Sensors and Actuators

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Lecture - 07

Recent Microsensors based system: Force Sensor, Basics of Actuators

Hi, welcome to this module, in the last module we have seen how to design how volatile organic compounds detection is important and how to fabricate the sensors for detecting such a compound. Now, we will go in the detail of fabrication in the in a previous in the next few modules, but if you recall from previous modules from module 1 till now we have seen several application of sensor. Now one more application of sensor is a flexible sensors; now where can we use flexible sensors.

We can use flexible sensors at several applications including biomedical robotics all right. How what if I say that I want to know the change in the pressure of my wrist every time when I first it like this, whenever I make a fist what is a change in the pressure of my in this particular area which is my wrist area right. I open it I close it I open it I close it doing that if I want to fabricate if I have a fabricated flexible sensor, I can quickly understand what is the pressure that I am releasing and I am making a fist what is a change.

But you cannot use if I want to know all the way around like all 360 degree I should know the pressure not only one side, either I can use many sensors I can use one flexible sensor which has a array of sensors. Same way there are a lot of applications I am just helping you guys , so we will see how to fabricate the flexible sensor.

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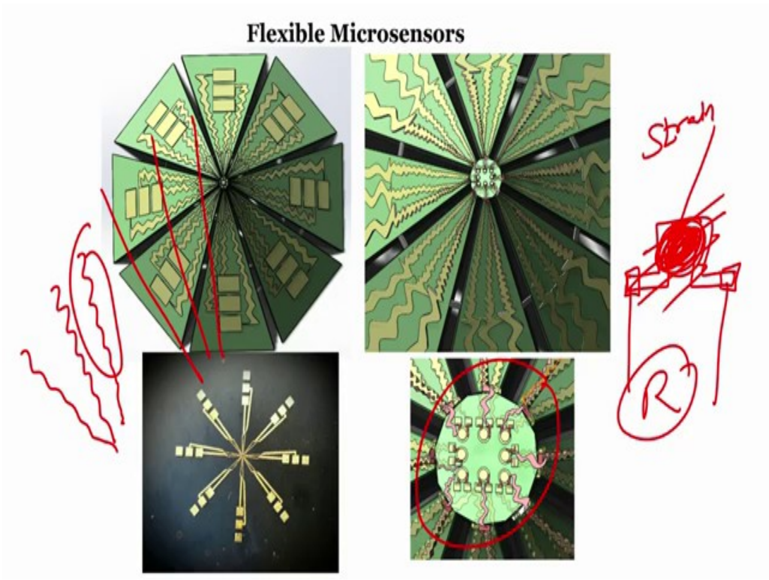

If you see the screen there is one kind of sensors that we have which has not only a strain gauge. So, if you see the sensors that we are discussing here right that you can see here these are like 1 2 3 4 5 6 7 and 8, 8 sensors are there ok. So, there are 8 strain gauges what I am what I mean by strain gauges strain gauges are a piezo registered that are doped with the help of boron doping right, so this is a strain gauge. If I apply if there is a strain there will be change in resistance all right, if there is a strain then there will be change in resistance. So, there is a strain gauge on the strain gauge there is an insulating material, on insulating material there is a gold pad on a there is a gold pad all right.

So, if have one to fabricate it will look like this, but where is the sensor here sensor is right in the center of this particular device that is why it is micro sensor it is a micro sensor right. And then you can see that the contact to the micro sensor we have used some zigzag pattern like this right. What is the reason of using zigzag and not like straight lines the reason is that, now it will have a less stress when the material is flexed. When the material is flexed there will be less stress and thus the contact will not get broken, it will not get damaged.

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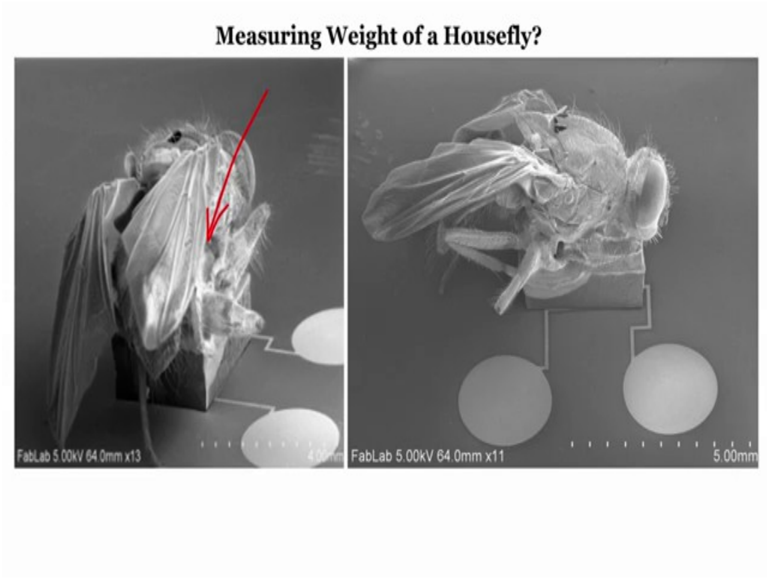

We will see how to fabricate this another application is to understand the weight of a fly. Now this is a micro fluff this a micro sensor which is capable of measuring the weight of a Housefly, housefly we see every day right several places and housefly itself has a lot of sensors. But we are not and we are not interested in understanding the anatomy of this particular insect, what we are understanding we are we are interested is can we fabricate a micro sensor that is able to measure the weight of a housefly that is our interest right.

Can we fabricate a micro sensor that is on flexible material right or on the silicon substrate that can measure the weight of a housefly how to fabricate such sensor that is our interest all right. So, until now we have seen a lot of sensors, now let us quickly see Actuators.

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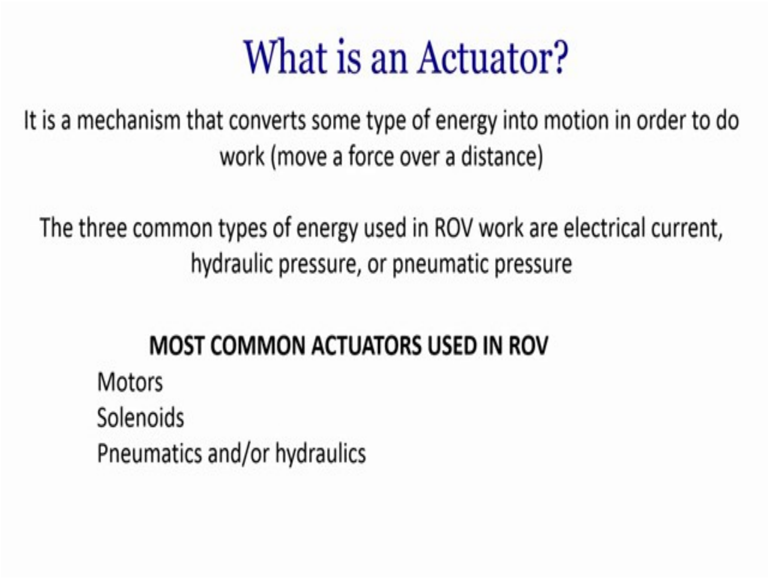

So, since the course is on sensors and actuators we should focus on both, but most of the time we will be looking at the sensor point of view. However, actuator is very important it is a mechanism which that converts some type of energy into motion in order to work right. Now move of force over the distance for example and if you want to understand the actuator right then in micro engineering there are several kind of micro actuators.

So, if you want to talk about remotely operated vehicle right, then there are lot of application of actuators. Remotely operated vehicle is also called ROV and the 3 common types of energy used in ROV work are electrical hydraulic pressure or pneumatic pressure. While the most common actuator is used in ROVs are motors solenoid valves as well as pneumatic or hydraulic and or hydraulics. So, this is the application of the actuators. However, if you want to see from the overview point of view.

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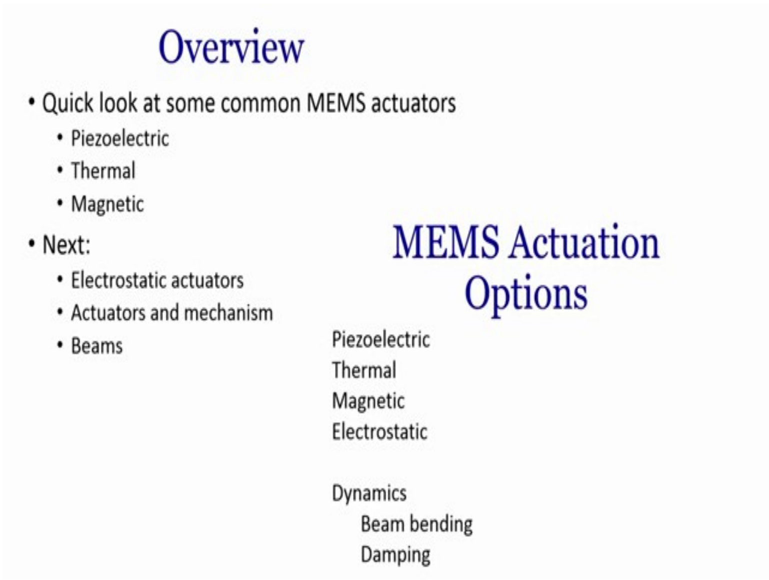

Then the over view if you see the slide then some of the common MEMS phase actuators are piezoelectric actuators thermal actuators and magnetic actuators. While other actuators can be the beams it can be electrostatic actuators it can be actuators and it is mechanism and when you want to use it then the option MEMS actuation options are piezoelectric base MEMS, thermally operated actuators, magnetically operated actuators, electrostatically operated actuators. While in terms of dynamics you can see the beam bending or damping these are the dynamic systems.

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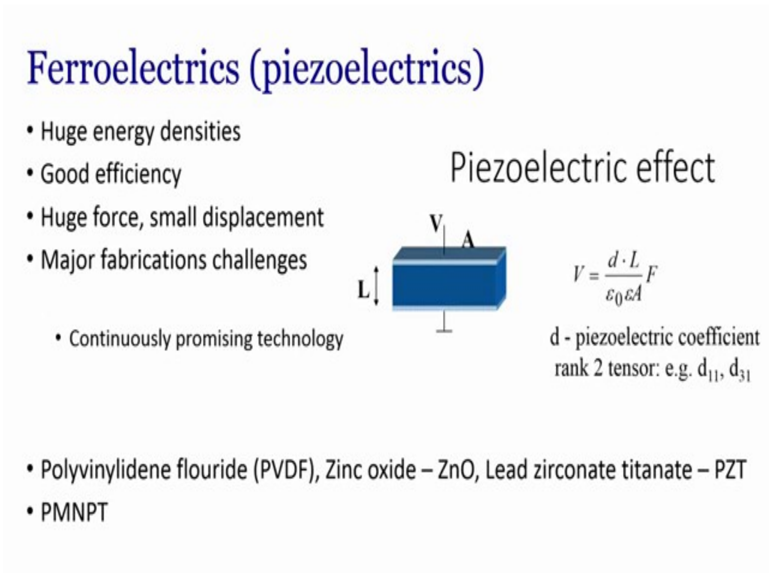

So, if I want to start with the piezoelectric or ferroelectrics then the huge energy densities, it has good efficiency a huge force can be measured small displacement. The major fabrication challenge in terms of piezoelectric is continuously promising technology ok. While if you know the piezoelectric effect it is nothing but when you apply a force that is a change in the voltage right and that is the piezoelectric effect or a reverse phase when you apply a voltage there is a change in the mechanical moment.

So, what are the examples of piezo actuators or piezoelectric actuators, see piezo resistive is different when you apply a force a change in resistance is piezo register here when you apply pressure there or force there is a change in the voltage right. So, what are the actuator materials or piezoelectric materials? The first one is PVDF which is polyvinyl polyvinyldene florid fluoride, second one is zinc oxide which is ZnO or ZnO, third one is Lead zirconate titanate which is PZT and 4 one is fourth one is PMNT and PMNPT. So, the most commonly used piezoelectric material when you want to fabricate a micro actuator is zinc oxide and PZTs.

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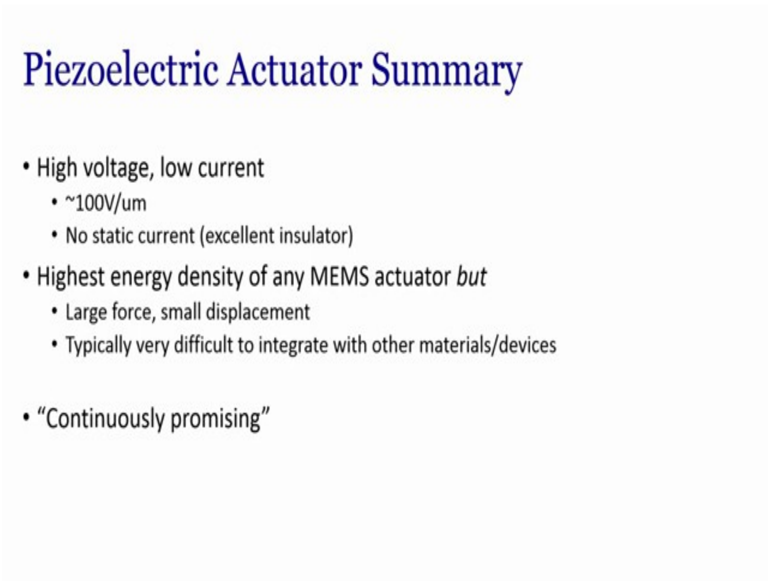

So, the one page summary we can write it down is that it has high voltage and low current approximately 100 volts per micrometer, no static current and that is why it is an excellent insulator. The highest energy density of any member actuators, but the large force and small displacement, typically very difficult to indicate whether materials and devices and there is but still it is continuously promising material.

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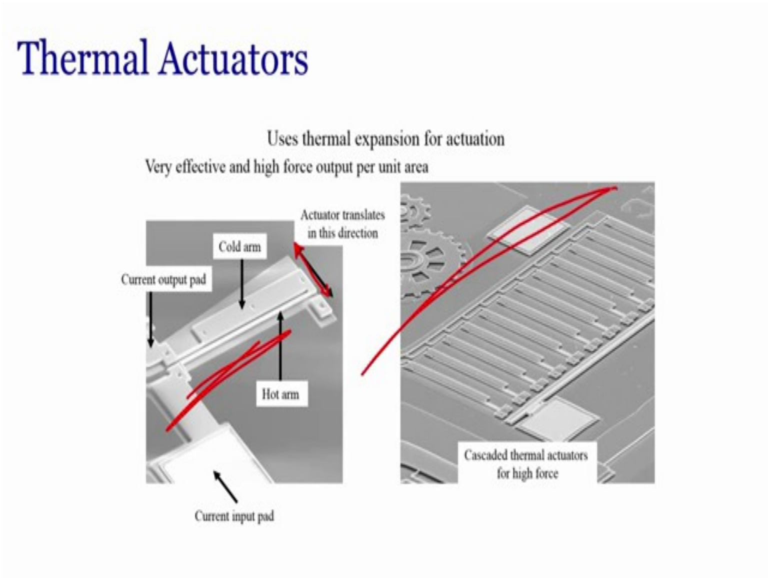

Now the another kind of actuators are thermal actuators and in case of thermal actuators it uses the thermal expansion for actuating very effective and high force output per unit area. The actual translates in this direction for example, the actuator will move in this particular direction depending on how the cold and hot arm are changing it is temperature. So, when we apply a current input pad then there is a displacement which causes the change in the, there is a heating in the actuator which consists the change in the displacement or translates into a directional point of view.

We can also have a cascaded thermal actuators for high force, if this is a single actuator we can have a array of actuators where we can generate a higher force compared to a single thermal actuator.

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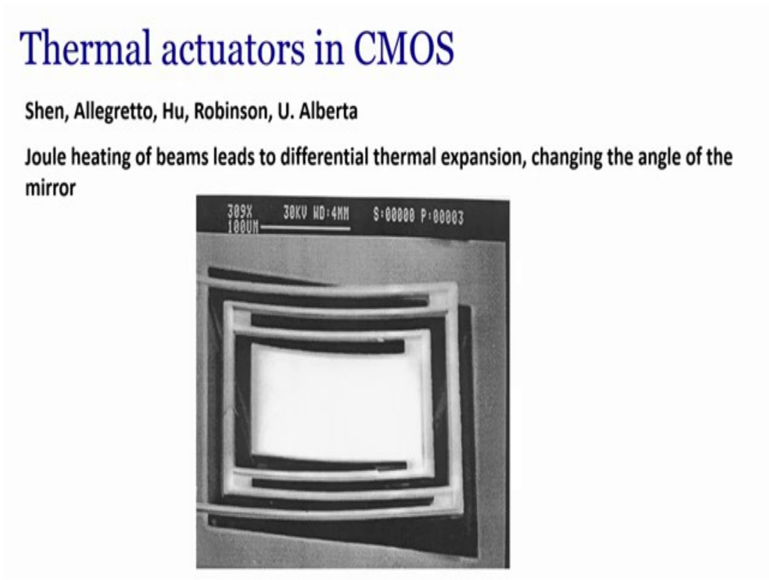

If I talk about CMOS which is complementary metal oxide semiconductor, then in there is a the work done by Shen, Allergretto, Hu, Robinson, U. Alberta, where they have worked on thermal actuations in CMOS and here the joules heating of beam leads to differential thermal expansion changing the angle of the mirror. If you see this is a mirror right and when there is a joule setting the angle of the expansion thermal expansion, because of the differential thermal expansion the angle would change and this would cause the change in the angle of the mirror. So, this is what thermal actuators had been studied.

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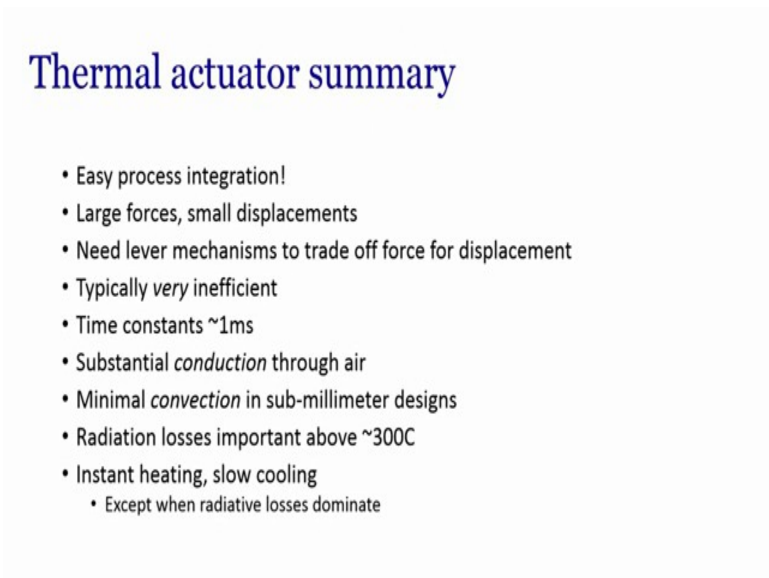

And if you want to have a comparison like the summary of the piezo actuator versus summary of the thermal actuator, then in case of thermal actuator the advantage are easy process integration. However, there is a large force is small displacements need lever mechanism to trade off force for the displacement which is the important point. Typically it is not so efficient like piezoelectric and that is why this in inefficient time constants are approximately 1 millisecond, there is a substantial conduction through air and there is a minimal convection in sub-millimeter designs.

The radiation loss is important about 300 degree centigrade there is an instant healing heating slow cooling except when radioactive losses dominant. So, these are some of the things that we need to understand when we are understanding the thermal actuator in detail all right.

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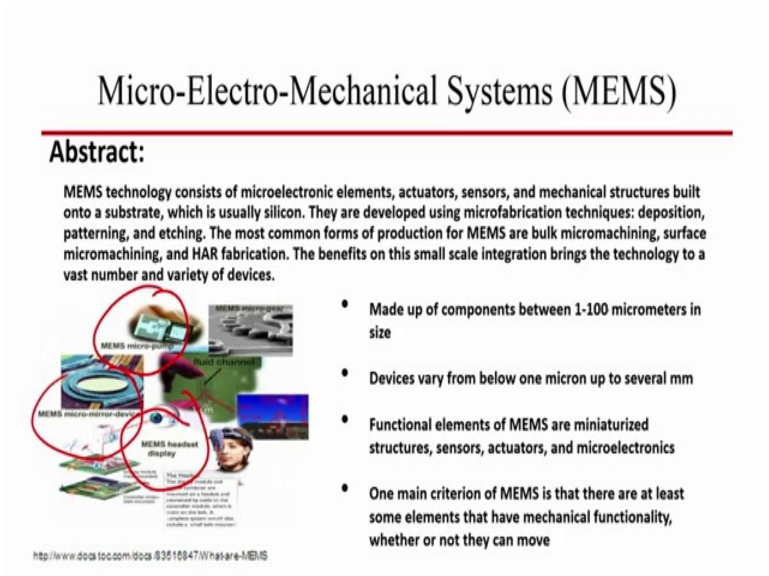

Now, let us see what exactly a MEMS are because, everything whether is actuator or a sensor we have to use a technology called micro electromechanical systems based fabrication technology. And if you see the abstract the abstract of the MEMS reads like this that the MEMS based technology consists of microelectronic elements actuators, sensors, mechanical structures, built onto a substrate.

Now, most of the time the substrate is a silicon wafer further the MEMS are developed using micro fabrication techniques that is deposition patterning and etching. The most common forms of production of MEMS are bulk micromachining and surface micromachining and HAR fabrication. The advantage or the benefit of the small scale integration brings the technology to vast number and variety of devices we will be seeing some of the devices in the in the next few slides.

Few examples are MEMS based micro pump, there is a MEMS based micro mirror device, MEMS the headset display what exactly MEMS are? So, the MEMS are made up of components between 1 to 100 micrometers in size the devices vary from one micron up to several millimeter. Functional elements of MEMS are miniaturized structures sensors actuators and microelectronics one of the main catted of MEMS is that there are at least some elements that have mechanical functionality whether or not they can move.

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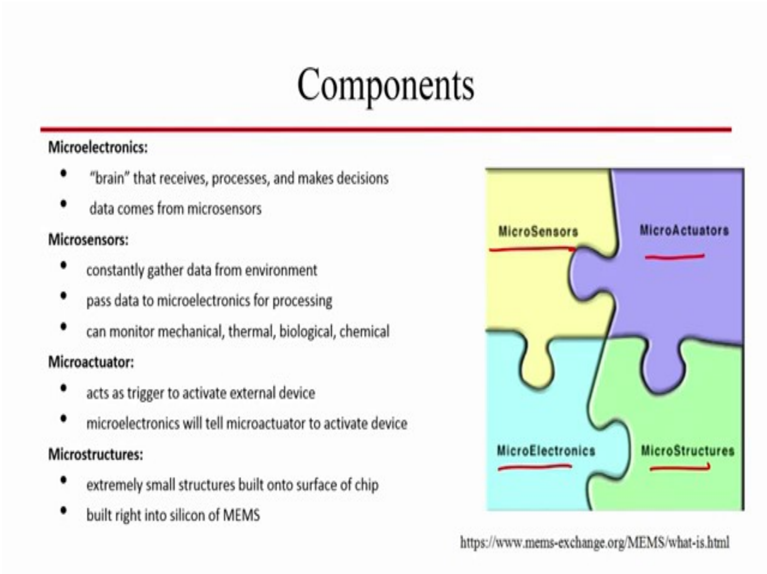

So, this is the one of the main criteria when you want to study the MEMS we will see the different applications right. Now let us see this is the last slide which are the components, the components of the MEMS are microelectronics micro sensors micro actuators and micro structures right. You can see microelectronics micro structures micro actuators and micro sensors.

So, when you talk about micro sensors microelectronics then microelectronics is a brain that receives process and makes reason data comes from the micro sensor when you talk about micro sensor. Then constantly it is role is to constantly gather the data from the environment, pass data to microelectronics for processing can monitor mechanical thermal biological and chemical changes.

When we talk about actuators then x as a trigger to activate external device, microelectronics will tell micro actuator to activate the device and finally micro structures are extremely small structures built onto the surface of chip built right into silicon of MEMS. Thus if you see in a way each of this 4 different components are interrelated right, whether it is actuator, whether it is sensor is structures or it is a electronics right.

So, we will see in the next class the details further details about the MEMS, how the fabrication processes are and then we will start to see how you can fabricate the sensor. Before that I want to teach you a very important topic called photolithography all right. So, till then you look at the lecture look at the things that I have taught you I will see you in the next class and we will learn the further application of other details about the MEMS, followed by the PVD technique CVD technique and lithography right. So, I will see in the next class till then you take care bye.