A Brief Introduction to Micro Sensors
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Lecture - 01
Introduction to Microscale Sensors or MEMS

Hi, I am Shantanu from IISER, Bhopal. So, I am going to talk about this course that is Microscale Sensors or MEMS. So, welcome to the first module of this course.

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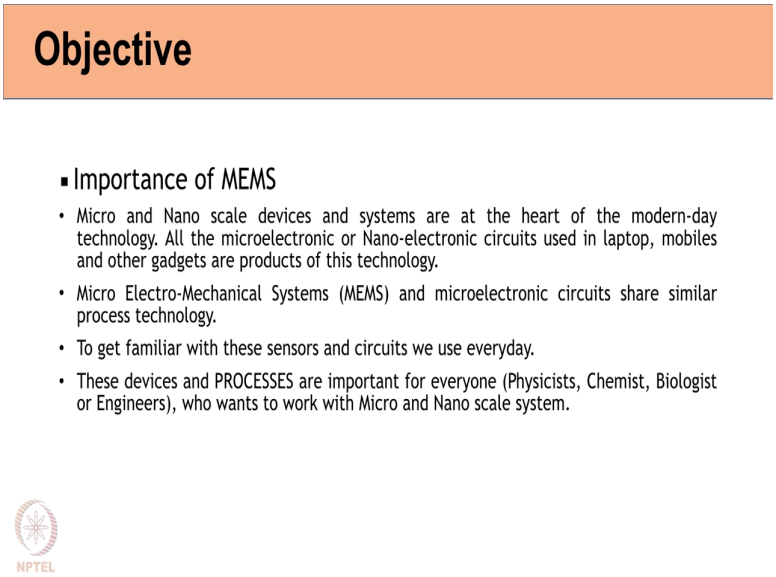

Before we go to actually the details of MEMS what we need to understand that why this is important, why MEMS are important, right. So, the first thing is you see that micro or nano-scale systems are at the heart of modern day technology you take like a laptop or a mobile phone there are a billions of transistors and other components, right which are kind of

very much necessary for that for the working of that particular device. Now, all this microelectronic circuits or all this elements are actually product of these technology ok.

Next is like micro electro mechanical systems which is topic of this course and microelectronic circuits which you are I guess many of you are already familiar with it like uses the similar kind of process technology. What does it mean? Means that the way this kind of sensors are made same way the microelectronic circuits are also made like the similar way. Actually microelectronic circuit process technology actually started from like several decades back right and MEMS or this sensors technology actually followed that technique.

Now, the idea or the objective of this course is to get familiar with this kind of sensors like how do they work, how are they made etcetera. And most importantly that processes by which you can make this kind of devices right and you see that one thing is that knowing this kind of sensors having an idea getting familiarized with this kind of sensors. The thing is like the more or the most important thing is that how like if you need to use or if you need any of this kind of micro scale sensors for your research or project, then how are you going to design it, how are you going to make it. So, that will be taught in this course.

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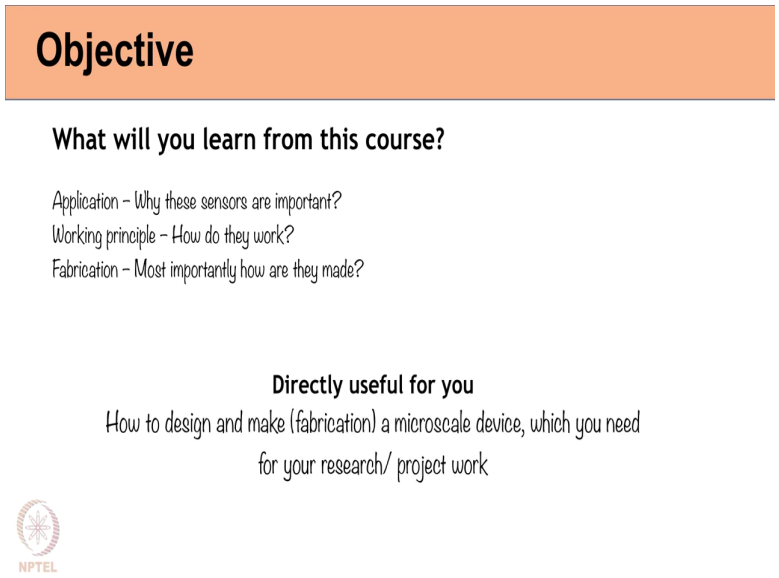

So, what will you learn? The first point is application, like why these sensors are important? Where you can apply this knowledge? Second is working principle like how do they work actually? And, the third is fabrication or the most important part that is how are they made? Like you see these are very small sensors right I am talking about micron or even smaller scale. So, how you can make a device in that scale? And as I was saying that directly for your research which is what is important is how to design and make micro scale devices for your research or project work.

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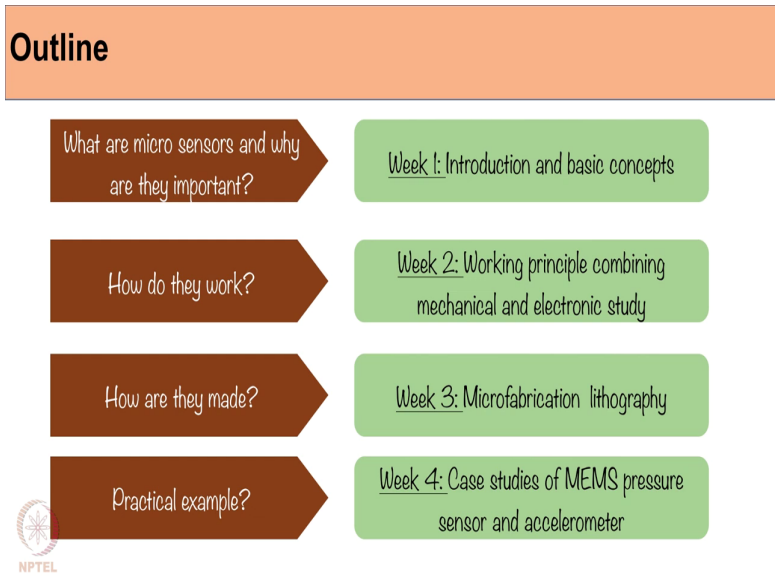

Now, the brief outline of the course; so, the first week you know it is a 4 week course and the first week we will talk discuss about like introduction and basic concepts. So, you will have an idea about what are micro sensors and why are they important. Then how do they work, like working principles and how in MEMS as we was talking about micro electrical mechanical systems, how the mechanical defining mechanical and electronic elements works together; so, that we will study.

And next is the most important part how are they made? Like micro fabrication or lithography these are the usual techniques we use for making these kind of devices and finally, practical example. So, case studies will be discussed with specific examples of MEMS pressure sensor and accelerometer and we will use this knowledge to make these two devices.

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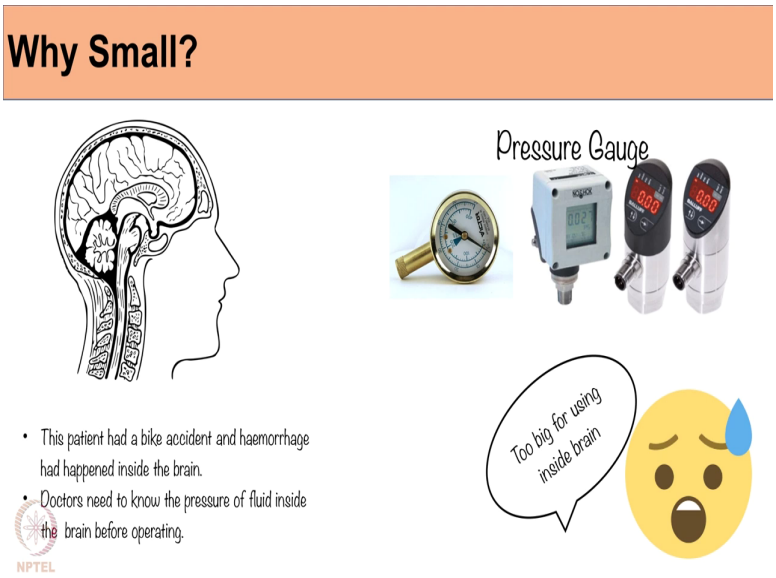

The next question, why we are talking about at all about these micro scale sensors? Why we need to go such small scale? We know that the pressure sensors or temperature sensors whatever sensors we are discussing going to discuss in this course are already existing. So, let me give you this example, that is let us say this patient had a bike accident and because of this some internal haemorrhage has happened inside his brain.

Now, doctors before operating they need to know that how much is the fluid accumulation inside his brain and for that they need to measure the pressure of the cerebrospinal fluid or blood inside his brain. Now, for that what we need? We need a pressure gauge and if you see these are the usual pressure gauges available in the market. These are pretty big in size right and you cannot open human skull and then just put this gauge inside the human skull, even

the proofs for this kind of pressure gauges are also very big. So, it cannot be put inside a human brain. What is the solution?

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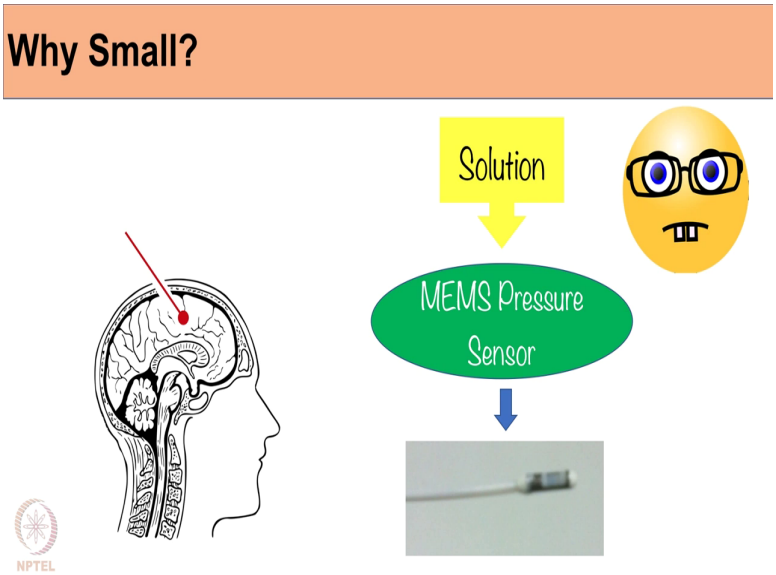

Solution is MEMS pressure sensor and MEMS pressure sensors can be this kind of small sensors which can be put on tip of a needle, ok. So, in on tip of a needle you can put this sensor's and then can drill a small inside the human skull and then you can put proof through that hole, and then the doctor will know from outside that how much is the pressure reading or how much fluid has build up inside the brain. And in this course, we are all going to talk about this kind of sensors which can be used in such a situation where the normal or the conventional sensors or gauges cannot be used.

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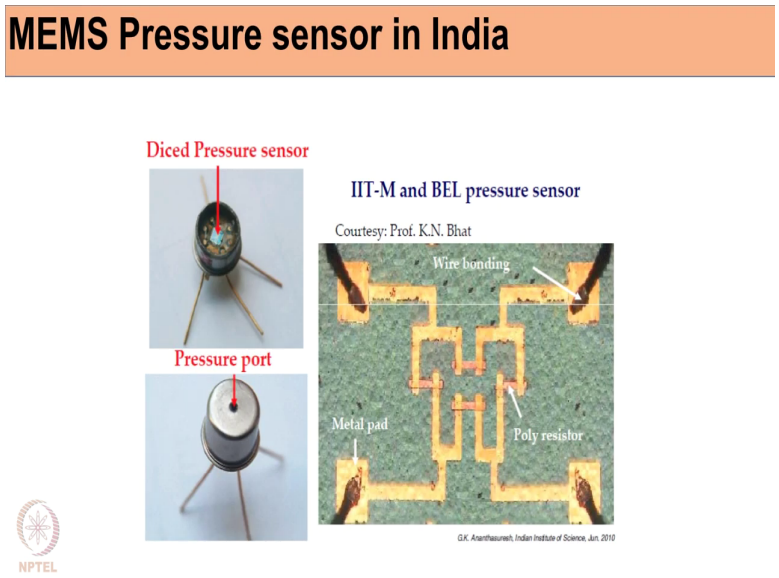

So, before going into the details let me just show you one glimpse of one of the MEMS pressure sensors made in India. So, this is Professor K N Bhat, but made in, IIT Madras; this MEMS pressure sensor totally made in India and with using Indian technology.

And this kind of sensors you can actually use for measuring like, I was saying that blood pressure or like intercranial pressure. Then let us say even on aviation technology for light combat aircraft we need to measure pressure at different points of the wing. And you cannot put a big pressure sensor on top of a aircraft because then the plane will not fly at all, right.

So, in those cases this kind of MEMS pressure sensors are used though packaged in different way, but the ultimately the sensor or the main chip is same.

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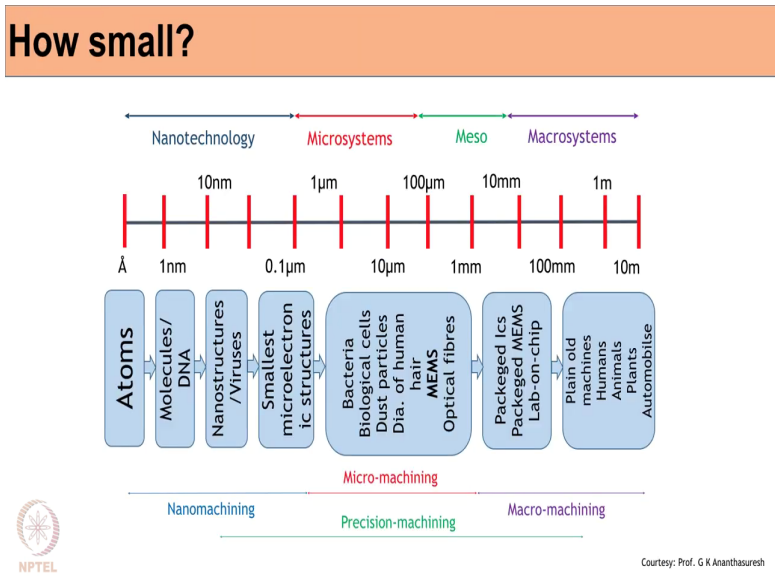

So, now as we are talking about small, let us give you some idea about what we mean by small, how small actually we are talking about, right. So, you know about atoms and all atoms are in angstrom range, ok.

So, one atom like hydrogen atom is about 0.5 angstrom or in that scale. Then you have molecules or DNA in nanometer scale, then nanostructures are access in like few tense of nanometer scale. In the smallest microelectronic like microelectronic structure is about let us say just about 1 micron or little lesser, then you have bacteria's, biological cells, MEMS devices and all are in that micro scale, right. So, and one humans hair diameter is about 100 micron or little more.

So, MEMS operate; MEMS devices operate in this range, then you have packaged ic's or like packaged MEM sensors or lab on a chip and finally, in the micro scale you have like plain old

mechanics or human animal plants whatever we see on our everyday basis and on our surrounding everything is macro scale. So, in this course we are going to talk about this region that micro scale region where the MEMS devices operate.

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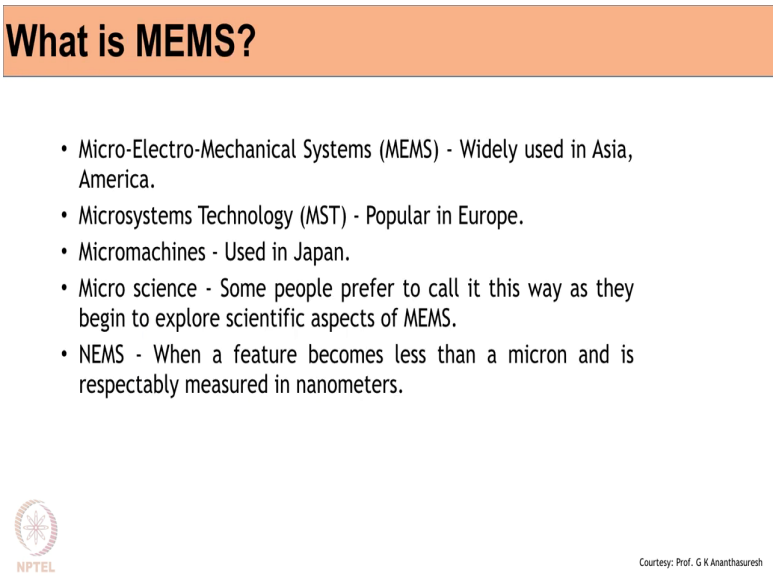

So, we are talking many many times about MEMS. What is MEMS? Full form MEMS is as full form MEMS is Micro Electro Mechanical Systems. Now, make MEMS or Micro Electro Mechanical Systems is more popularly in like India or US. Whereas microsystem technology is mostly used in Europe, then micromachines used in Japan or micro science by some people around the world like that.

So, it has different different names in different countries, but ultimately this all point points to the systems or devises which are in micro scale and which operate in micro scale range. And if you go to even below 1 micron which geometries or which feature size can be measured in

nanometer scale, then it is NEMS or nano electro mechanical systems. For the part of this course we will be only restricted to micro electro mechanical systems.

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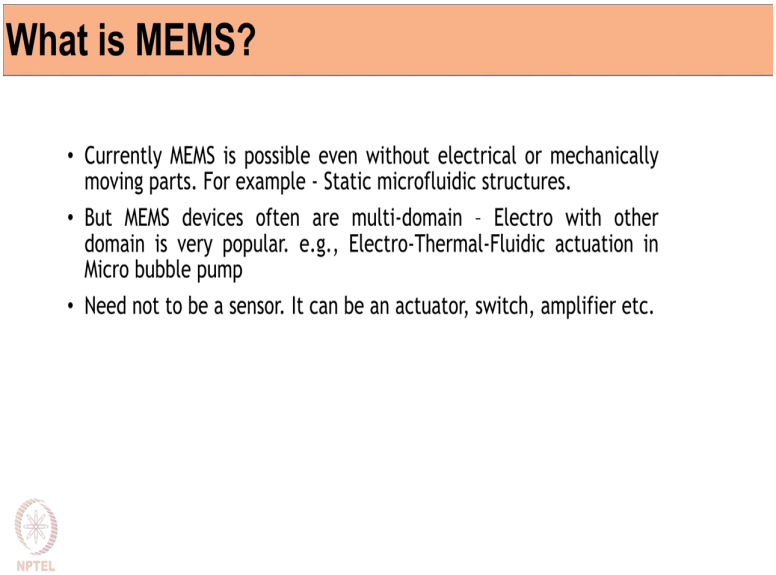

Now, we know different nomenclature of MEMS. So, let us talk about in little bit more detail about MEMS. So, as I am telling that micro electric mechanical systems right, but currently MEMS devices are possible even without electrically or mechanically moving parts for example, static microfludic structures.

So, we will go or discuss about these things while we move on in this course, right. But, along with the electric and mechanical part even the thermal fluidic and other domains are also very much important in this course. And, you will has you will see many examples of electro thermal, fluidic actuations or micro bubble pump etcetera in this course. Another

important point is that the MEMS need not to be a sensor it can be a actuator also like switch or amplifier etcetera. So, we will discuss this as we move along.

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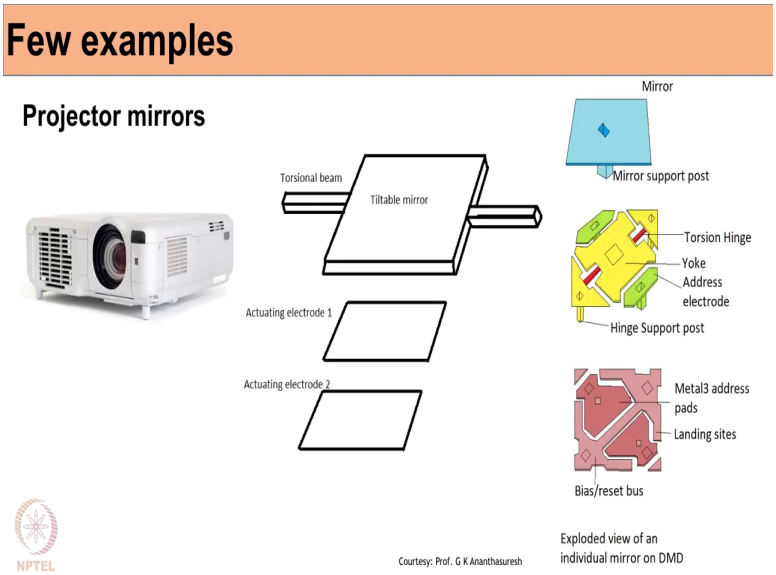

To give you some examples of MEMS devises, right. The first example is like this projector mirror. So, these are tiltable mirrors which tilting angle you can control using electrical signals or pulses and in this case, this tilting angle will decide that where the pixel will form and what will be the intensity and colour of the pixel etcetera. So, there are like thousands of this micro mirrors which are working inside a projector to make the picture projected on your screen.

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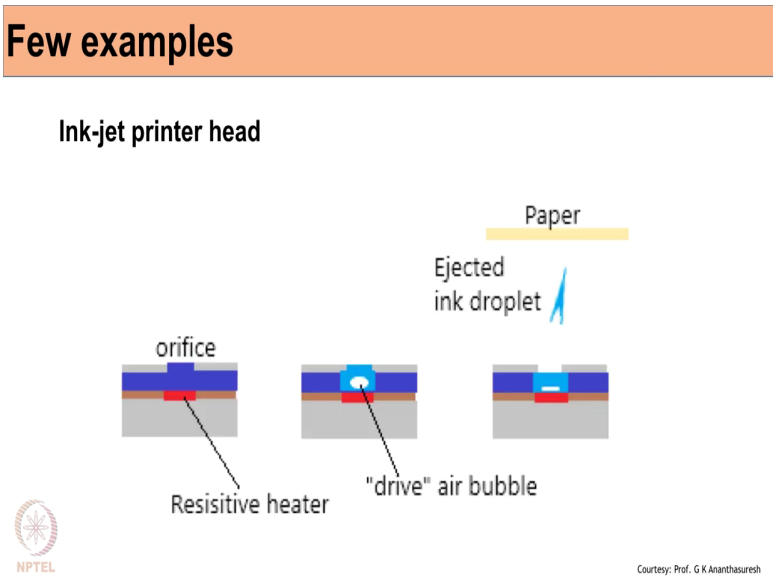

Then, an ink-jet printer; what is an ink jet printer? So, as you can see; so there is an orifice through a hole and then you have your ink which is surrounding a bubble. Then you have a resistive heater. So, as you pass some current it heats up and the bubble or the air bubble burst and that shoots out the ink on the paper. So, this is how ink jet printer head works, this is also product of micro technology or micro electro mechanical system.

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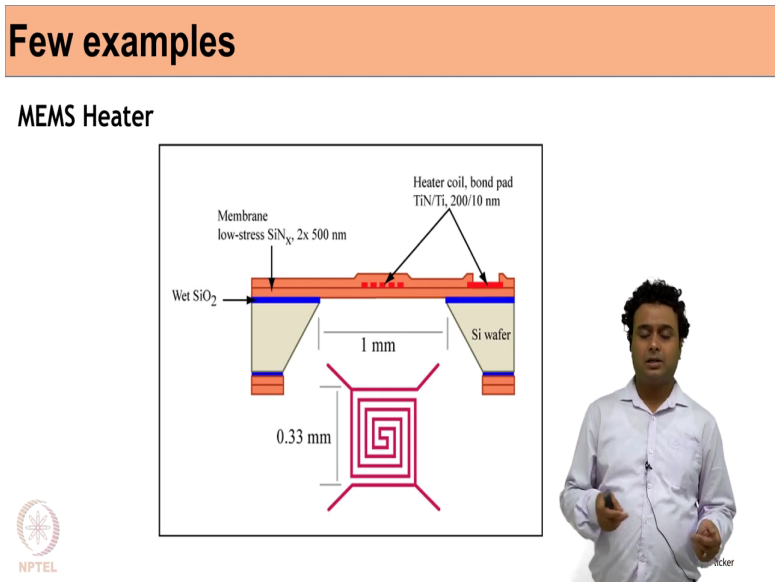

Another example is like MEMS heater as I was saying that it is not only a sensor it is an actuator also right, for that purpose I can give this example where you can make this micro scale coils at specific space on your silicon wafer and then you can heat up only at that region that particular region. And so microscopically control the temperature at different regions of your samples.

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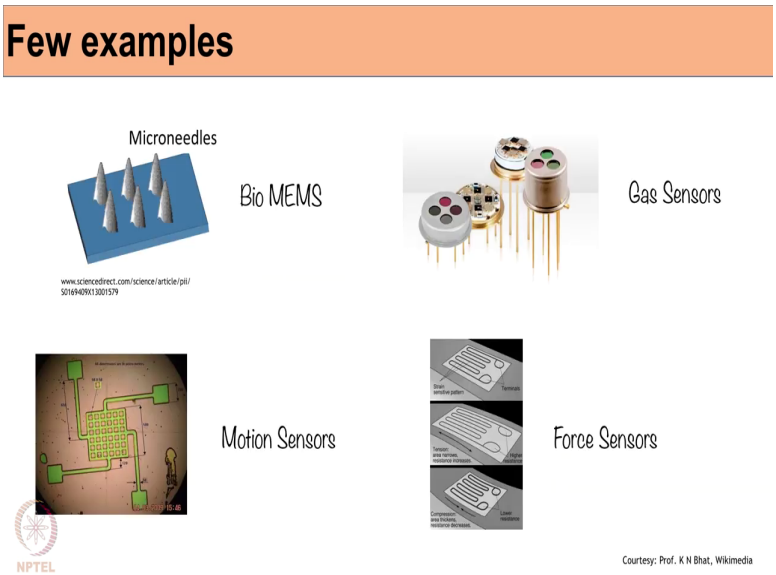

And few more examples of MEMS of where it is useful for biological devices MEMS is now a day's very much important for making micro needles etcetera which are very much important in for separating cells or injecting some fluids from one system to another system. This kind of micro needles can be made using MEMS technology, then micro fluidic devices which are also very much important in biological system like for experimenting with biological system there also you need micro system or this kind technology.

Then another very important example of MEMS is motion sensors. So, you see your mobile have all this you play these games like motion games right and there you have your different sensors which are called like accelerometer for measuring acceleration or gyroscopes for measuring rotation. And these kind of sensors are actually in micron scale range and this is product of this micro system technology which we are going to discuss in this course.

Then you have like chemistry based MEMS sensors like gas sensors where actually if some material is exposed to some kind of gases, then what happens is there are some conductivity electrical properties like conductivity or resistivity etcetera it changes. And by measuring that electrical voltage output you can measure that how much is the presence of this that gas or what is the concentration of that particular gas in the ambient. So, there also you can use this kind of micro electro mechanical systems.

Next is very important example that is force sensors. In case of force sensors you have a material which if it is exposed to stress or strain, then it is electrical properties changes like if you bent it, then it is under tension and it is becomes little bit elongated and because of that it is resistivity changes like for piezoresistive materials.

And in those cases by measuring how much is the change in resistance you can measure that how much is the deflection cost, and from that deflection you can measure that how much is the force has been how much force has been applied for making that deflection. So, this kind of force sensors are also made using micro fabrication technologies.

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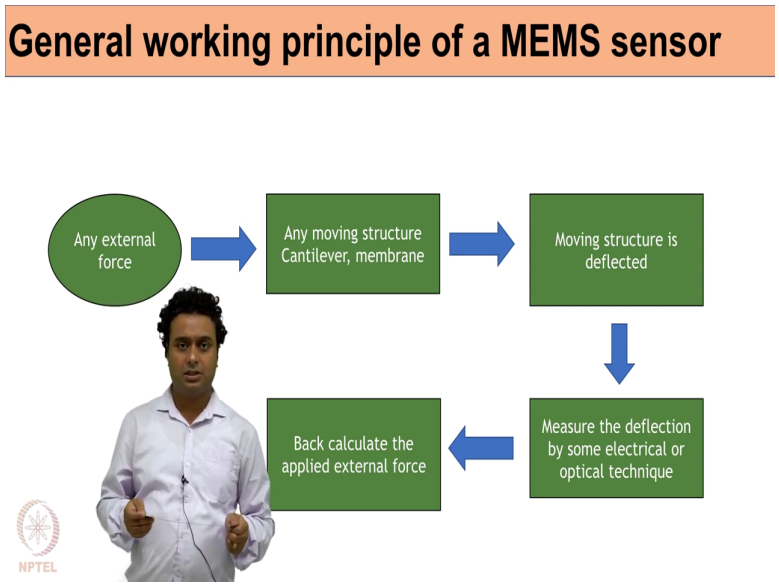

Finally, I will end this module with this slide that is general working principle for MEMS sensor. You take any MEMS sensor it can work following this general principle. So, there is some external force which is applying on some moving structure. So, let us assume this is like a cantilever which fixed is this that at this end free at this end, right.

Now, if I apply an external force, then it bends like this. Once it bends then if I put some piezo resistive material as I was talking in the last slide, piezo resistive material which changes its resistivity because of stress or strain then its resistance changes.

And once this moving structure is deflected the resistance of that electrical property is changed and by measuring that electrical property we can calculate that how much is the deflection and how much is the force I am applying to make this deflection. Other than electrical properties it can be also the deflection can be also measured using optical

techniques also. Like, let us say if you have focussed laser on this end of the cantilever then as it deflects, then the reflected beam also shifts. And from that shift now using a photo detector we can measure that how much is the deflection of the cantilever tip and accordingly we can measure that how much is the force applied on this particular structure.

So, any MEMS sensor you take or in general any MEMS sensor you take there is an external force which is acting on some kind of moving structure like cantilever or membrane and that structure is because of that force that structure is deflected. And then that deflection causes some kind of electrical change or optical change through which we can measure that particular deflection and can back calculate the applied external force. So, this is the end of this module.