Lecture – 49

Introduction to MEMS Simulation using Comsol Multiphysics.

Hi, Welcome to this particular lecture. This lecture is focused on, MEMS Simulation, using COSMOL Multiphysics. Now you see, why you need to learn a simulation. Right? For this particular course? We have seen a fabrication of sensor. Right? But, there are lot of questions that we need to address, before we fabricate the sensors. And simulation will help us to answer those questions. So, some of the questions can be, if you have the experimental data. Right? I need to understand or verify those data, then you can use particular simulation software.

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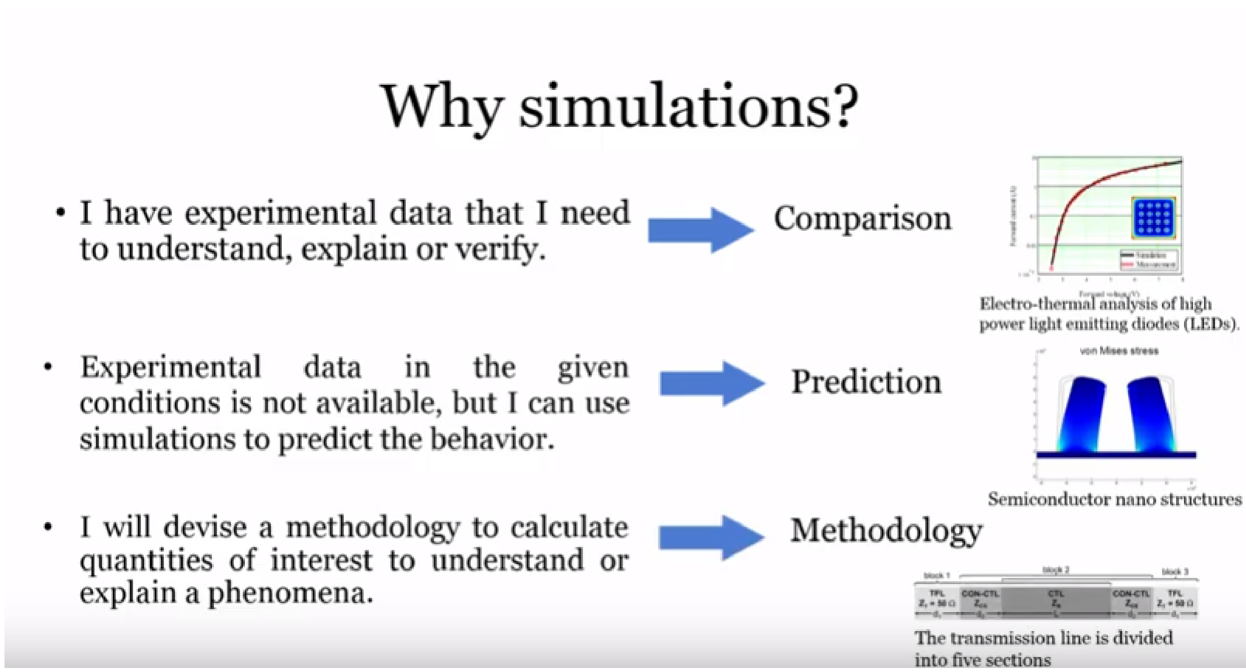

Second can be, if experimental data, data are given and the conditions are not available, I can use the simulation to predict the behavior. While the thought can be, if I devise the methodology to calculate the quantities of interest or explain a phenomenon, then you can use the simulations. So if I see, why exactly simulation is required, then these are the three answers to the question, that we can design or simulate the device, if the given data is, if you have given data, set of data. Second one is, to understand how device will perform, if you fabricate, using the conditions, that you have it in mind. Right? And, the, and the third one is to understand the Methodology, is correct or not. Right? So this three things are there.

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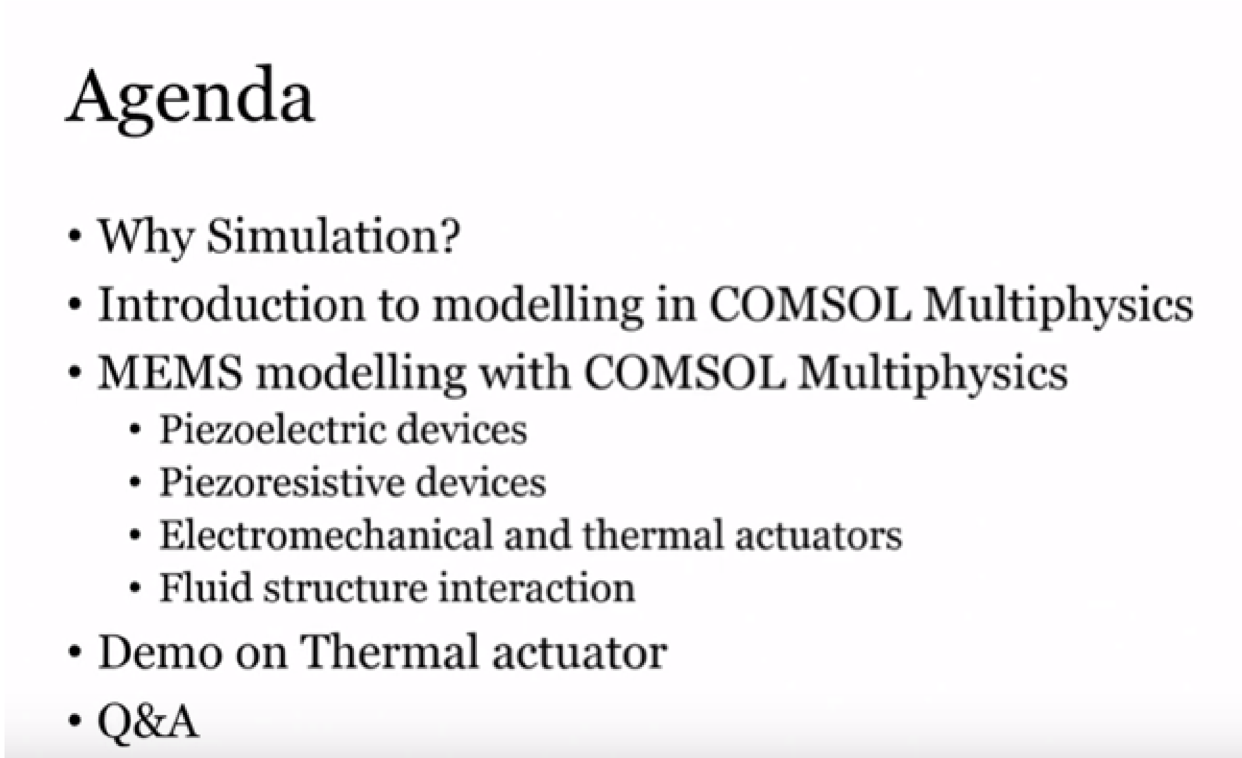

Before we go this particular thing, let us see what will be, you know, talking in this particular lecture. We'll be understanding, why we require simulation, which we have just seen three different reasons. Introduction to modeling in COMSOL Multiphysics. And then we will see, few of the of MEMS modeling, with COSMOL Multiphysics. We will talk about Piezoelectric devices, we will talk about Piezoresistive devices, we will talk about Electromechanical and thermal actuators, we will also talk about, Fluid Structure interactions and then we will actually see the Demo on Thermal actuator, following by, some Questions, Answers if you have, You can always ask us, on the Forum.

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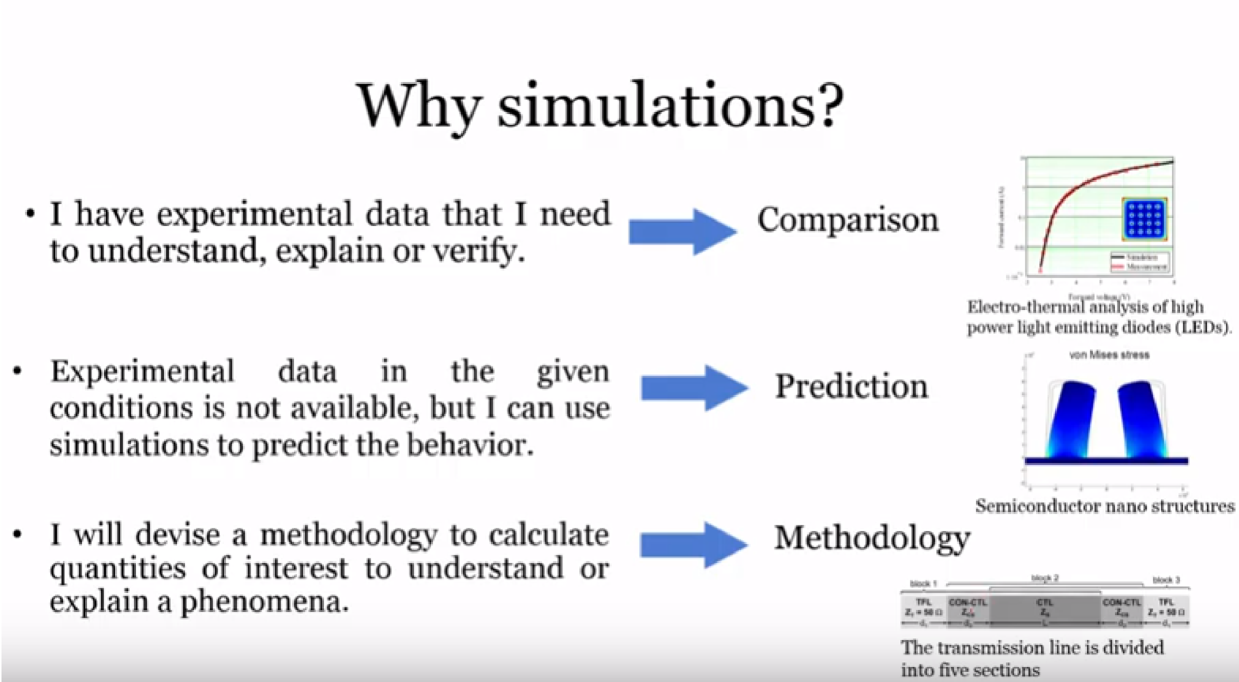

So, let us move to the, this particular slide. Now, for example, if I have the experimental data, then, how can I explain or verify? So you need to compare. So some of, for example, you can do the measurement and simulation; for example: ETM, Electro Thermo, Thermal Analysis of Light Emitting Diodes, you can, you can do a comparison, with whatever data you have obtained, with this simulations. Second one is, when you understand the nano structures, the stress in the nano structure. And if you want to predict that, how much would be the stress on applying such an amount of force, then you can understand or use this simulation. Finally, if the transmission line is divided into five sections, you can understand, whether your methodology or quantity of interest to understand particular phenomenon is correct or not. You methodology to design the device is correct or not. So for that you require COMSOL Multiphysics.

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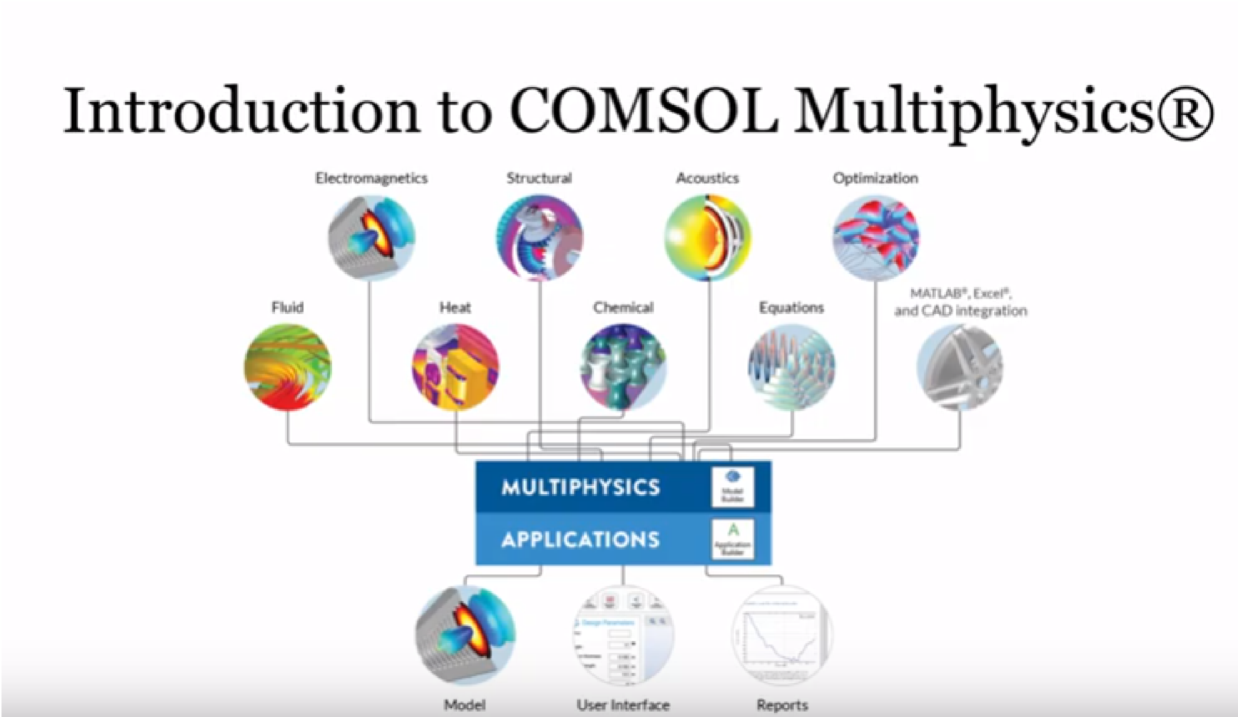

So when you talk about COMSOL Multiphysics, we will be discussing the details, in one of the class, about how to use this software. But for you to understand, how, what are the applications and where you can use this particularly software. So first one is in; Fluid Dynamics. You can use to understand the Macro Fluidic system and the fluid flowing through the, particular channel. You can use the in Electro Magnetics, you can use in heat. We just, you know, if you take an example of a heater, you can easily understand. In structure thing, for example, if there is a cantilever and you want to know the stress and strain in the cantilever, in terms of chemicals, what chemicals you can use is, in that particular software. In terms of Acoustic sensor, if you want to understand whether the, acoustic sensor, that you have designed, suppose the diaphragm, whether it will work correctly or not. To verify your equations, for optimization, as well as for, integrating, the MATLAB, and Excel and CAD. Right? So this is the advantage of COMSOL Multiphysics. Of course, you can do, Multiphysics with application, for example, you can have the model and then you can use the interface, to find and generate the results.

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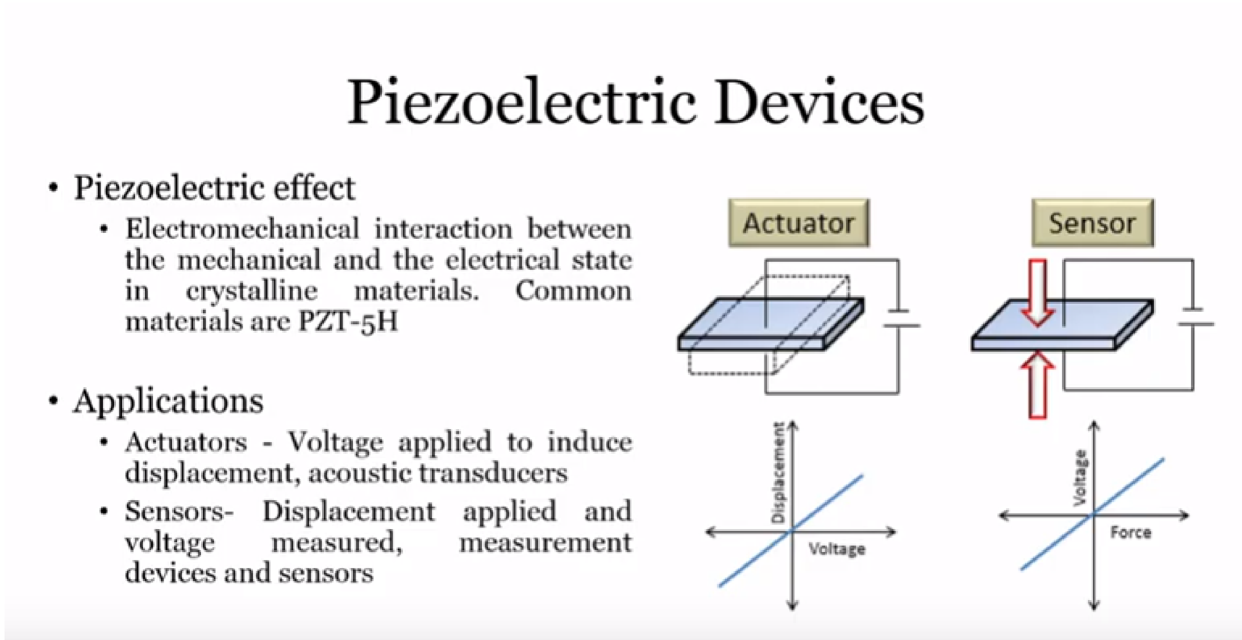

So like I said, we will be discussing of piezoelectric device. Let me just go quickly through the Piezoelectric Devices and then in the experimental class, we'll see in detail, how this electric, piezoelectric device can be used with the given COMSOL Multiphysics, Software. Now when you talk about piezoelectric effect, that this is a, electromechanical interaction between the mechanical and the electrical state in crystalline materials. You know that, when I apply a pressure on a piezoelectric material, there is a change in the voltage. Right? There can be many applications to piezoelectric material, for example; you can this Actuator, for understanding the displacement, in terms of Acoustic transducers, it can be used for the, displacement applied by you have any sensor, measurement of devices and sensing. Lot of applications are there for piezoelectric material.

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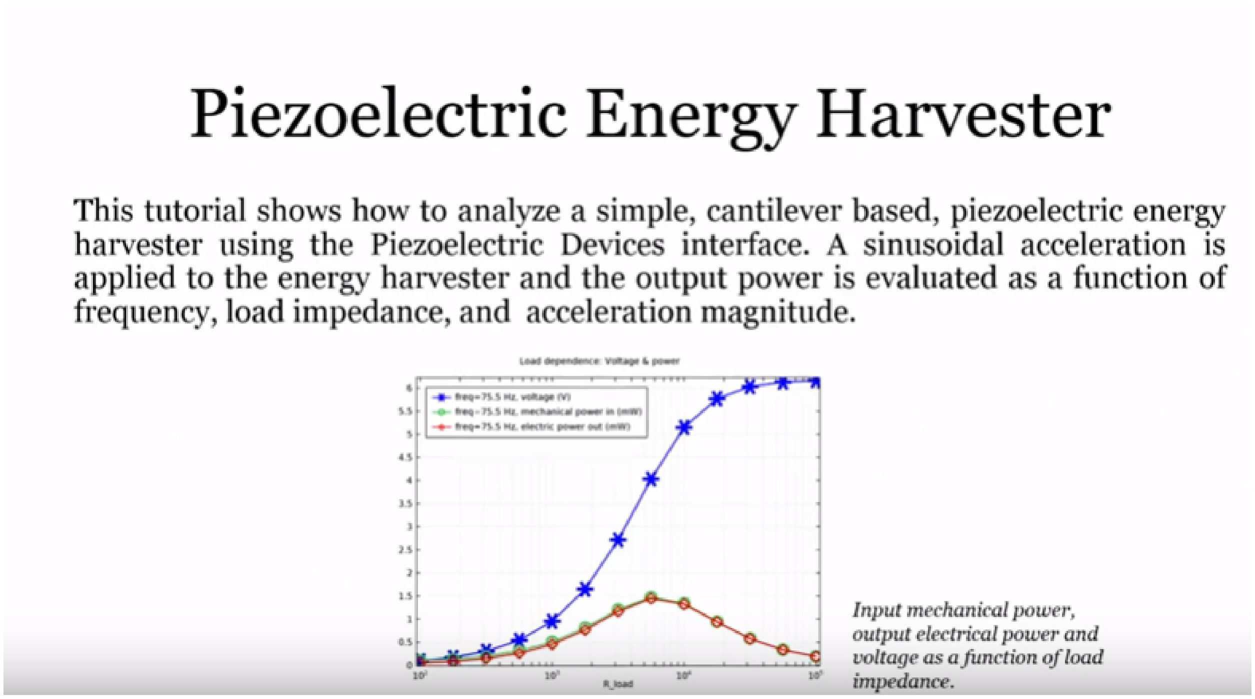

It can also be used as a energy harvester. And you will be looking at the **tutorial**, on how to analyze a simple, cantilever based, piezoelectric energy harvester.

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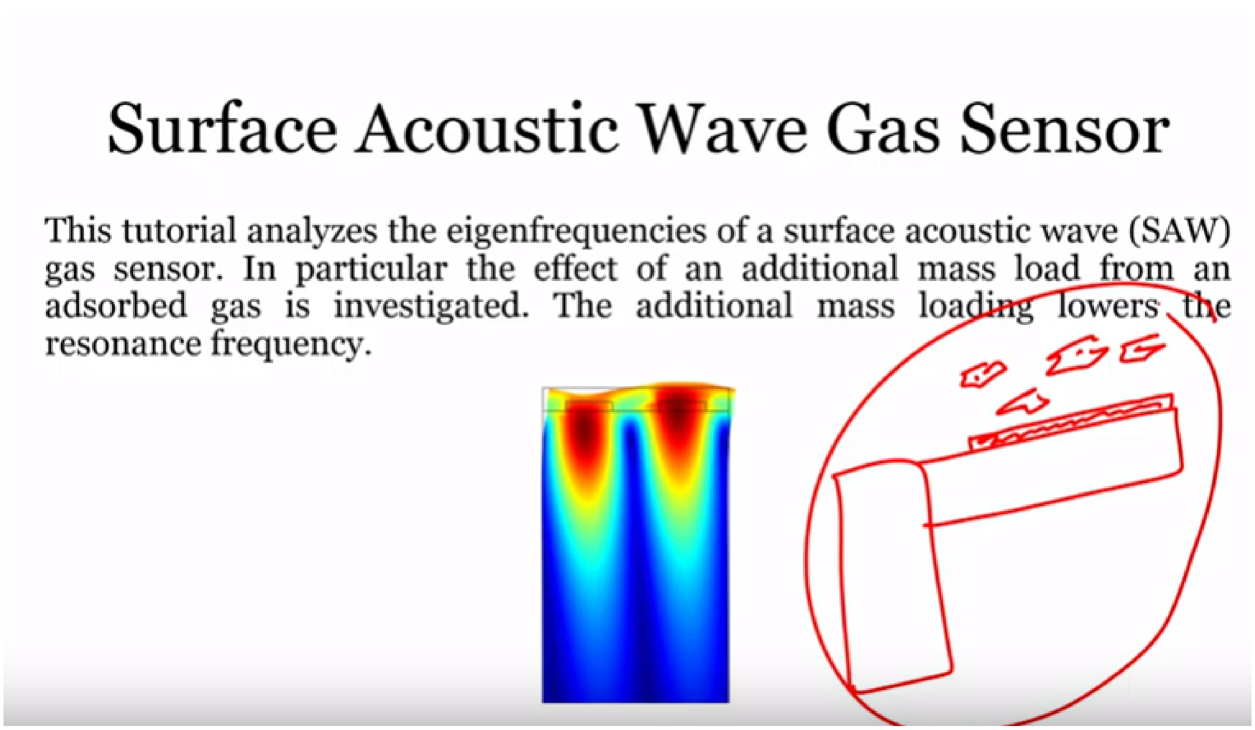

Then we will also see, Surface Acoustic Wave Gas Sensor. So anyways, the tutorial will be analyzing the eigenfrequencies of a surface acoustic wave that is (SAW) acoustic sensor. And in particular, we will see the effect of additional mass load from the absorbed gas. So, for a given material, when the gas is absorbed, there will be a change in the mass and this mass, lowers the, resonance frequency. So, suppose I design a cantilever and I say, this is the silicon vapor and I have a cantilever. Alright? Then cantilever will vibrate at particular frequency and if I have a sensing material on the cantilever, when there are guest molecules. Right? Loaded in this cantilever or onto the cantilever or absorbed in the cantilever, the frequency, the resonance frequency would be, different. That resonance frequency, we can, we can understand the or we can simulate it help of the COSMOL Multiphysics.

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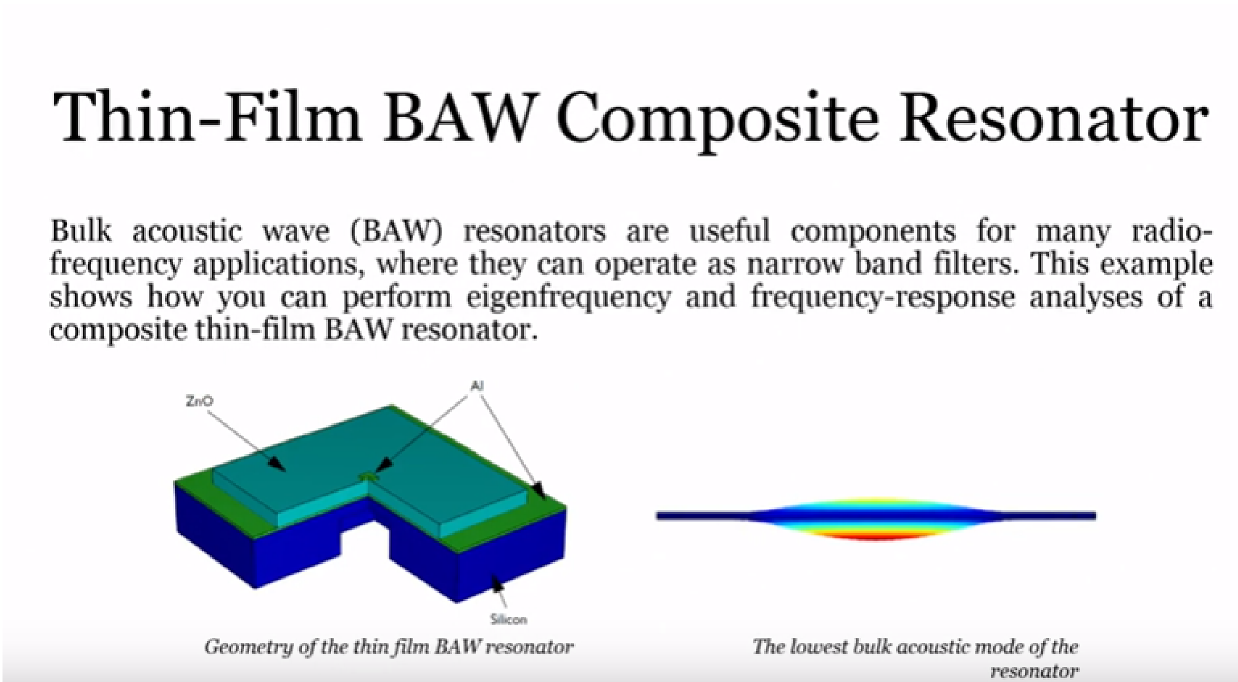

We can also design and simulate, Bulk Acoustic Wave Resonators, which are useful components for many RF applications. Right? In particularly, when they can operate at the narrow band filters. We will discuss this thing in detail.

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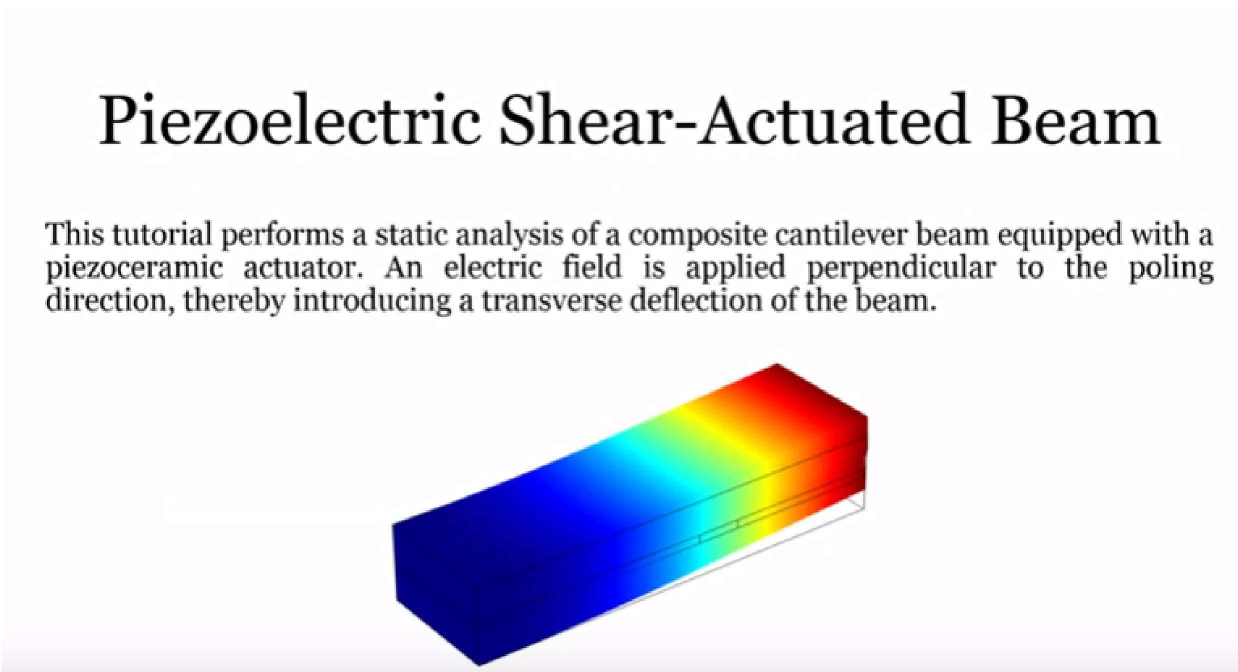

We will also understand the, piezoelectric Shear-Actuator Beam. And in this tutorial particularly, a static analysis of composite cantilever beam, equipped with a piezoceramic actuator, will be taught. Then we will see, Piezoresistive Devices.

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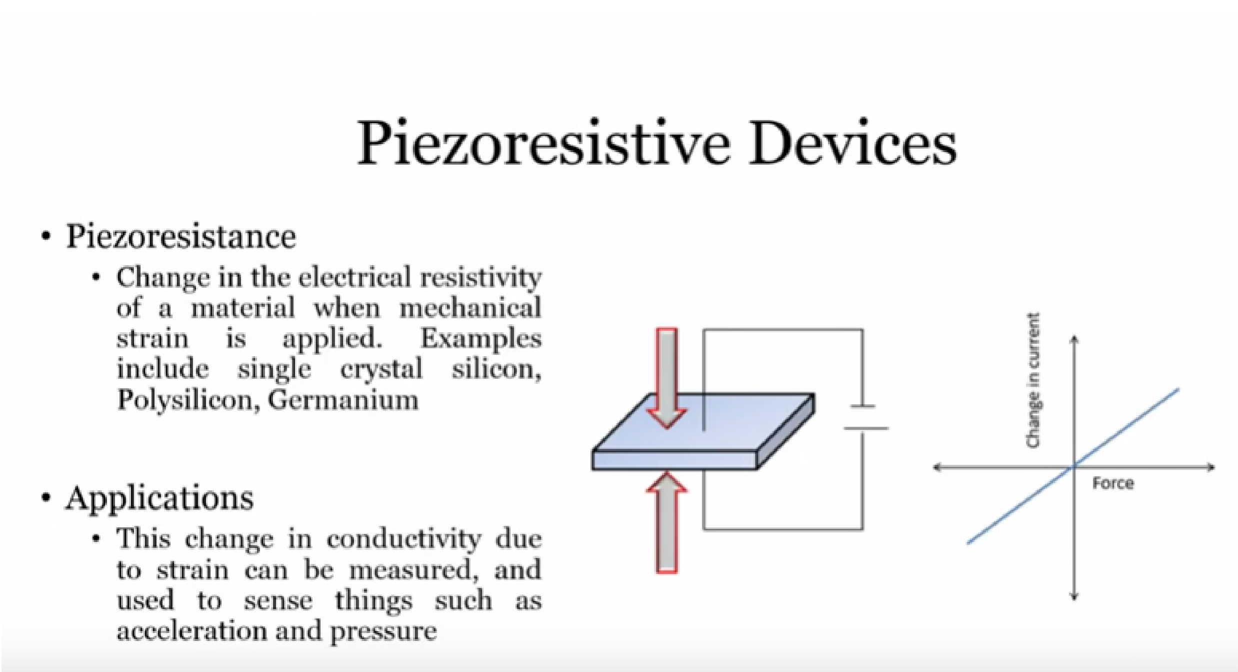

Now the difference between Piezoelectric and Piezoresistive is that, In Piezoresistive devices, when we apply a pressure, there is a change in resistance. When in case of Piezoelectric, on the same thing, when we apply a pressure or force, then there is change in the voltage, electrical signal. So the example of Piezoelectric devices are; Silicon, Polysilicon, Germanium. While the applications are; there is a change in the conductivity, due to strain can be measured, to use the, used to sense things such as, acceleration and pressure. There are lot of other applications, in terms of, bio-medical domain, lot of applications in terms of electronics domain. If you know the use of, COMSOL, it, it can make your life easier. Okay.

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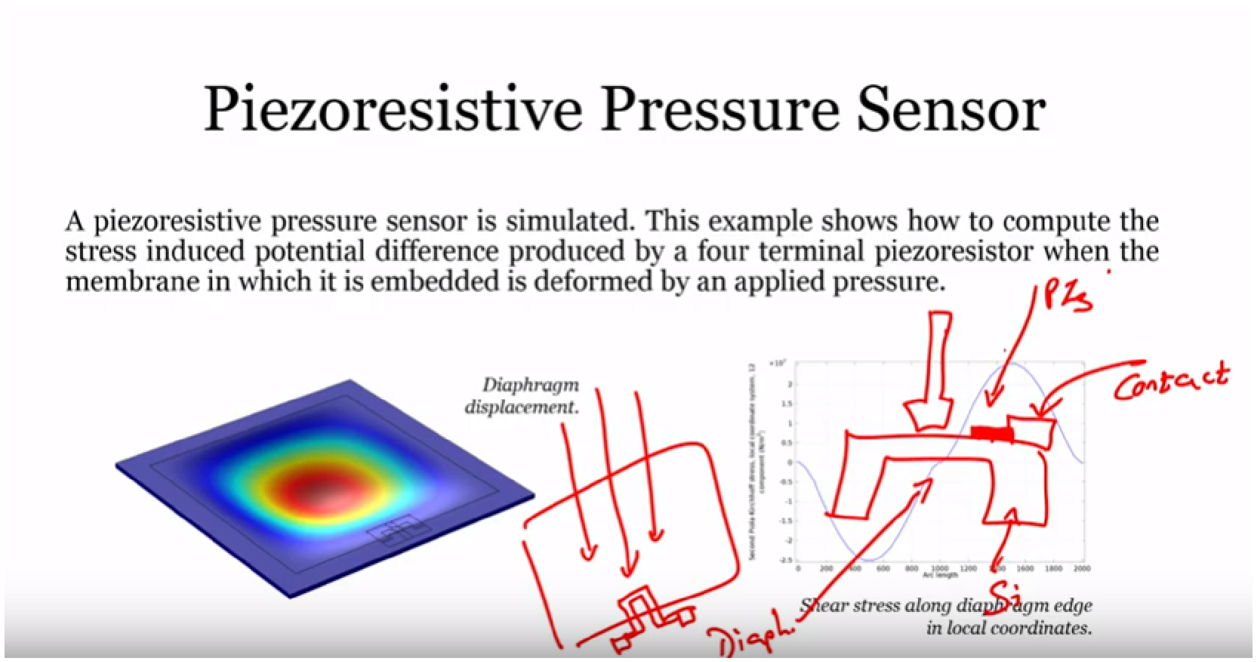

Now if I have a diaphragm. Right? I want to understand, if I apply a force, what is the change in the diaphragm? For example Piezoresistive Pressure Sensor. If I have, let's say, this is the silicon vapor and I design my sensor and the sensor is here. Okay? On this one. And I'm applying a pressure or force, on this particular ship. Now you understand? If I draw a cross section, the cross section is like this and the sensor is here. Okay? And the edge. If I app. This is the sensor. Okay? And this is the contact to the sensor. Right? This is the contact, this is my Piezoresistive Sensor, this is silicon vapor, this is the diaphragm. If I apply a force, on this particular diaphragm, then this diaphragm displacement and that diaphragm displacement, causing the change in the Piezoresistor, can be, simulated, with the help of, COMSOL Multiphysics. You see. So this is nothing but, a pressure sensor. If I apply a pressure and if I see the change in the resistance, is nothing but, I can design my Pressure Sensor, with the help of Piezoresistive material. Right? So that is the advantage of using the Simulation software.

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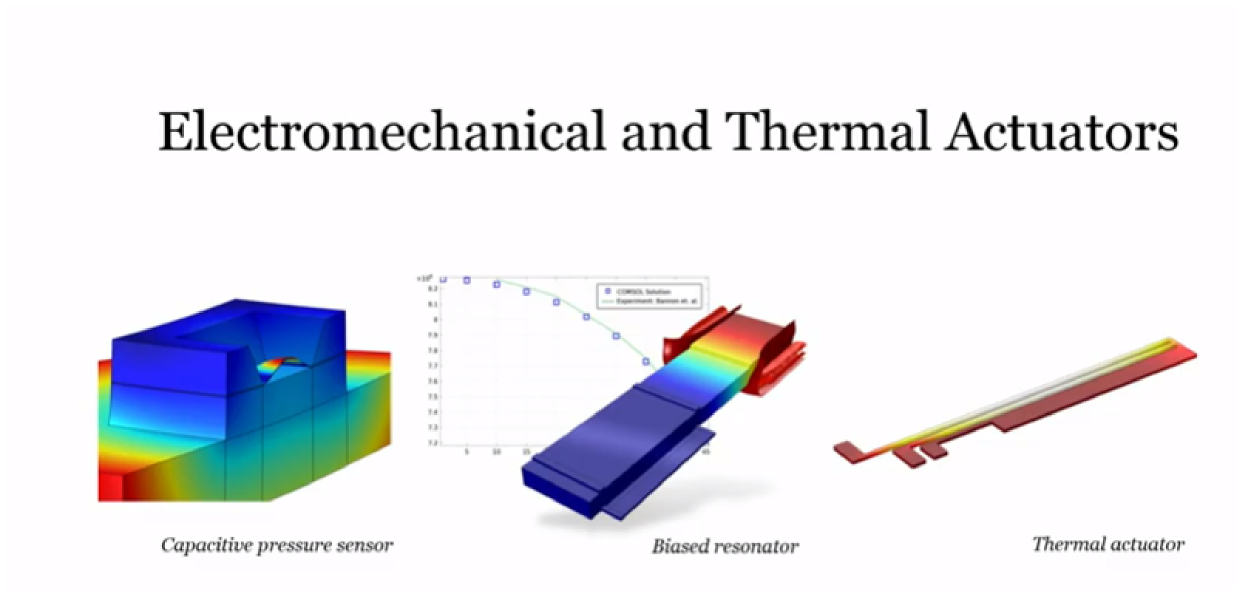

We will again see in, in detail, in the ETA class. While we will also understand the Capacitive Pressure Sensor, the Biased resonator, as well as the Thermal Actuator, in detail, in the, in the, following lecture.

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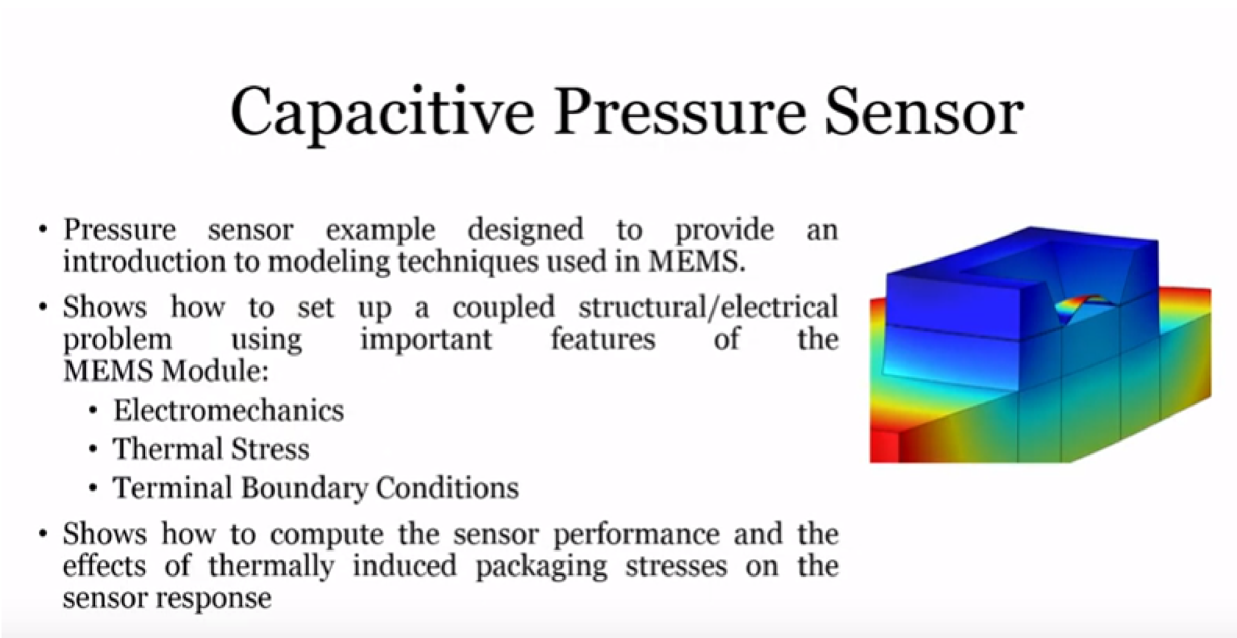

How the capacitive Pressure sensors would be used and how to setup a coupled structural electrical problem, using important features of MEMS Module? Such as Electromechanics, Thermal Stresses, Terminal Boundary Conditions. This everything we can design with the help of this particular simulation software.

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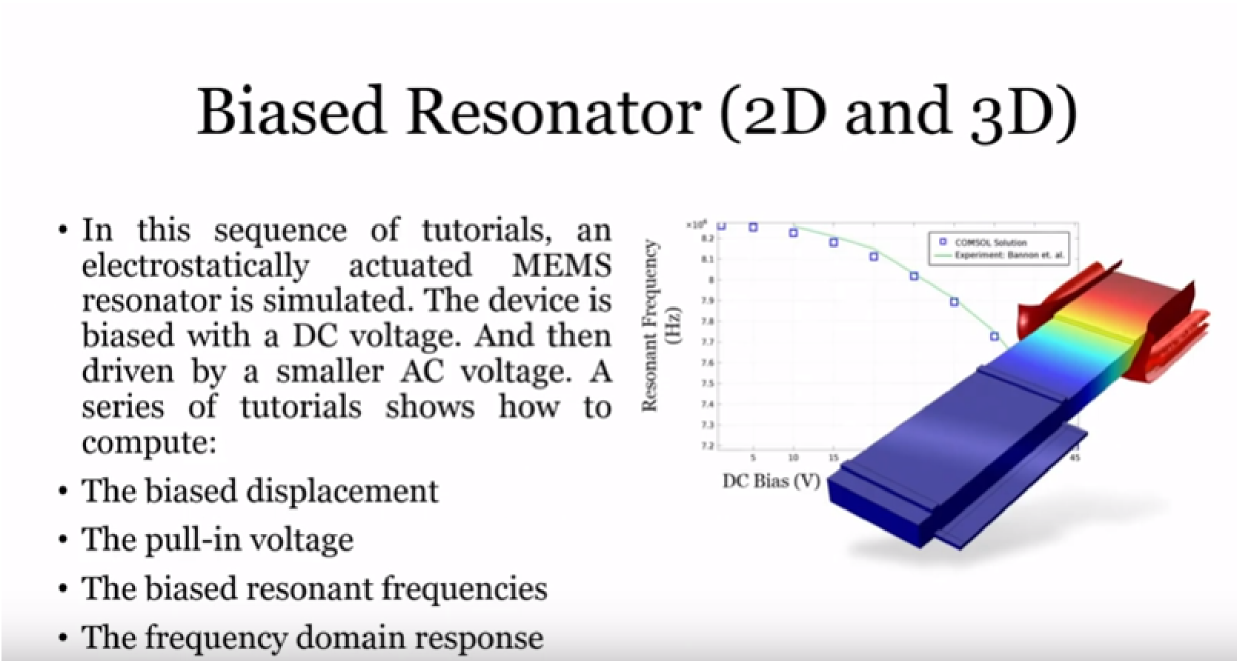

We'll, we'll also see how the Biased Resonators can be used, how the pull-in voltage, biased resonant frequencies, frequency domain response, occurs.

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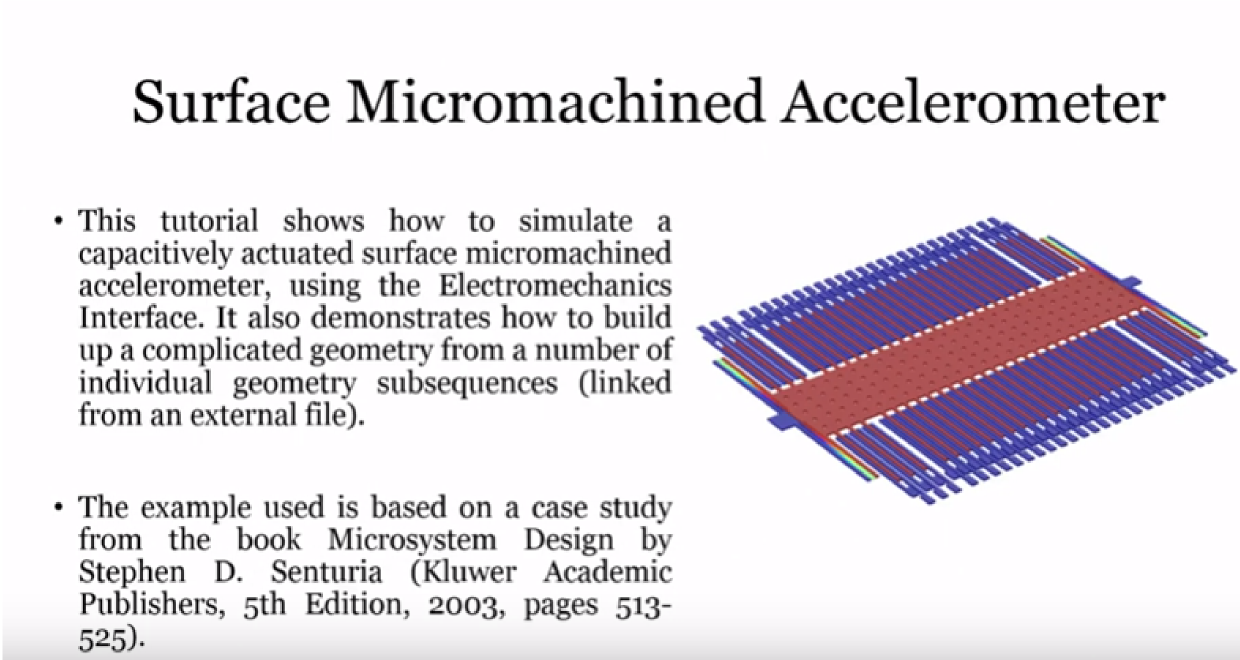

And we also understand the Micromachined Accelerometer. How we can design or simulate Micromachined Accelerometer. And the, the example, for this particular thing is based on the case study, from the book, Micro System Design, by Stephen.

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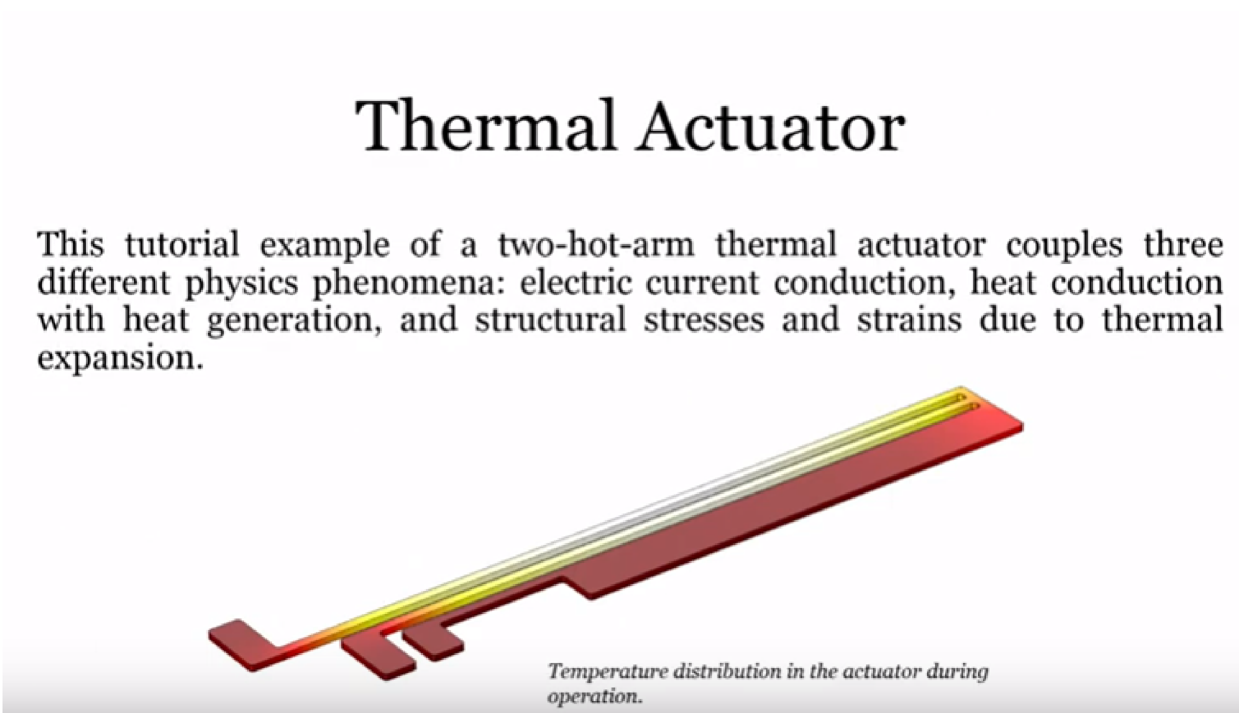

While we will also design the Thermal Actuator, in which, we will take an example of two-arm, two-hot-arm thermal actuator and that will couple with the three different physics phenomenal, such as, Electric current conduction, heat conduction, when with, heat generation. Okay? So all of these structures stresses another thing. Same way, if you want to understand the design of the microfluidics, you can also use the COSMOL Multiphysics in detail. Where you understand the fluid structure interaction, during, from the, when is the fluid is flowing, in this particular, in microfluidics channel. Alright?

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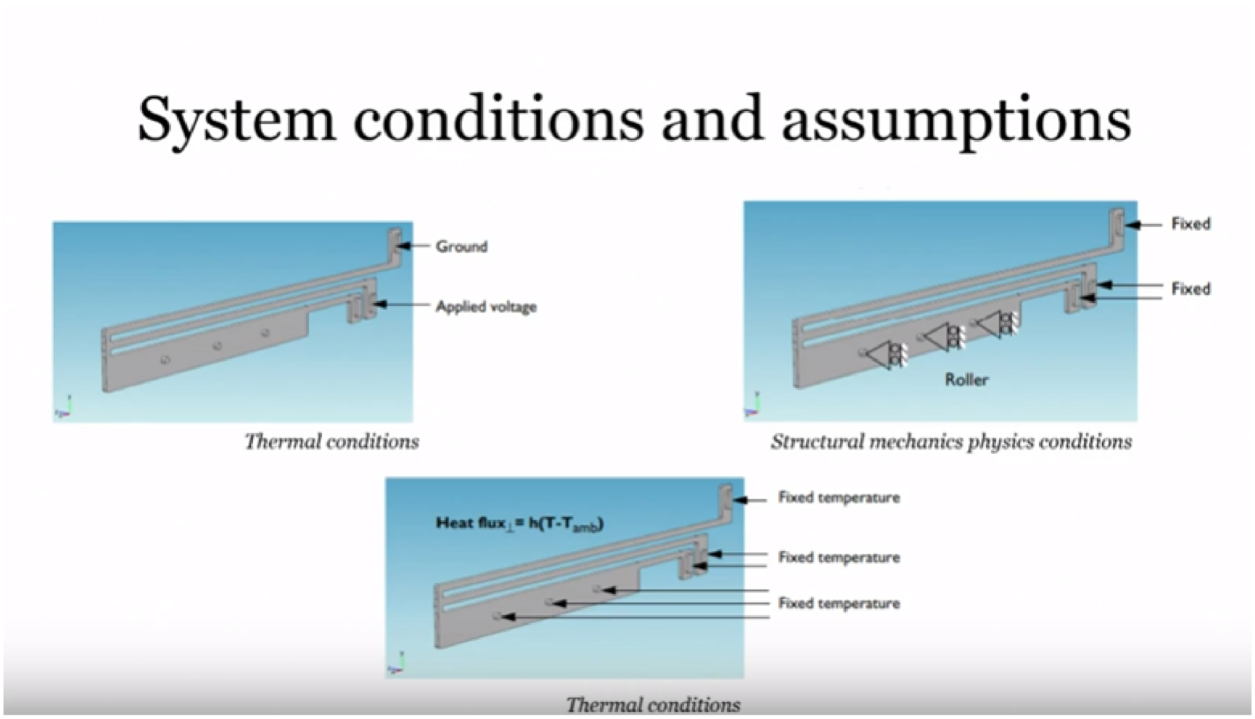

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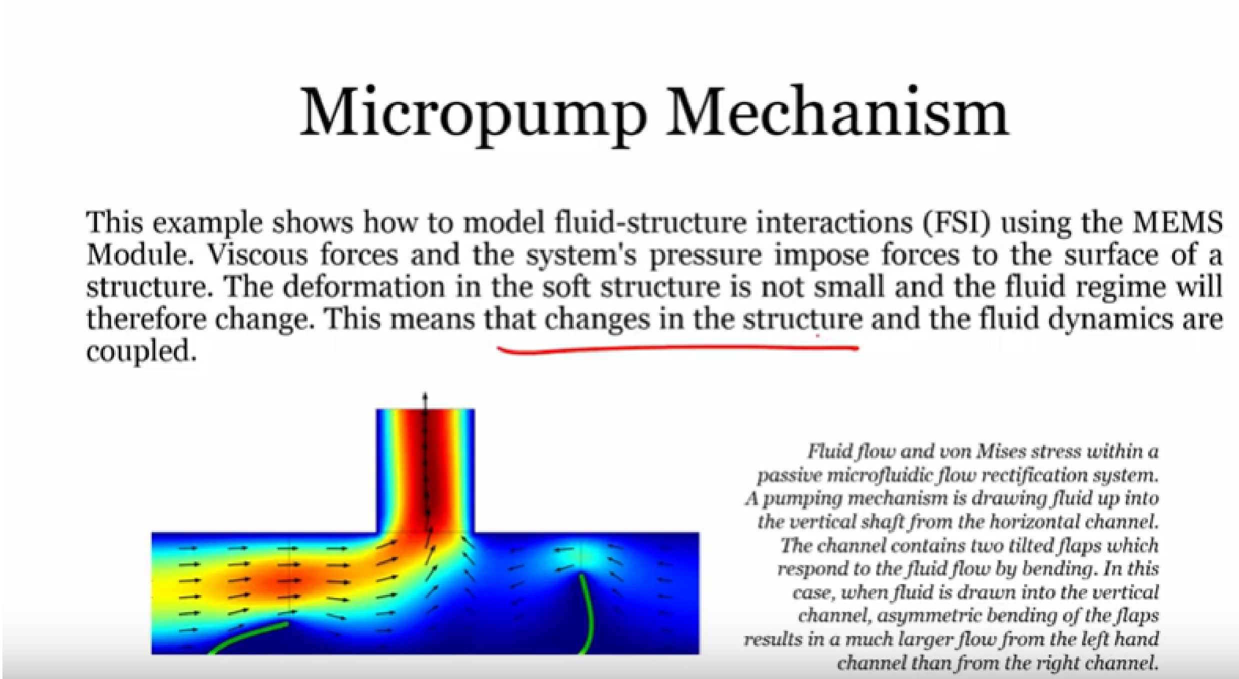
And, same thing we will understand the,



how exactly the, Micropump Mechanism would be, used. We'll see that, the, this particular example we will see, how to model the fluid-structure interaction, which is (FSI), using MEMS Module. You can understand Viscous forces and the system's pressure impose forces to the surface of a structure. Also we see the deformation in the soft structure, which is not really small, is not small and the fluid regime will change. This means that changes in the structure and the fluid dynamics are coupled. This, why, why we can say that this changes in structure and fluid dynamics are coupled. We'll discuss in detail.

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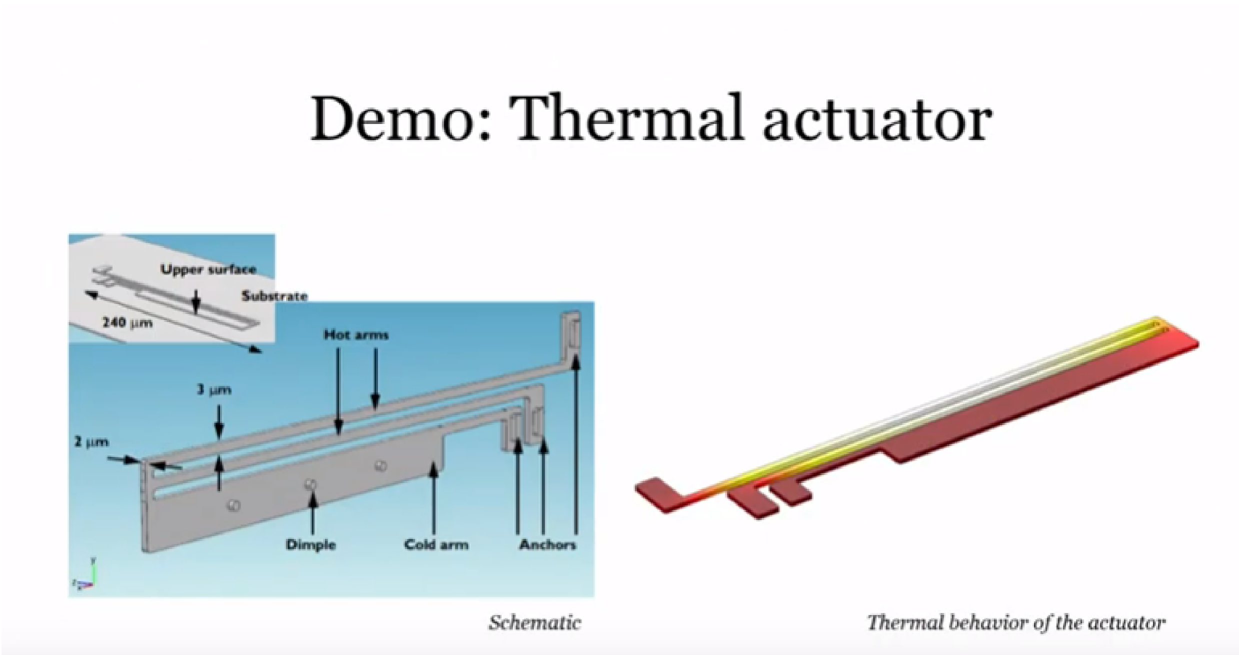

We'll, Thermal of, Demo of a Thermal Actuator and
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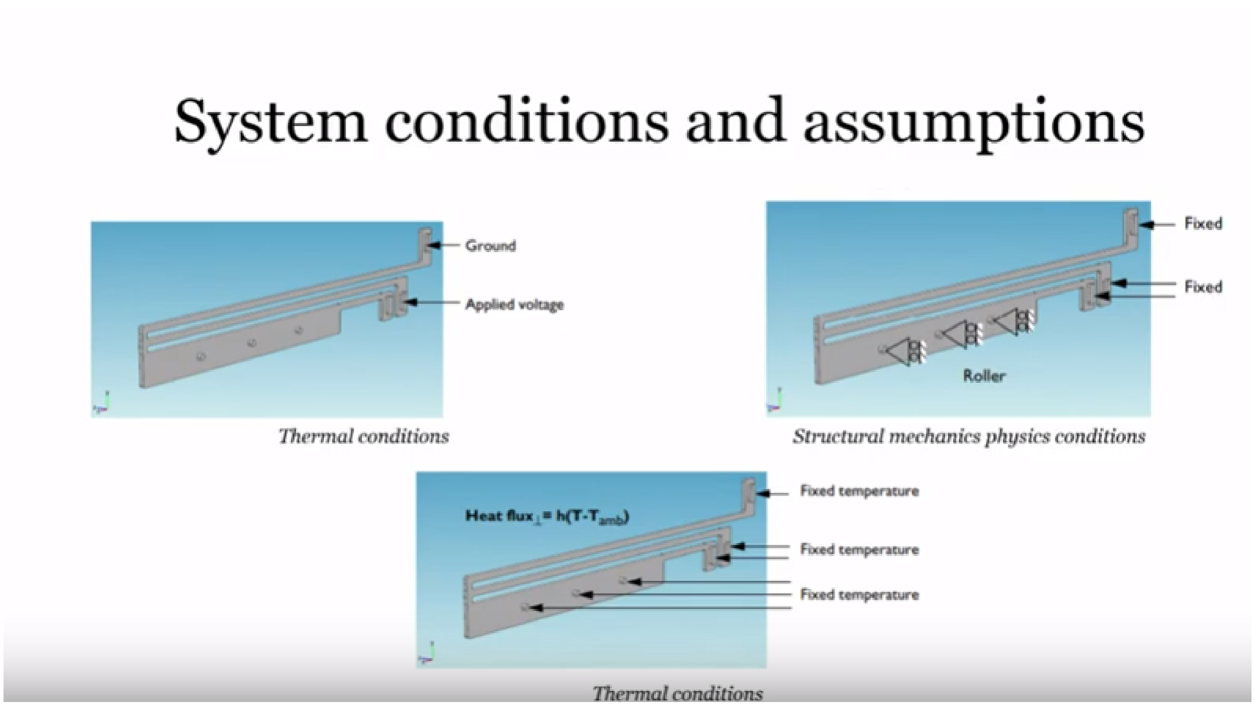

how we can, you know, design this particular actuator and then we will end up the, T, TA class on that particular lecture load. So the, the idea of showing you the COMSOL Multiphysics and to take lot of application is to help you that, before you go for fabrication, suppose you take the help of, INUP, in sense that we have in IASC. If you go to that particular program, if you want to fabricate a device, before you could do the fabrication, if you have finished the simulation, it will be easier for you to design process flow, accordingly. Right? Thus understanding simulation, using Multiphysics, COMSOL Multiphysics, can help you out to reduce the, you know, cost in a way, because you know the performance or you have simulated the device performance. And when you fabricate a device, you can compare that performance, with the, fabricated one. Right? So having said that, let us see in the experimental class, how this simulation can be used. Till then, I will end up my, this particular introduction, to COMSOL Multiphysics Theory and learn this as a, as an example, so that you can design lot of sensors and transducers, before you fabricate the device. Right? Again, we have a FAB lab right over here, but it is always advisable to use stimulation, to get the results and then to move for the fabrication. Alright? So, if you have any questions, feel free to ask. Till then, you take care. And I will see you, sometime later. Right? Bye.