Sensors and Actuators

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Lecture - 19

Hi, welcome to this module. Here we will be looking at where exactly the MEMS space sensors are used and what are the additional application of those sensors. And finally, we will conclude this particular lecture series saying that how MEMS space sensors, understanding of MEMS space sensors and actuators can be useful for several applications.

So, if you talk about MEMS space sensors, MEM stands for Micro Electromechanical Systems, micro stands for 10 raised to minus 6, minus 6 the order if you want to understand, it is similar to human, the human hair thickness is close to 80 to 100 microns, 80 to 100 into 10 to the power minus 6 um. So, this is the thickness that we are talking about from few hundred microns to few microns and when we talk about such a smaller miniaturized sensors and actuators where are they actually used. If you just take an example of automobile then if you take an example of a car then there are several sensors in your car.

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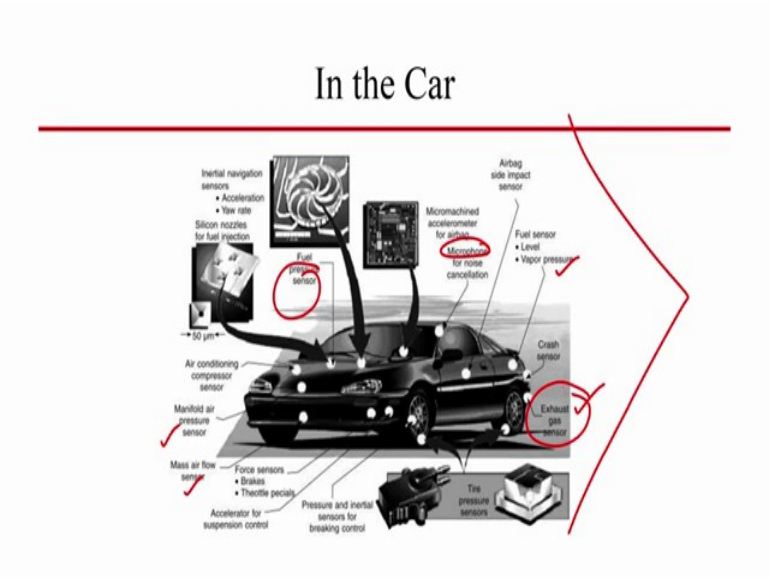

So, if you see the slide what do you understand that in a given modern car, you will have plenty of sensors we will start with few and lot of these sensors, we will also see in terms of process flow in this particular class. We have the initial navigation sensors there is an accelerometer, there is a yaw rate, then there is a fuel injection system; this is for nozzles for fuel injection system, then we have air conditioning compressor sensor, we have a main fold air pressure sensor.

We have a mass flow the air flow sensors then we have four sensors for brakes and theottle pecials where accelerometer for suspension, pressure and inertial sensor for braking control. We have tire pressure sensors, exhaust sensors, we have gas sensors and we have crash sensors, we have fuel sensors, airbag sensors, micro machined accelerometers, microphone for noise cancellation so, many sensors into one automobile when you get it.

And, a lot of sensors we will be also looking at how to fabricate it for example, we will look at the pressure sensor, we will look at the flow sensor, we will see how it can be used for a gas sensor this MEMS based device, we will. So, for vapour pressure sensors, we can say of microphone as well. So, a lot of things that we will learn in this particular again there is a pressure sensor here, what you learn here in this course can be utilized for several applications excluding biomedical, it can be used for automobile industry as you can see right over here (refer video). Now, if we talk about gas sensors, it becomes very simple and we have discussed in one of the modules.

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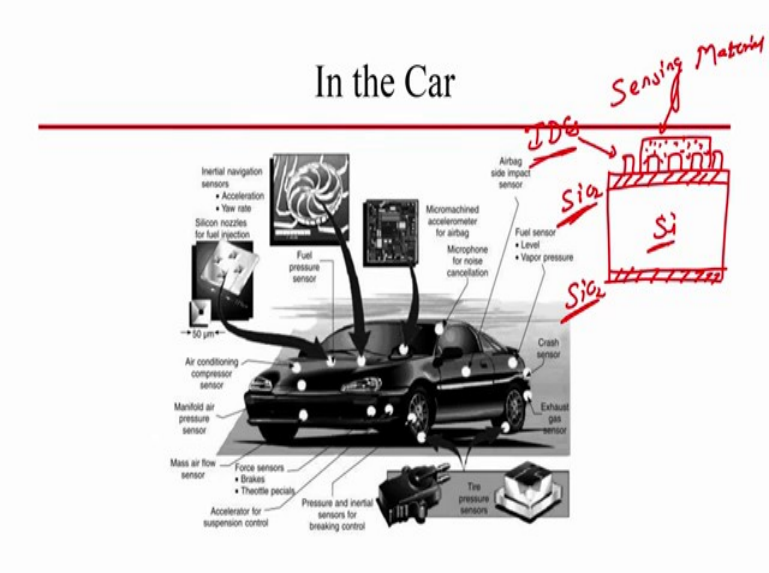

If you want to design a gas sensor the what you require is that you should have a substrate, you should have the contact pads and you should have the sensing material on the contact pads. This becomes your so, if it is this silicon then we say that this is an oxidized silicon wafer right like this, then you have SiO 2 silicon wafer SiO 2 and you have interdigitated electrodes this is your sensing material, sensing material.

So, you have interdigitated electrodes, you have silicon dioxide, you have silicon wafer, you have sensing material. Now, if you want to improve the sensitivity, the sensing material does not work at room temperature, you can add the heater to this, you can add a heater to it. If you add a heater to it then you have to do perform a micromachining.

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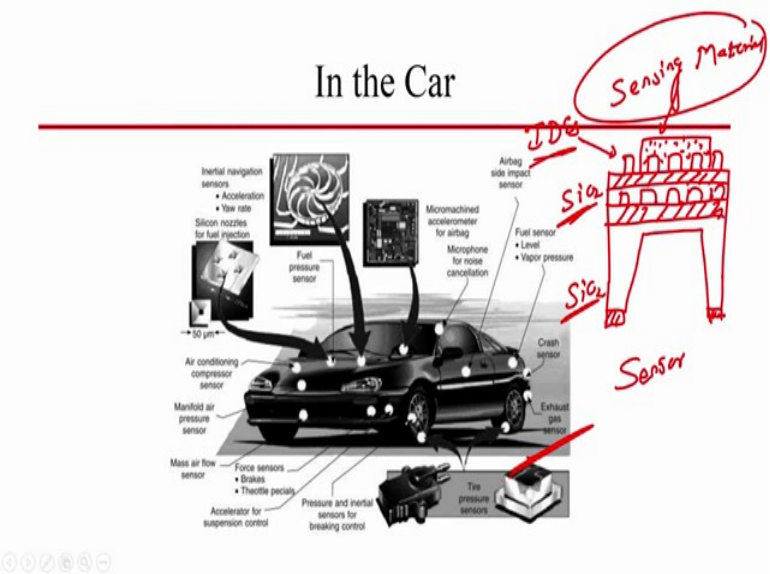

So, in that case if you want to add the heater then this will be like you have a heater right, you have a silicon dioxide. On heater there is a contact to a heater, there is a cross section (Refer Time: 04:42) it and then you have the since you have a heater you want to make sure that it heats at low temperature, for that you can create a diaphragm and this becomes your sensor. This sensor depending on the sensing material, you can use it for measuring the exhaust gases.

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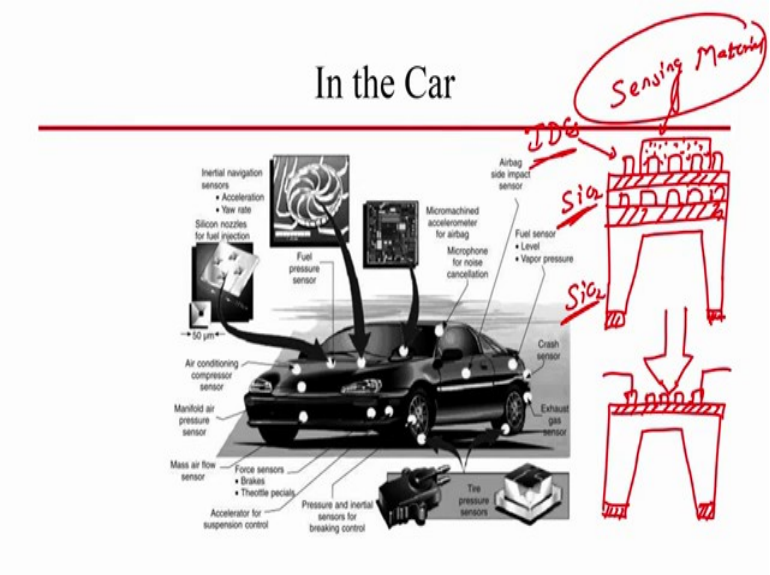

So, this is a very quick example of how can you design a gas sensor for such a vehicle system, you can design a pressure sensor, you also have the similar kind of work, you have the strain gauge or you have a pressure sensor. I will have oxide layer, you have contact pad and then you apply a prior force here if it is a strain gauge and depending on the bending of this diaphragm, the strain will change and you can measure this strain using these contact pads right pressure sensor. So, easy to fabricate, it requires only two mask process to fabricate and this these things we will be learning in the course in next few modules.

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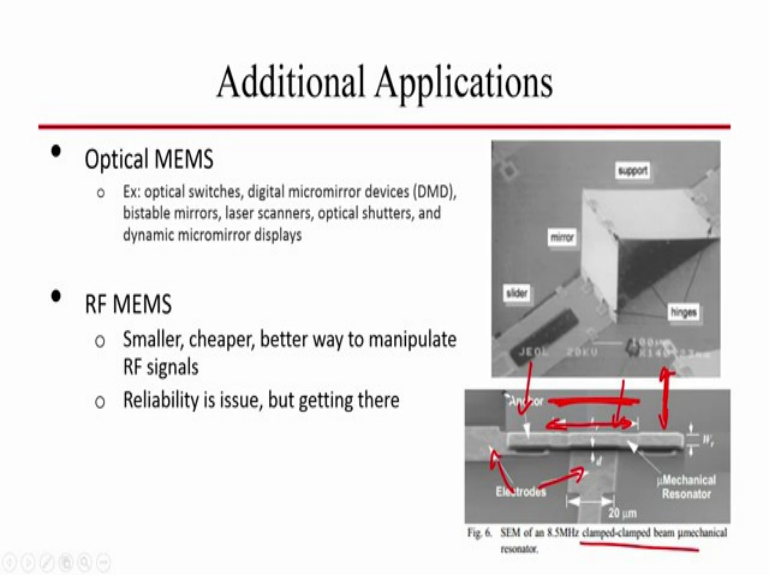

Now, what are additional applications of this MEMS? So, additional application are in the area of RF, Radio Frequency MEMS it can be the radio frequency switch, it can be in the area of optical MEMS where we are looking at optical mirrors which is micrometers bistable mirrors, laser scanners, optical shutters as well as dynamic micrometer displays. While if we talk about RF MEMS then it can be used for radio frequencies which is it can be smaller, cheaper, better, and then there is a reliability issue, but you know getting there since there is a lot of failure while fabricating the device.

But, if you see the slide what you observe is that if you talk about a clamped-clamped beam micromechanical resonator, this beam is clamped from two different regions and this is the anchor, these are electrodes for applying the voltage. When you apply a voltage, this mechanical beam will resonate and the resonation will be in this particular direction right. So, it will resonate in this direction. In some of the cases when you develop the switch, it will resonate in this direction.

So, this can be a micro resonator or it can be work as a RF MEMS and so, it will only work at a frequency of 8.5 mega Hertz resonating frequency. This is an example of the mirror you can see that there is a slider, there is a mirror, there is a support and there are hinges, it is a micro mirror that the SEM of micrometer, this is a SEM of your resonator.

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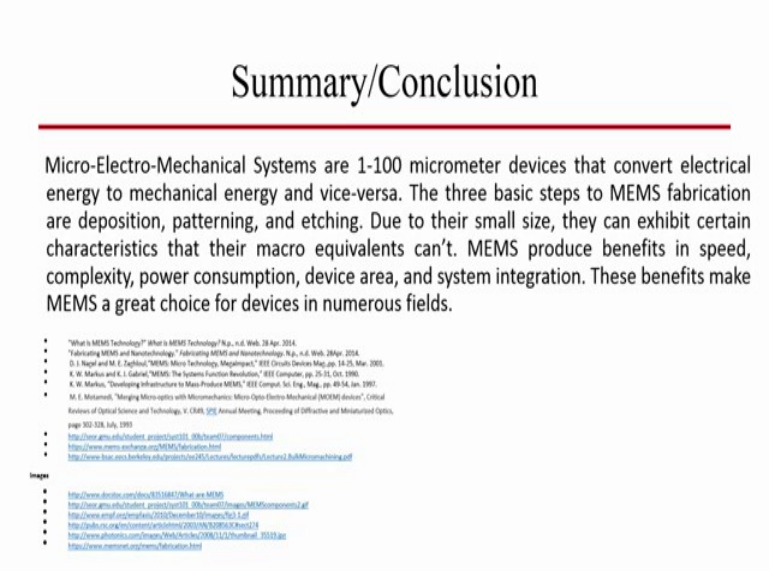

So, in conclusion what we have understood about this particular lecture which was focused on MEMS is, that MEMS are systems which are in a 1 to 100 micrometer range and that can convert the electrical energy to mechanical energy and vice versa, if you are talking about piezoelectric. But, if you are talking about piezoresistive then you apply pressure which is mechanical energy to resistance again mechanical to electrical.

There are three basic steps in MEMS fabrication are deposition, patterning and etching. So, deposition you can use PVD, CVD, we will talk about PVD, CVD, for etching you can use chemical etching, which is the wet etching as well as dry etching. For patterning you can use photolithography, photolithography you have positive photo resist, negative photo resist white film mask and dark film mask.

Then due to their small size they exhibits a very certain characteristics and their micro equivalents cannot produce that kind of characteristics that is a advantage of MEMS. Finally, another advantage is in speed, complexity, power consumption, its device area and system integration. So, these are another advantages of MEMS over their counterparts which are macro in dimensions and this benefits MEMS as a great choice in as a device in several applications and in numerous fields.

When we are talking about automobile, we are talking about communication we were we can use the MEMS in medical and in several other applications. So, it is really important to understand this particular part of a bigger umbrella which is electronic systems, a part of this is MEMS and MEMS based devices and sensors are used in several fields. This is

the summary for you that any system that is between 1 to 100 micrometer, we can call it MEMS.

The system generally transforms the electrical energy to mechanical or vice versa, this system is faster, miniaturized, it carries a lower power consumption, its device area will be lesser, it is easy to integrate in a system. And finally, the step for fabrication of MEMS space sensors there are three main steps one is deposition, second is patterning and third one is etching. So, this is all for this particular module. In the next module, we will be looking at how silicon is fabricated from silicon mould or silicon bowl and then we also can see how we can grow silicon dioxide.

But, before that if I want to give you five important key concept about MEMS then here are those. The first concept is MEMS are made up of micro electronics, micro actuators, micro sensors, this is the first key concept. So, microelectronics, micro sensors, micro actuators, and micro structures, these four thing constitutes a MEMS. Again I am repeating microelectronics, micro sensors, micro actuators and micro structures. The second key concept in the area of MEMS is three basic steps deposition, patterning and etching.

The third key step is chemical etching is popular because of its high etching rate, fourth step is three times of pressure sensors are there; one is capacitive pressure sensor and there is a piezoelectric pressure sensor and then there is a thermal pressure sensor right. So, three kind of MEMS based transducer if you want you say thermal transducer, piezoelectric transducer, and you have capacity transducer.

Finally the fourth concept I will say is that the or fifth concept is that the benefits of MEMS are speed, consumption, size, system. So, again if you want to see five key concept first concept is it is made up of microelectronics, micro structure, micro actuators. The second concept is deposition, etching and patterning are the important steps. Third is chemical etching is faster, it is more preferable because of the high etching rate. Fourth one is there are three types of MEMS based transducer capacitive, thermal and piezoelectric and the fifth one is that the speed, power consumption, size and the system integration all on one chip is beneficial.

So, these are the five key concepts for the MEMS, here we will stop our lecture and I will see you in the next lecture talking more about silicon as a substrate.

Till then you take care have a nice day.

Bye.