean room, so air shower is one more layer before you enter the clean room facility.

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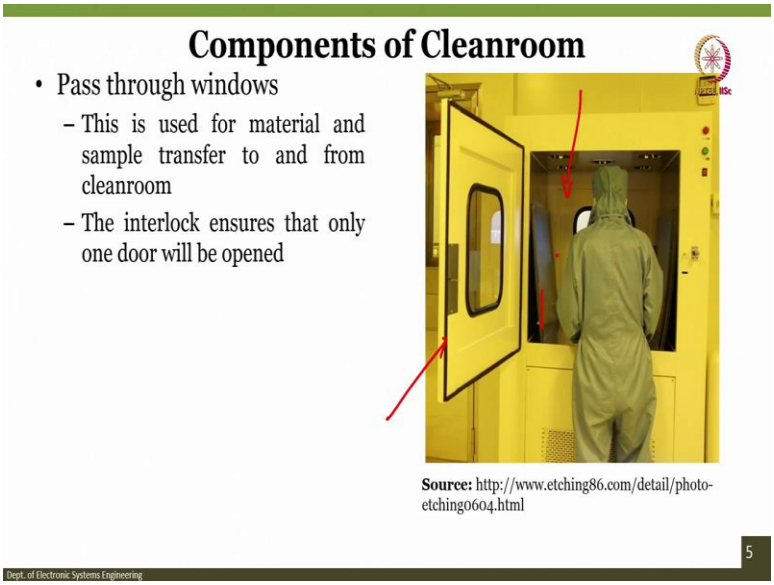

Sometimes depending on the clean room you may or may not have air shower, but again depending on the type. Now, there is something called pass through windows in which you do not have to really come out of the clean room, as you see you have to gown yourself before you enter the clean room. Just to avoid the particles from your clothes, hands even from the hair, this all are the contaminants, so, you have to count yourself and it may be very difficult to take out the gown and come out and then handover the materials to your colleagues.

So, what we have is something called pass through windows, pass through windows is used for materials and sample transfer to and from the clean room. And the interlock ensures that only one door openg. So, when this door is open, the another door, another side is closed, then when you place the device or whatever the material in here, you close this door 1, then the door 2 can be opened at a time only one door can be opened. So, there is also things to know.

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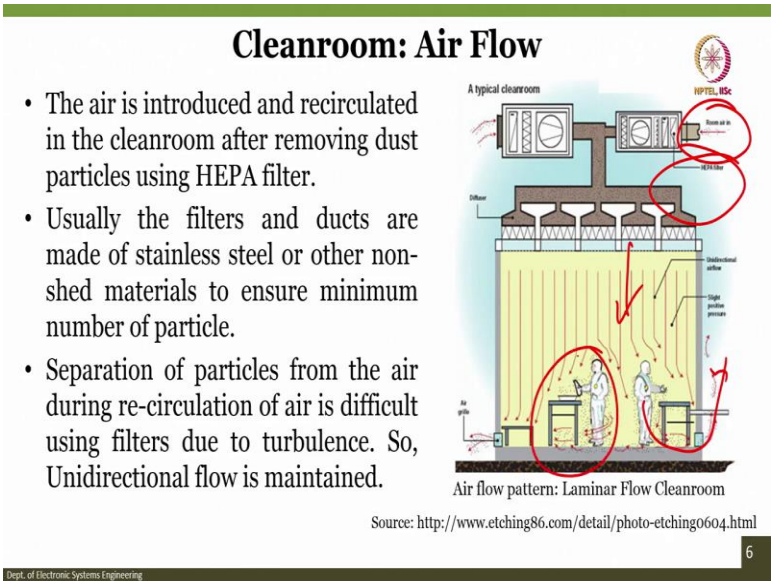

So, how the air flows you can see here, this is room air in there are HEPA filters you have to pass through it, and then there is a unidirectional flow in this direction, there is a slightly positive pressure and whatever things are out it will be exhausted right with the air grill, you can see the personnel working in the clean room. So, the air is introduced and re-circulated in a clean room after removing the dust particles using HEPA filters.

So, the air also has a dust particle, it is removed by HEPA filters. So, usually the filters and the ducts are made up of stainless steel and other shared materials to ensure minimum number of particles. Separation of particles from the air during the recirculation of the air is difficult using filters due to turbulence. So, unidirectional flow is very important, if there is turbulence you understand, what is normal flow and turbulenct flow. So, when there is turbulence, it will be difficult to re-circulate air and that is why the flow is kept in a unidirectional fashion.

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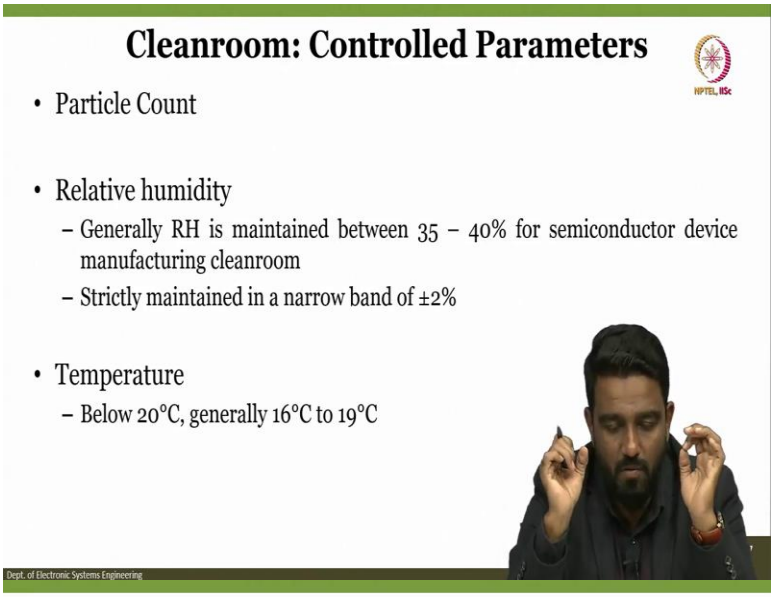

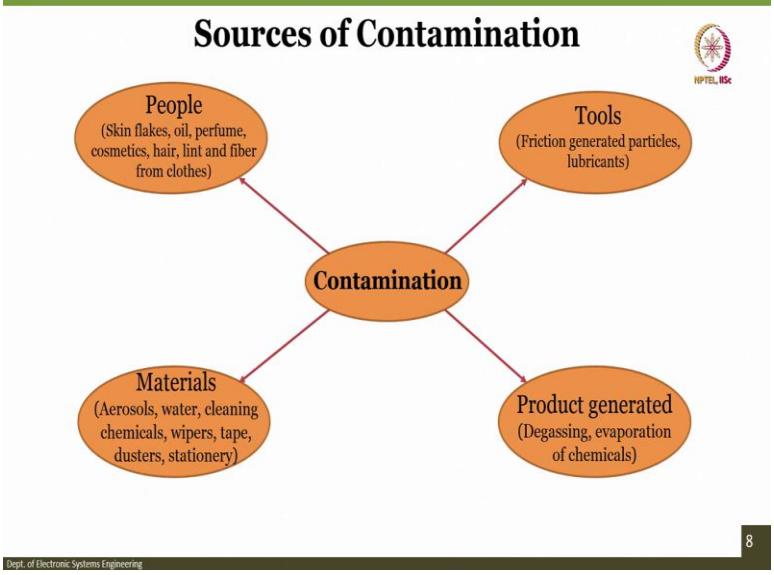

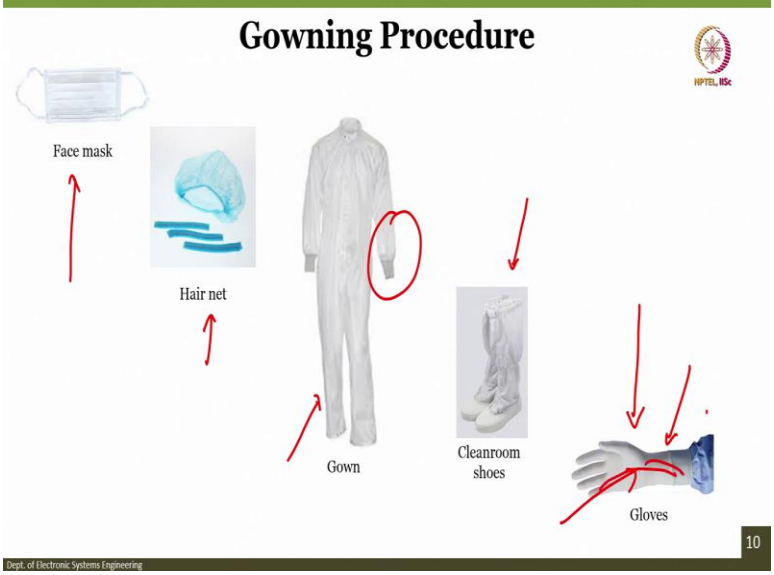

So, what are the controlled parameters for a clean room lab, the one first parameter is the particle count, very important because depending on the particle counts the clean room is classified into several categories. The next important component is relative humidity and generally relative humidity which is known as RH is between 35 to 40 percent for semiconductor devices.

Where, it is maintained with a small a narrow band of plus minus 2 percentages and temperature is below 20 degree and it is kept generally between 16 to 19 degrees centigrade. So, the sources of contamination, sources of contamination are several the most important source of contamination. So, what I was saying is that you have to maintain all these parameters.

And then within this parameter still you do understand that what can be different source of contamination. So, the most important source is people, remove people and the clean room will be clean, but you cannot use clean room then. So, skin flake, oil, perfume, cosmetics, hair, lint and fiber from clothes, everything is a contaminant.

Tools, tools that are there in the clean room so friction generated particles, lubricants, these are all contaminants. Product generated, so, during the evaporation or during the sputtering or wet etching there are chemicals that will be evaporated. So, degassing, evaporation of chemicals all these things are also part of the contamination. And finally, we have the contamination due to materials this can be aerosols, can be water, cleaning chemicals, wipers, tape, stationeries, dusters, everything that is there is a part of contamination. So, you should be extremely careful when it comes to the working, in a clean room standard.

Now, the other items which are not permissible, absolutely not, this is you have to understand not permissible are normal paper, there is a special paper for the clean room, pencil and fabrics from natural fibers, wet, dry and dusty clothes not allowed, not allowed you see, not allowed, not allowed, loose clothes, these are loose clothes not allowed, dangling jewellery is not allowed.

So, make sure that when you work in a clean room environment, these things are not there. Now we will have a separate lab session where we will teach you how to gown yourself. However, the some of the important procedure is that you need to have a face mask. Now all of us are now used to, wear the facemask so it is easy.

Hair net, you have to cover the head so that hair will not fall. You have to gown yourself, this a gown, you have the clean room shoes depending on the class of the clean room either you can have this or you can have shoe cover and you should have gloves and gloves should be over your gown very important it is covering this one.

Now should not be under it, glove you see, gloves are over it not under it, the reason of why gloves are over it because there is chemical spill, it will not touch your skin no matter what. So, there is a reason of wearing the gloves in this fashion as you can see in this particular slide.

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Gowning Procedure

- Gowning and PPE
- Gowning procedure should be strictly followed for the person's safety as well as to save fabricated device from human generated contaminations

Source: https://www.creativesafetysupply.com/wall-sign

Source: https://www.alibaba.com/product-detail/Dust-free-Clean-Room-Working-Clothes_60470016126.html

PPE

- Personal Protective Equipment
- Proper gowning is mandatory before entering cleanroom for any process. There are process-specific PPE to wear before starting the process.
- Face shield is mandatory during handling chemicals
- Working at wet benches:
  - Nitrile gloves
  - Mapa gloves
  - F-Telon gloves
- Latex and vinyl gloves are not allowed

So, Gowning and PPE. What is PPE stands for? PPE stands for Personal Protective Equipment PPE. So, gowning procedure should be strictly followed for the person's safety as well as a fabricated device from human generated contaminants.

You see, when the loose clothes are there. It may get stuck between the machines and there should be a notice which you will generally see outside the clean room where it says that wet hair, net, lab coat, gloves and booties, this is all which is a part of the clean room standard protocol one has to follow. Finally, when you wear to the gown should look something similar to this depending also on the gown, something similar to this.

Again depending on the class of the clean room the type of the gowning would change, what are the personal protective equipment? So, these are the equipment that are used and it is mandatory to use before entering the clean room what are those?

So, face shield, gloves, then, face mask, hair net, these are all the PPEs. So, working in the wet benches in particular there is acid or solvent bench, you should understand which kind of gloves you should wear Nitrile, MAPA gloves or F-Telon gloves. So, latex and vinyl gloves are not allowed.

So, that is another thing you need to understand while you are working on acid or solvent bench. Now, why we are telling all these things because you will be looking at the wet etching and you will be looking at the dry etching.

So, wet etching requires a person to use the chemicals and when you use the chemicals there is a reason that there is a way to gown yourself and you use a chemical, particularly gloves. So, that a person is not affected to avoid any incident.

So, during working at wet bench it is mandatory to wear labs shoes (closed toe shoes), very important you cannot wear chappals and go in, you cannot wear slippers and go in, you have to wear shoes in which the toe is closed, aprons, face shield, appropriate gloves. Never rub, very important thing, never rub your eyes or touch your belongings wearing contaminated gloves.

You have to throw the gloves and then only you can touch your mobile or your face in case you want to. But make sure that you throw the gloves, wash your hand and then only touch your belongings. Always follow MSDS, what is MSDS? Material Safety Data Sheet.

So, there is a safety data sheet for every material, there is a PDF where you can check what are the hazardous symbols, what are the procedure to operate or to use the chemicals, at what temperature the chemical will be corrosive or it will be oxidizing or it is flammable. It is very important to learn, read the MSDS data sheet or material safety data sheet before using that particular chemical.

Now, you will also see there are some certain hazardous symbols that are placed outside the clean room, the first one is Gas Under Pressure, second is Corrosive, third is Serious Health Hazard, Acute Toxicity, Health Hazard, Flammable then Hazardous to the Environment, Oxidizing, Explosive, these are some of the symbols that you will see depending on the laboratory that you work on, or work in.

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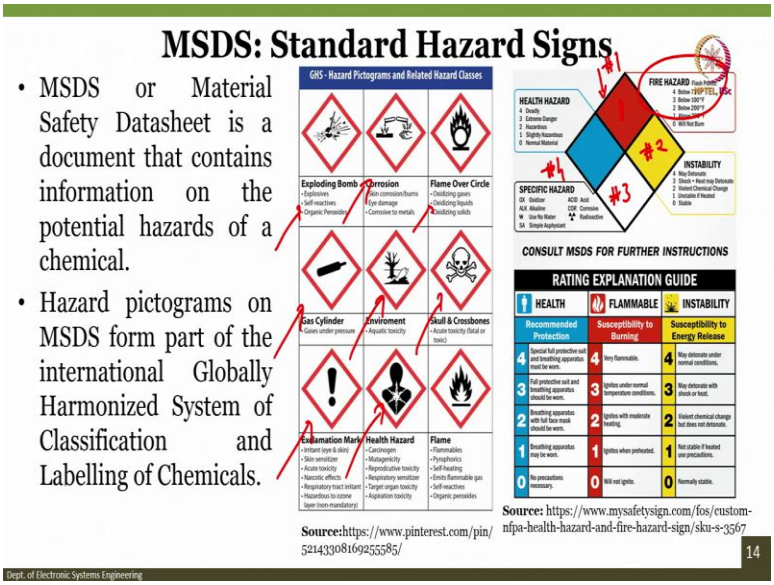

Like I said there is a MSDS, or Material Safety datasheet. And if you see that Exploding Bombs, then Corrosion, then Flame Over Circle, Gas Cylinder, Environment, Skull and Crossbones, every Exclamation Mark is used for Irritant, skin sensitizer, acute toxicity, narcotic effects, respiratory tract. Health Hazard what are the health hazards? There is a carcinogen or there is a mutagenicity or there is a reproductive toxicity or sensitizer or organ toxicity or aspiration toxicity falls in the health hazard.

The flammable, flammables can be pyrophoric self heating, emits flammable gas, self reactives, organic peroxides these falls in the flammables. Corrosion, corrosion is what, skin corrosion, Eye damage, Corrosion to metals. So, these are all the pictorial representation of the materials or the items available inside the lab, you should be careful, you should be following the MSDS.

So, the another way to understand is by looking at the color. So, the red color stands for the fire hazard, the blue color stands for the health hazard, the white color, so I will just put some numbers so that for people who may not be able to identify colors, it will be easier. So, the first one here, 1, because every person will have different screen. So, you may not be able to see the exact color that I am able to see here. (In case if there is the case). So, 1, 2. 3 and 4.

So, 1 which is red color you at least understand there is a red color stands for the fire hazard, the blue color which is or let us go in the sequence, and number 2 which is yellow color stands for instability, it can be the shock or unstable if heated, there is two examples.

Then number 3, which is white color, it stands for the specific hazard oxidizer, alkali, no use of water, acid is there or corrosive environment is there, it is white. And blue color which is number 4, it stands for health hazard, which includes deadly, extreme dangerous, hazardous, slightly hazardous or normal material.

So, these are some of the things that is very important again, why I am telling you or teaching you all these things is because we will be looking at the fabrication and for fabrication you have to understand that you are going to use the chemicals and those chemicals are placed in the laboratory and that laboratory standards are clean rooms standards and the clean room standards requires anyone to follow the protocol which has a gowning protocol and the protocol for using different materials.

So, when you want to use different materials, you have to go for material density of the safety data sheet and if you want to go for MSDS sheets or MSDS then you have to also understand what kind of symbols are there, that is pictorial representations or you have to understand the colors also. So, all these things are kind of interlinked interrelated for achieving the common goal even there are different objectives, they are still somehow interrelated.

So, we can now see that from 4 to 0, this is how the recommended protection is there, for health, for flammable and for instability. This slide you can just pause and you can see what kind of material is there for which, 4 is given versus 3, 2, 1 and 0. For example, for health, there is no precaution necessary is there then 0 would be there, for flammable we will not ignite 0 would be there, for instability, normally stable 0 would be there, just to give you an example. So, from 0 to 4, this is how the numbers are given. Let us go to the next slide.

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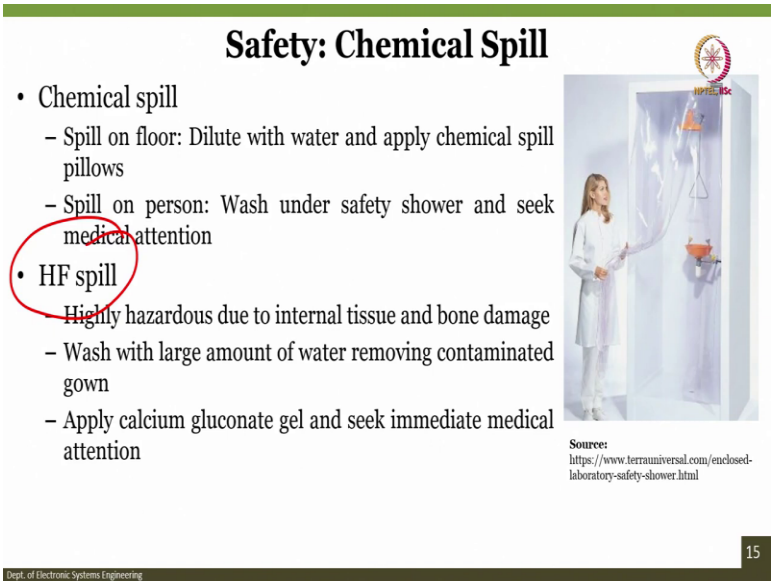

Now, that is about the MSDS. Now we there is something called chemical spill. So, what are the safety for chemical spill? Spill on floor dilute water and apply chemical spill pillows, there is if the spill on floor is there then we have to dilute it with water and you have to apply chemical spill pillows that are already chemical spill pillows available in the laboratory.

If you do not know what to do, do not touch the chemical because you do not know what kind of chemicals are there. Spill on person, a person by accident has some kind of spill, you wash under safety shower and seek medical attention there is a safety shower in most of the labs when you see you will understand and you have to follow the procedure.

HF spill, hydrofluoric acid very dangerous acid. It is highly hazardous due to internal tissue and bone damage, you will not understand but it will immediately affects the bone, wash with large amount of water removing contaminated gown, apply calcium gluconate gel which should be there in the laboratory and immediate and seek immediate medical attention.

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Then another safety is electrical safety. Now, you will see several electrical outlets and it can be as many tools. Many of the tools use high voltage supply. Practicing the electrical safety is very important in the clean room, you cannot use, while you are washing your hand or if the virus are on the floor it is not allowed, you need to properly shield the cables. This is totally not allowed.

And there are different symbols that you have to keep for electrical safety like shock hazards. Then there is a hazardous voltage is there, electrical hazard is there. We have to keep it out from that particular region. So, everything you need to follow it comes to electrical safety.

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The last one but not the least is a fire safety. And for the fire safety you have again different categories whether it is wood, paper and textiles or it is flammable liquids or it is flammable gases, electrical contact or is it cooking oils. Depending on that, what kind of extinguisher you should use? It is not like all the extinguishers that we see are the same.

So, again there is a different extinguisher right from red, light blue, dark blue, black and yellow. For the one which is wood, paper and textiles, we use water, foam spray, ABC powder, wet chemical. So, let me tell you what exactly each one is, red one the first one here is a water. Second is foam spray, third is ABC powder, fourth is carbon dioxide and fifth is wet chemical.

So, if there is a wood paper and textile you should not use carbon dioxide because it will flame it with further, for flammable liquids you cannot use water and wet chemical you can use foam spray, ABC powder and carbon dioxide. For flammable gases you can use only ABC powder nothing else can be used or you should use what is recommended.

Next one is electrical contact only ABC powder and carbon dioxide you should not use water, not use foam spray otherwise you will have more fire, you should not use wet chemicals only ABC powder and carbon dioxide. Finally, for cooking oils and fats, you can only use wet chemicals. So, again depending on what kind of fire is there, you should be using that particular fire extinguisher.

Again very important that should be there is a fire alarm in most of the labs. Not most of the labs, in every laboratory, so if there is a fire alarm, you can just press a button and you need to evacuate the building as soon as you can. There is an emergency exits symbol next to your lab whenever you see the lab no, now you will say that where is the lab? We are taking these online classes.

But at some point in time if you want to work in a Fab Lab or any other labs, these are the important parameters even you are doing your undergrad and you are in the fourth semester, fifth semester, eighth semester and you are using any laboratory, the laboratory should be equipped for the all the safety standards.

Particularly the chemical labs, wet labs, they should definitely follow the standard and dry labs, they should also have the fire safety electrical safety, per say not may not be chemical safety because there would be no chemicals. That is why it is called dry labs. So, that is the end of this particular session.

In the next session we will talk more about different devices, starting from the silicon wafer, how the silicon is made? Why silicon because silicon is a substrate that is used to fabricate several kinds of devices. So, till then you take care, look into this fire safety, electrical safety, chemicals safety, MSDS all these parameters. Safety features are very important part, whether this course or any other course you need to understand, what are the safety parameters. So, with then I will take your leave. I will see you next class. Bye.