Sensors and Actuators
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Lecture - 06
Recent Micro sensors based system: E-Nose

Hi, welcome to this module, in the last module what we have seen we have seen the microfluidic chips and it is application in drug scanning right. Whether it was a case of selecting particular drug from the set of drugs or we discussed about a little bit about immunotherapy, where we can design a microfluidic platform that will act as a patient centric platform to help a clinician to select a particular drug for that particular patient right.

So, it will be like a interface between a patient and a selection of a drug, the platform itself will help the clinician to determine which drug to use. So, the point here is the use of microfluidic chip, when you are discussing about my microfluidic chip it comes under micro fabrication right. And then whether if you include inter digitated electrodes or a micro heater it becomes a sensor right. Now once a sensor that we will be discussing in this module is called VOC sensor. Now what exactly VOC means? VOC stands for Volatile Organic Compound. Now what is volatile organic compound, right? The organic compound that is volatile in nature for example acetone, for example methanol, for example ethanol, propanol right.

You can also take an example of petrol, diesel, kerosene right these are all volatile organic compounds. Now why to determine or why to fabricate sensors that can detect volatile organic compound what is the use of that. So, volatile organic compounds are not only fine in chemical laboratories, but they are also available in paints. In the paint that you use at home there are VOCs, same thing our breath that we exhale contains lot of volatile organic compounds and if that is the statement then what can be the application; the applications are enormous, how?

If the breath contains several volatile organic compounds along with carbon dioxide humidity, and if a person is suffering from a particular disease, then will the volatile organic compounds in the breath changes. So, how it can be used the research says that for person suffering from ketosis is diabetes all right, will exhale a higher concentration

of acetone compared to other volatile organic compounds. Same way a person suffering from lung cancer will exhale a higher concentration of nitrogen oxide compared to other volatile organic compounds. That means, if we can understand the breath signature, we can identify whether a person is suffering from a particular disease or not.

So, I give an example right I give an example of what I gave an example of a person suffering from ketosis, I gave an example of a person suffering from tuberculosis, lung cancer. Now there is another example of tuberculosis, I have not given you example till now tuberculosis, but that can be another application of the volatile organic compound sensing devices.

In case of tuberculosis as well there are certain sets of VOCs that are in higher concentration compared to the other VOCs that are found in the breath. Thus if you can develop a system that can understand or study the breath signature then it will be a noninvasive way of determining a disease. So, what I mean by invasive, invasive is when you cut the body and you place something within the body.

For example, there is a knee replacement right, then you have to cut the body cut the part of that particular you know the organ right and you had to place a new organ right or a place of fixture to help that organ to work properly right. Invasive you are going inside the body invasive, minimally invasive; minimally invasive is like a glucometer you prick the finger minimally invasive or catheter ablation minimally invasive open heart surgery invasive; what about noninvasive.

Noninvasive is where you are not using any device within the body, you are not using invasive method you are not using minimally invasive method. So, understanding the breath signature will be a noninvasive way of understanding the disease or determining the disease. So, how can we design such sensors and whether designing such sensors will be sufficient for us or we need to integrate some other modalities to come up with a solution. So, what do I mean by that you see when I have array of sensors right, then the array of sensors becomes like our nose; if you talk about nose it has lot of sensors correct and those sensors through the olfactory lobe are connected to your brain that is your neural system right or neural network.

So, then the nose is just a sensory organ like it can smell, but how we feel there like how we know that the smell of orange who is different compared to smell of a mango right.

You can easily delineate right how? Because, based on the outputs of the sensor the brain has been trained that certain number of VOCs present in a particular pattern will be of orange, whilst the way that mango will smell would be different because of the presence of different kind of smells. So, the you have to train your brain you have to train the neural network.

The neural network is connected with your nose which are array of sensors and that is why you are able to distinguish between two different fruits or in fact many fruits not only that we are blessed to have lot of sensors. We can see the fruit right vision somebody telling us ear audio, we can test and we can delineate various orange or mango right. So, we have several sensory organs we can even feel it, if you hold a mango and if you hold an orange you will understand the difference right touch.

So, many sensors are already within us, what we want to understand is can we replicate the nose with the neural network and that can be done when you fabricate sensors which are meant to detect VOCs. But single sensor cannot be sensitive and selective and that is why we want to have group of sensors, and this group of sensors we need to that output data needs to be fed to a neural network whether there are neural network can be trained and thus we can make an electronic nose which is an artificial nose right.

So, we will be be learning as a part of this course how to design electronic nose and in detail how to design a sensors that can be fabricates that can be integrated to the entire system alright. So, if you see the slide.

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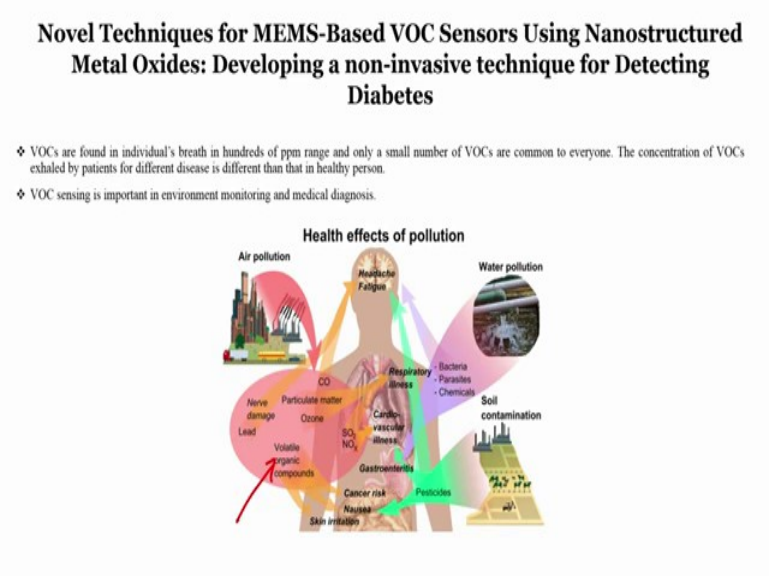

We will be discussing on novel techniques for MEMS based VOC sensors using Nano structure metal oxides. Now when I will explain you the fabrication I will tell you that if the importance of nano structured right. Why we had to go for nano alright and the idea is to develop a non invasive technique for detecting diabetes. Like I said the VOCs are found in individual breath in hundreds of parts per million range and only a small number of your VOCs are common to everyone.

The concentration of VOCs exhaled by patient for different disease is different than in the healthy patient or the healthy person. VOC sensing is important in environmental monitoring as well as medical diagnosis. So, if you see what are the health effects of pollution right. First is if there is an air pollution right the quality of air is not good, then what kind of effects can be there, it can be the nerve damage, it can be because of this cancer is there nausea is there skin irritation is there. So, if it talking about the VOCs exceeding the certain limit causes us cancer, causes nausea, causes skin irritation if there is a particulate matter and ozone it causes respiratory illness. If there is a lead in the you know in the air then we have a nerve damage.

So, the health effects of pollutions are enormous the second one is water pollution. What if the water is polluted if the water is polluted then we there are bacteria's parasites chemicals and that can have the fatigue that can have headache right. Same thing if there is a pesticides in the soil, the soil is contaminated then there can be nausea, there can be

cardiovascular diseases, there can be fatigue and there can be gastro (Refer Time: 12:45). So, the point is that the VOCs from the pollution that we are talking about and from air water and soil pollution we are focusing on air pollution and from air pollution we are focusing on volatile organic compounds.

So, you can see that volatile organic compounds in particular are responsible for causing skin irritation are responsible for causing nausea and are responsible for causing cancer risks. So, we are interested in developing sensors for VOC alright. So, how to fabricate the sensor, all right so, we will be looking at fabrication of sensor I will teach you in detail, but how the sensor would look like.

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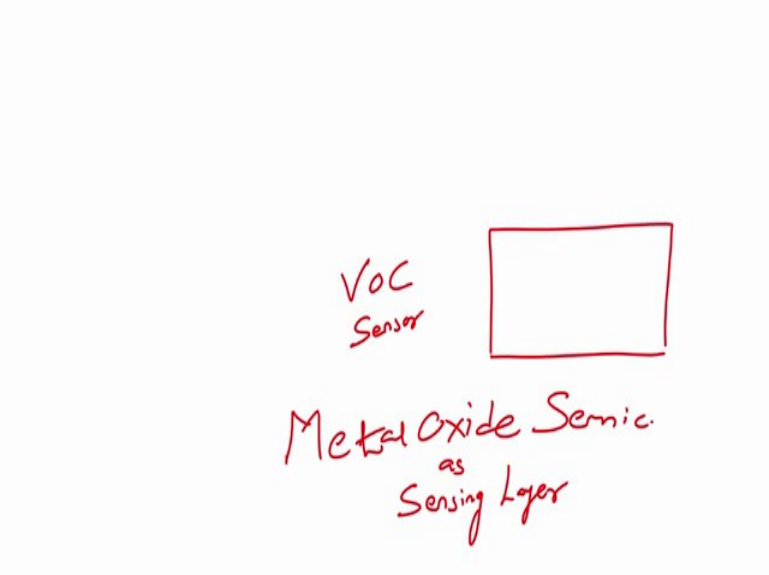

A sensor if I draw a cross section then and if I am using a metal oxide semiconductor material; a metal oxide material as sensing layer right, how my VOC sensor volatile organic compound sensor should look like all right that is what I am drawing in the schematic. If I have a fabricated a sensor using metal oxide semiconductor material how the sensor should look like.

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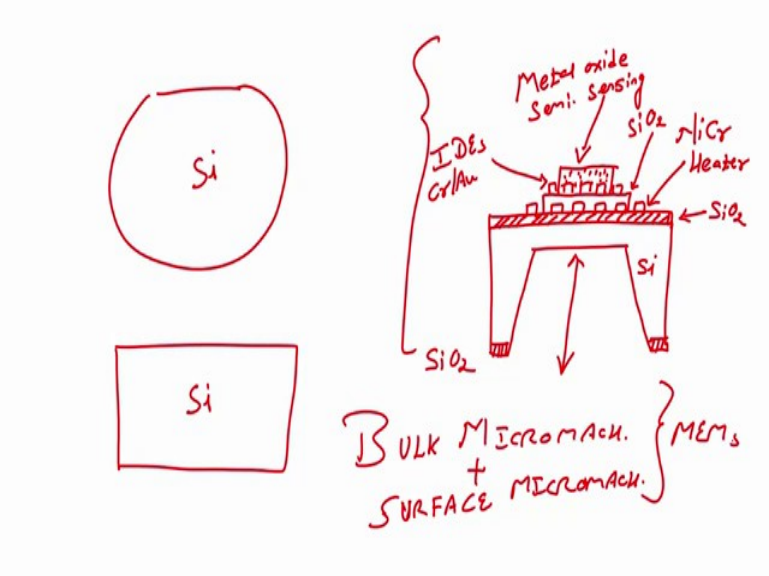

So, we will use an oxidized silicon substrate just ignore my drawing skills. So, this will be my silicon dioxide, this would be silicon and again this one would be silicon dioxide. Now if I am using metal oxide semiconductor sensor I need to heat it up. So, I will have a heater; I will have a heater or heater I will have an insulating material, on insulating material I will have an inter digitated electrodes and all inter digital electrodes I will have a sensing layer reward it this is my micro heater. This is metal oxide semiconductor sensing layer, this for will be my inter digitated electrodes, it can be chrome gold this is how my sensor should look like all right.

Now, if you know if I take a silicon wafer, if I take a silicon wafer right and I draw cross section of silicon wafer which will be like this correct. Now how I have h this silicon dioxide sorry I edge the silicon wafer this silicon this is silicon, but if you see this particular sensor then here we have a substrate which is like this is not it. How do h silicon or bulk of silicon for that we have a technique called bulk micro machining, alright.

So, we will discuss this thing and then the how to grow oxide layer, how to grow how to deposit heating material, how to pattern heater on that how to have another oxide layer right. Because you see this one is another oxide layer because, you cannot have two metals one over each other because it will get shorted you got it.

So, this is one way of creating a sensor there is another way of creating sensor will be bulk plus surface micromachining all right. We will see, what is bulk micromachining what is surface micromachining, when we understand, what is or what are MEMS? MEMS stands for Micro Electromechanical Systems, all right.

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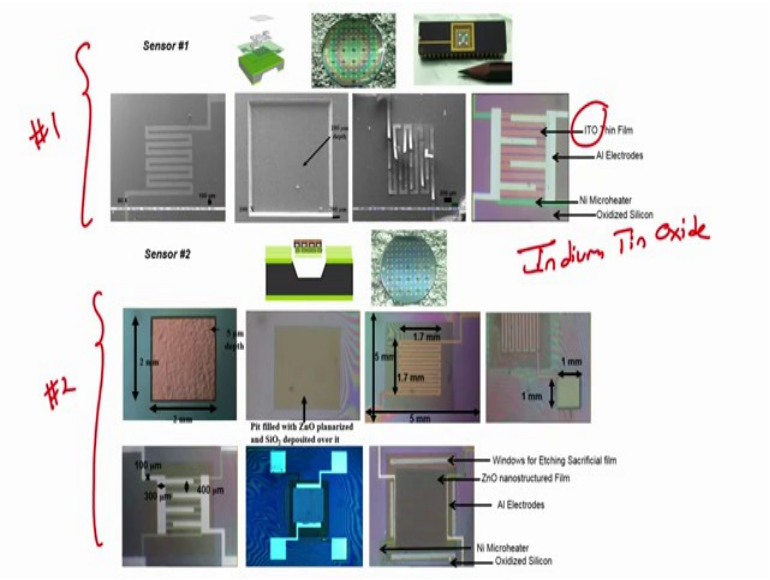

So, this is example of such a sensor we will discuss how to fabricate this in some other module right. Now you see that this sensor number one and sensor number two; sensor number one is fabricated first is a heater you can see this is an heater right. Then on the back side there is a pit that is created by etching the silicon wafer using bulk micromachining, then we have a we just want to know what is the maximum temperature the heater can achieve before it starts breaking.

On that heater, there are in inter digital electrodes which are you can see made up of aluminium electrodes on this inter digitated electrodes we have indium tin oxide based thin film. ITO stands for Indium Tin Oxide; indium tin oxide based thin film we will discuss how to deposit this thin film.

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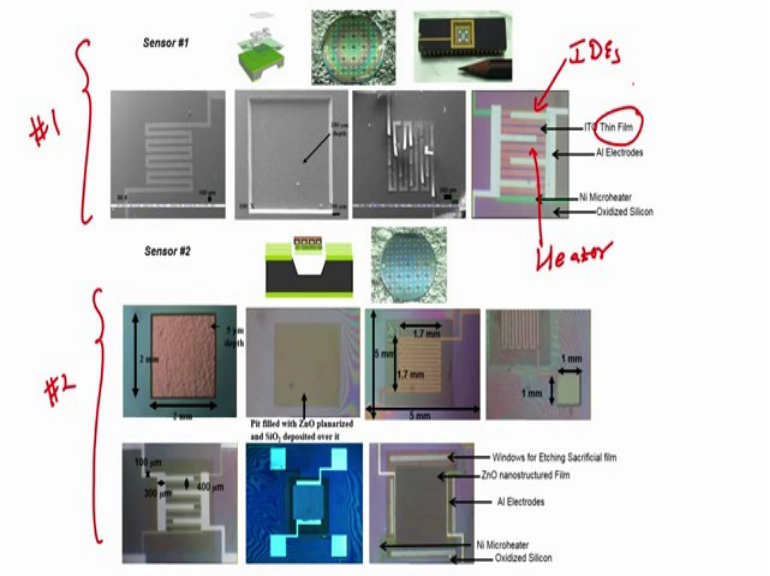

Now what is why if there is a sensing film or if there is a thin films, how can we see the introduced electrodes as well as the heater, how we are able to see, how we are able to see the inter digitated electrodes and how we are able to see the heater right. The reason that we are able to see even though there is a presence of indium tin oxide is indium tin oxide, zinc oxide, tin oxide, indium oxide. These are all transparent conducting oxides or TCOs; transparent conducting oxides or TCOs. Thus in the fabrication of solar cell people have started using ITO for contact.

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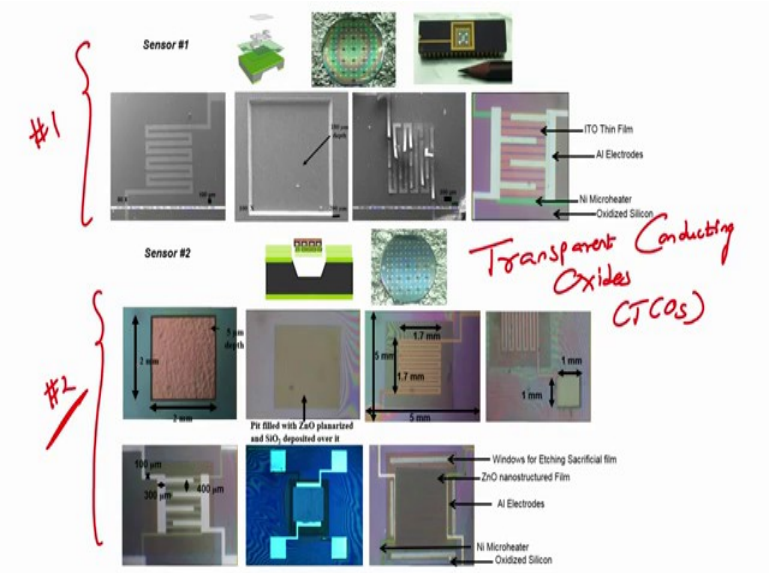

Now there is another way of fabricating a sensor that is sensor number two which is bulk plus surface micromachining based sensor alright. And here what you can see there is a creation of a pit I will tell you how to create it do not worry about it just understand that from the silicon wafer.

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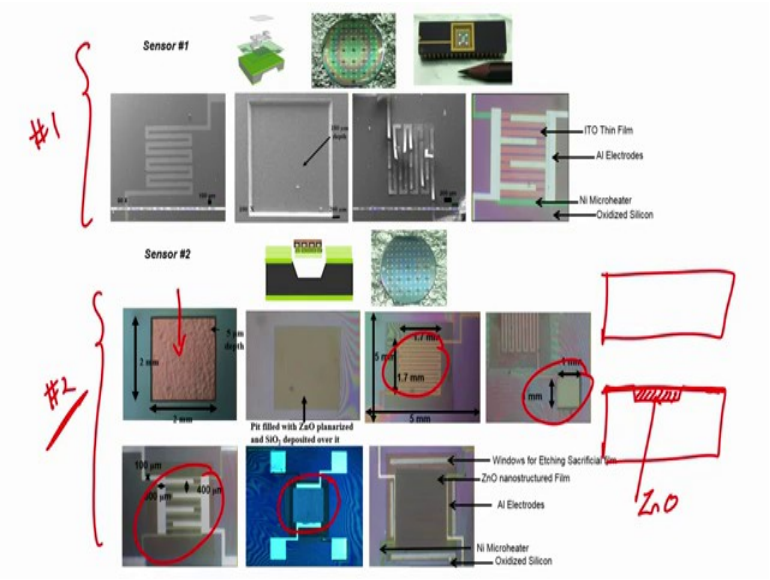

That we have we have created a pit like this all right and then we have used a surface micromachining to bulk micromachining to create a pit, on that pit we have filled the material with zinc oxide. Then we have linearized the material; we have linearize the material alright on that we have a micro heater; on micro heater there is a insulator after which we open the contact of the heater then we have inter digital electrodes then we have a sensing layer.

Now, this is a nano structure of zinc oxide that is why you cannot see the inter digital electrodes below it and then we open the windows on four side and etch the zinc oxide that we have deposited initially. This zinc oxide will act as an sacrificial layer do not worry about it we will discuss this thing in the class where I will be showing how to fabricate this particular sensor. The point is if the advantage of this particular technique is that now you can see that the heater requires less amount of power compared to this, because it has to heat only a few microns of layer. But in this case it has to heat about 100 microns of the diaphragm.

So, the power consumption in sensor number two is less compared to power consumption sensor number one. However, the mechanical stability of sensor two is poor compared to mechanical stability of sensor one all right. So, this is the end of this particular module let us see in the next module how can we fabricate a flexible sensor and how can we fabricate a strain gauge followed by the actuators. Till then if you have any question, please free to ask me, asking through the forum and I will see in the next class bye.