**Fabrication Techniques for Mems-based Sensors: Clinical Perspective**

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**Lecture – 03**
**Introduction to Microengineering Devices Contd**

Welcome to this module this is module number 3, for our lecture 1 for Fabrication Techniques for Mems-based Sensors Clinical Perspective. So, until now we have seen several sensors right and we have also talked that how the sensors can potentially solve an important problem in medical diagnosis or in clinical research.

So, let us see in this particular module some other sensors right and let us understand that how we can use our understanding of microengineering and technology to fabricate those sensors.

Now a very important point that is there right now or a very important disease or you can say that the most prevailing disease is diabetes right. And we have seen that for understanding the blood glucose level concentration right, what we have to do? We have to puncher the finger. And then we have to put a drop of blood on the glucometer to understand the blood glucose concentration.

Now this is minimally invasive technique because you are puncturing your body. How about you find a non invasive way that means, without puncturing your body can you detect diabetes? Or a matter of fact is can you detect any disease can you diagnose any disease without puncturing your body right. And that is better technology which can facilitate a person to go to a doctor and not worry about puncturing the body right. You have feel that pain of needle going into your veins right.

So, you assume that every time you want to measure the blood, you have to puncher your finger and it is painful right. So, what is that alternative technique, what is that alternative technique? And that is that we can detect or we can diagnose the particular disease from the concentration of the gases that we exhale right; we inhale, we exhale.

So, when you exhale from a patient to patient from person to person, there are several VOCs that we exhale along with the things that we already know which is carbon dioxide right CO 2, but along with CO 2, what else or what other VOCs we exhale.

Now, when I talk about VOC, what does VOC mean? VOC means Volatile Organic Compounds. So, when you say volatile organic compound, what does that mean? Organic compounds that are volatile. Can you give me an example one example? VOC think about organic compounds that are volatile right, have you thought about it? Is it petrol? Is it diesel? Is it ethanol? Right; a alcohol, Is it acetone? Methanol, butanol, isopropyl, alcohol right kerosene; so, all this are volatile organic compounds that compound is suppose I take up drop of petrol and I put a drop of petrol on the on the table, what will happen? It will it will evaporate; it will operate at room temperature volatile right.

So, when I talk about ketones or alcohols right. Then certain amount of this VOC's we exhale in our breath and the concentration of VOC changes, if a person is suffering from a particular disease. So, if we can selectively delineate separate out delineate that particular VOC from the group of VOCs from the breath of a person, then we can have a non invasive way of diagnosing a particular disease is not it right.

So, exciting field of research right; so, how can we do that how can we do that? Now you see we are blessed to have lot of sensors, we are blessed to have lot of sensors. if you think about my hand right I can feel it, I can feel the surface I have touch sensors. I have force sensors, I can understand how much force I am applying right. Then sound, then taste sensors, then optical sensors, then nose, smell right; just to you just to name few, there are there are thousands of sensors within our body right.

So, now if we have this many sensors, let us take from one of the idea that we already know and that is our nose. So, let us say this, if I am I blind fold myself. So, I cannot see right and I put something on my ear. So, I cannot hear and I cannot taste, I put a tape on my mouth right and I cannot touch only thing is I can smell alright. And if there is a lemon that is s cut lemon or orange, can I distinguish just by smelling lemon and orange?

And 90 percent of people can 90 percent of people can, how ?By smell right by smell that means, there are sensors within our nose in a form of array and that sensors gives us the sensitive data that is this is the concentration so and so right or at least qualitative analysis right; that this is the smell of lemon this is the smell of orange, but how we process this? How I can distinguish between just by smelling lemon and just by smelling orange right?

So, you further understand that now how our nose functions is our nose connected with some other part of our body and you will say yes it is connected with your brain right; that means, brain has that pattern that whenever nose give you that particular smell it has a signature that that immediately tells you this is a smell of lemon.; that means, our nose is connected with your brain or with our brain right. And that means that if I want to mimic the same function in forms of sensor because you see a nose right; there are so many sensors within the nose, all are micro sensors; so small even nano sensors. So, if I want to design a nose using my micro technology, what we can call? It is an electronic nose. It is an electronic nose or it is an e nose right.

Now in our body, our nose is connected to brain; here also we need to connect the nose to brain which is your artificial neural network. Or we need to understand or recognize the pattern that is why pattern recognition right. So, you no need to design the sensor, you need to fabricate those sensor you collect the data by inserting or you know you put the sensor in a chamber and let different VOC's pass through the chamber and you collect the data.

Once you have a good amount of data you can you can train your neural network right and then you can test it. Now it looks so simple it is not, because now there is a factor of humidity right. But if you study well and if you understand, then the research articles the literature says that the person suffering from diabetes will exhale a higher concentration of acetone compared to other volatile organic compounds.

So, what does that mean? That from that VOC's that we exhale, the person suffering from diabetes would exhale acetone in a higher concentration that our sensor should sense it. Then not only it has to sense it, but at it has to selectively delineate from the group of other VOC's, from the group of other volatile organic compounds right.

So, can we design the sensor can we design the sensor? So, that when you want to design this kind of sensor or group of sensors right. You should know micro engineering you should know micro technology alright and you can design this array of sensors of course, you can design array of sensors which are bigger in dimension; larger in dimension, but for the smaller sensors for the micro for the nano sensors, you need to go through this particular technology.

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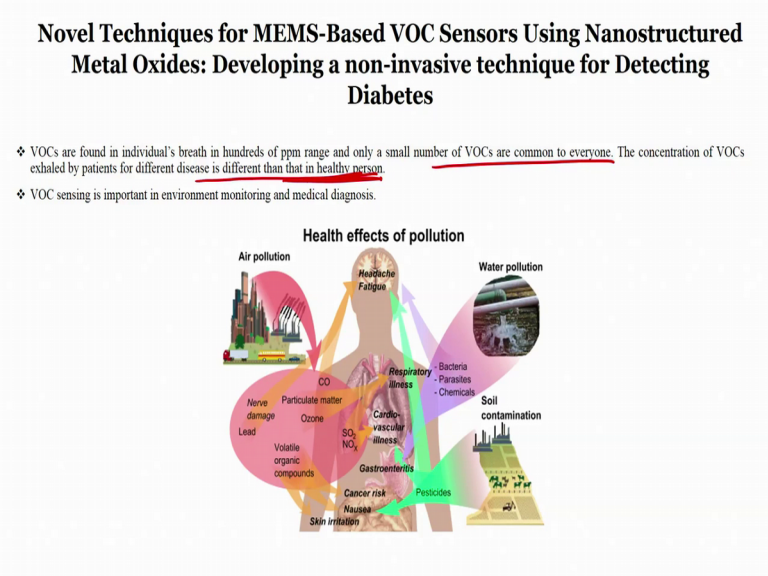


So, when we say that when we say that generally you see the effect of pollution on our health air pollution right water pollution, soil contamination, it causes several things. For example, if you see the air pollution air pollution cause see what are the air pollutions carbon monoxide, particulate matter ozone right lead SO 2, N O 2, NOx, VOCs volatile organic compounds. So, we are in this particular category we have to see this particular group.

Water pollution, we are talking about bacteria, parasites, chemicals; I was talking about antibiotic resistance in the last module right and what does this VOCs affect to which kind of organs, you see respiratory illness. It causes cardiovascular illness and just not VOCs, but in total air pollution, but if you just talk about VOCs it causes cancer risk, nausea, skin irritation right. It is a harmful these are cases are harmful. You see it is clearly states that VOC is can cause cancer can cause cancer.

So, if you have seen a newly painted wall then that will smell differently. And people should not go for a newly painted wall because it will emit VOC it will emit VOC. So, now VOC sensing is very important and you can also sense other gases. So, there are two techniques that we will learn in this particular course; one is called VOC sensor, sensor that can sense volatile organic compound; second is called gas sensor, sensor that can detect various gases that can detect various gases alright. So, we will see how we can design this VOC sensor or gas sensor using micro fabrication.

As I stated VOCs are found in individual's breath in 100 of PPM range and only a small VOCs are common to everyone. The concentration of VOCs exhale by patient for different disease is different than in the healthy person right. So, VOC sensing is important in environment monitoring and in medical diagnosis very important right. So, when you talk about VOC we had to see sensors and right now in front of you can see two types of sensors sensor one here, when we will see in detail how we can fabricate the sensor

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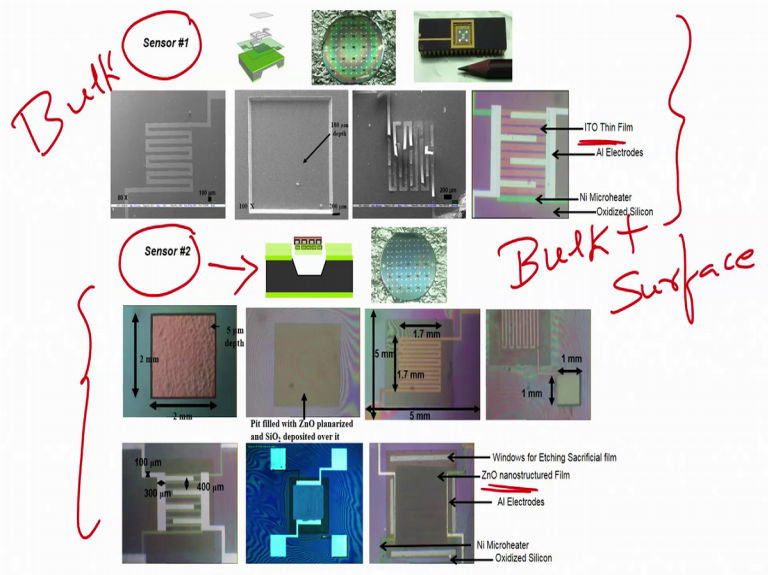


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This sensor is fabricated using bulk micromachining bulk micromachining alright. While you can see sensor two which is this particular sensor, this is used or fabricated this is fabricated this is used for detecting VOCs and it is fabricated using bulk plus surface micromachining bulk plus surface micromachining alright. Sensor one is fabricated using bulk micromachining, micromachining and we will see how we can fabricate this particular types of sensors that can be used for detecting volatile organic compounds or it can be used for detecting gases alright. And of course, the main part of the sensor is the sensing film here you can see we have used indium tin oxide here we use zinc oxide and you can use several metal oxide semi conductors or you can say conducting semiconducting oxides or semiconducting oxides metal oxide semiconductor or semiconducting oxides alright.

There are several kind of semiconducting oxides and how the sensing works, we will discuss in detail when we talk about the sensors sensor in the in the following lectures. Now, if we talk about a flexible force sensor or flexible sensor right you need to design first flexible sensor and you to know what kind of substrate I should use. So, that my sensor will not crack or it will not get destroyed.

So, I would like that even it is not really important or necessary for a micro engineer to learn the schematic tools particularly, if we talk about pro e or solid works or catia right. It is always good to learn right most of us when we study electronics or electrical engineering right, we kind of ignore the design and design is very important aspect in fabricating any equipment including sensors. How well you can show your schematic representation, because that will help that will help not only the person who is fabricating, but also it will help for a person who is understanding reading the literature right.

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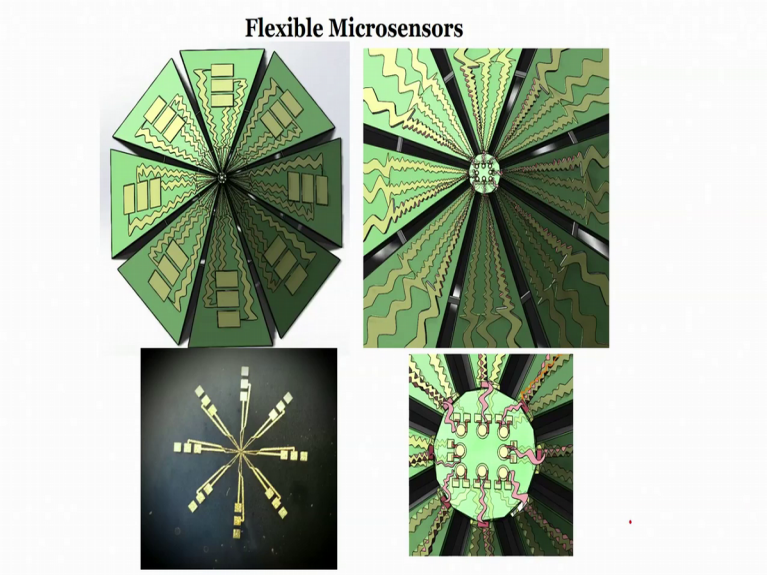


So, if you want to fabricate a flexible force sensor, let us see the design on the screen right now what we can see. If you see this particular sensor; this sensor consists of the sensor exactly is in the centre here alright or you can see this is the magnified view of this particular image here. So, if I can show you what magnification we have used we have magnified this area. So, what you see? You see few sensors here, still it is difficult to see right still if is difficult to see.

So, we have further magnified this area, now it is little bit better right. What does it has? It has a strain gauge alright it has a strain gauge. Let me draw a little bit big strain gauge so that we understand and this strain gauge is made up of piezoresistive material, we can use conducting polymer P dot PSS. On this strain gauge there is insulator, what is that there? There is insulator. On the insulator there is an electrode. I am just making it thicker ah so we know electrode. Mind that there is a insulator between the strain gauge and the electrode alright.

Now, insulators have the strain gauges, how many points? It has 2 points right; it has 2 point 1 and 2 electrode 1 point you get it. This is what you can see in this particular image. You see this one or you see this one or you see this one or this one or this one. There are 3 points going out 1 3 1 2 and the pink one is your third one, two from strain gauge, one from the electrode. On this electrode we have so, that there is a electrode right in centre, there is a electrode and this electrode is made up of gold is made up of gold alright. Strain gauge I told you P dot P S P dot PSS and this is the flexible substrate; that is why you can see here three pads 1, 2, 3 right. There are three pads; these are contact pads for the sensor; contact pad for the sensor.

So, what you will do with this flexible force sensor right? We can connect these flexible sensors on the robotic arm, we can connect on a surgical device, we can connect this on a catheter, we can connect this particular sensor with a three d printed cone to measure the property of a material.

For example, elasticity of the material to measure the electrical and mechanical property of a tissue right; so, it has many applications; it has many applications.

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Now, if I want to measure let us say this is the last slide of this particular module and you can see what you have you have a housefly right. And housefly is sitting on what? Housefly is sitting on a flexible sensor; it is sitting on a flexible sensor. So, you can see that there is a sensor at the bottom and there is a cube here you can see this cube right on which the housefly is sitting alright.

And we want to measure the weight of the housefly; you want to measure the weight of the housefly is our sensor sensitive enough to measure the weight of housefly or what is a weight of a housefly right. You can see this is an s e m image of a housefly and of course, the fly is dead, otherwise it will fly. So, this house fly is dead right and we have placed the housefly on the sensor alright.

So, without housefly and with housefly we can see the change in the resistance of this particular sensor and from that we can correspond that what is a weight of a housefly or how good our sensor is. Before we can measure the fly, we have to first characterize our sensor right. We have to compare it with the commercially available sensor and see that how it responds to different force right. And in fact, when you really observe the tiny things flying around us right, we generally do not care; if there is a housefly, we kill; if there is a ants, we kill right; if there are ants we just kill.

But have you ever thought that such a small thing is flying all around how beautiful the structure maybe. What is the structure of the housefly right? How it can see? How it can feel? Are there sensors on the housefly right?

When you really try to observe these small tiny beautiful things in nature of course, I do not say that you should have a lot of housefly in home, but I am just asking you to appreciate the beauty of the smaller structures, smaller insects smaller, organisms around you and really understand that how beautiful the nature is. And from that design of the nature, we can get lot of ideas for designing our sensor right.

This all inspiration you can see, so tiny and still it can you know do so many things with its small with a small structure, is not it? Is not it beautiful when you see in s e m?

So, anyways, the point is not to just appreciate the beauty that nature has, but also to understand the design that nature gives us right. When you really understand the design of the nature you can implement it in your sensors and that is how we can come up with novel design of sensors that can help us in solving a very important problem in clinical domain alright.

So, with this a line we will stop this particular module and we will see in the next module in the next lecture in fact, that how we can fabricate a particular sensor and to understand fabrication we should understand lithography, but before you move on to lithography. We will first see what do you mean by bulk and surface micromachining right.

So, I will see you in the next class till then you just look at the sensors that we have been discussing in all three modules. And now we will go on to understand how we can fabricate these sensors and how what is the application of each of those sensors alright. Till then you take care and I will see you in the next class bye.