Sensors and Actuators
Dr. Hardik J. Pandya
Department of Electronic Systems Engineering
Indian Institute of Science, Bengaluru

Lecture – 43
Discussion and Microscopic Inspection of Fabricated Sensor with Silicon as a Substrate

Hi, welcome to this particular lab class. In this lab class, we will be showing it to you how to operate a microscope and look at various sensors using the microscope, all right. Now, you may have already seen in one of the lab class that we have basically three microscopes; one is a stereo microscope, second one is a inverted microscope and third one is a metallurgical microscope, correct. Then there are advanced microscopes like scanning the electron microscope, transmission electron microscopes, right, there are florescence microscopes and many more.

What we will be showing in this lab class is how you can see the sensor under the microscope and identify whether sensors are fabricated correctly or not. For example, if I show you the inter digitated electrodes, whether the width of those inter digitated lines are 10 microns if we have fabricated for 10 microns or not, whether the spacing between two electrodes is 10 micron, are the electrode short, are a electrodes broken right, this everything you can see with the help of the microscope.

So, how to use microscope to inspect your sensors, this is the part of this particular lab. And again, Anil who taught you earlier how to deparaffinize tissue right, he will be taking care of this particular component. We have designed the set of experiments specifically focusing on sensors and actuators so that you get a very good idea, not only from the application point of view, which I cover in most of the theory classes, and from fabrication point of view but also from performing the simulation which is COMSOL multiphysics right.

And then, I am applying it with the integration of signal conditioning module sensors with signal conditioning modules which large part of it another TA has taken a part of the lab component. And then showing you each lab separately so that you understand what are the characterization tools. Further, if you have seen in one of the lab component we have also taught you how each and every component of a vacuum system looks like right, and that is not that just for this course ok.

We are in the right time because I got this new equipment in the lab and before we keep it together, we have all the components for you. So, it is a very good thing because generally we see the entire equipment. What is within the equipment, what is inside the equipment? So, this is what we have taught you in the lab class. It is a physical vapour deposition technique; it is a thermal evaporation cum e-beam evaporation or thermal evaporations less e-beam evaporator.

So, you just focus on this because these sensors that he will be talking about or showing you in the microscopes are fabricated using this particular equipment and other equipment. And this equipment that we will be; we have shown you in the lab is called thermal evaporator, it will help you to deposit different metals onto the substrate. Same way, e-beam operator also helps you; I have taught about e-beam and thermal evaporator in a theory class.

So, you can recall that particular sections all right. So, I will request Anil to take over and show it to you show you sensors; you show them sensors under the microscope and how they look like all right ok. So, I will see you in the next class. Till then you take care. Bye.

Welcome to this module. In the previous module, we saw a silicon wafer that was fully deposited with gold and I told you what is the thickness, how do you design it and all right. Today, I am going to show you one small sensor that we have made by patterning that same gold ok.

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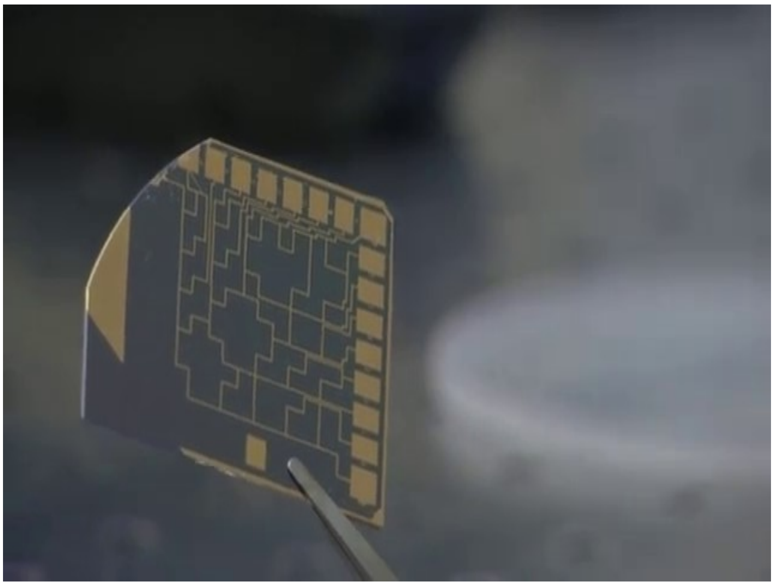

So, I am just holding it in a twister in my hand. You can see it in my hand. So, it is patterned. There are lots of twists and turns on this design but the interesting thing is that when you look it under the microscope at every turn, you can see an inter digitated electrode structure of 200 nano meter spacing and width; that is the precision. So, this device was made using electron beam lithography, not optical lithography. You have learned about optical lithography right.

Why we have gone for electron beam lithography? It is because; so you can see the device very clearly. So, you can see that there are a lot of right turns and left turns right. But I will show you under the microscope that these left turns are not continuous left or right turns are not continuous. And at the junction of these turns, there is actually inter digitated electrode structure which is fabricated using electron beam lithographic.

Now, why electron beam lithography? It is because optical lithography can have only fan like 2 up to 2-micron or 3-micron feature size. Anything below that because of the inherent nature of the light that is used. We use a laser, UV laser. We cannot go lesser than that because it is fundamentally avoid interference patterns and what is a pattern that is formed on the wafer correct.

Now, if you go for electron beam lithography, electron beam wavelength is much smaller than visible light or anything in the optical spectrum ok. With that you can find out by h c by lambda relation; Planck's relation. What is that h nu, electron energy is equal to h nu which is equal to h c by lambda. So, electron beam has a higher energy ok, so that means, that lambda will be smaller; very low h c by lambda. So, we can go to very small wavelength.

And the smaller the wavelength, smaller the feature size that you can obtain on the wafer. That is the fundamental science behind it, the physics behind it which you understand these things very well before. Because then you will understand that whatever we make practically is inherently tied to a lot of mathematics and physics which is very wonderful.

Now, so I told you that electron beam is used; h c by lambda relation, so lambda very low lambda, very high electron energy. So, we use electron beam to make these patterns ok. So, you saw the vapours. Let us look at it under the microscope. So, we are using metallurgical microscope to view the sample and we might have to go up to almost 20 x magnification to see the features. So, let me switch on the monitor.

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So, this is a metallurgical microscope. We have x, we have see seen about this microscope and all in the part of this course. So, I have kept the sample here under 10 x magnification ok.

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Here you will not be able to see what is there, we will see in the screen ok. Now, the sample is kept, and objective is focused at 10 x magnification.

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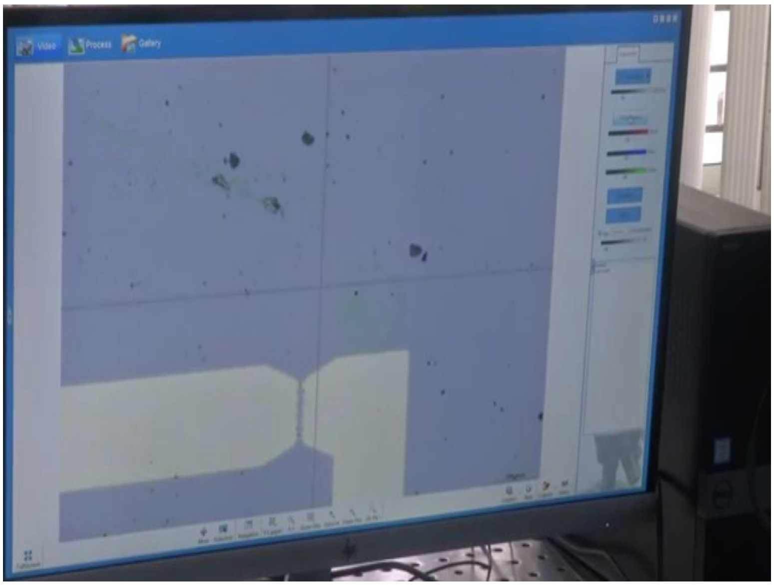

Now, we will be looking at the screen. So, now, I have focused it onto the screen. So, you can see that the continuous lines that you had seen in the sensor, we can see a junction where there are electrodes. See you can see this junction I am, so you can see the junction between these and the electrodes are there.

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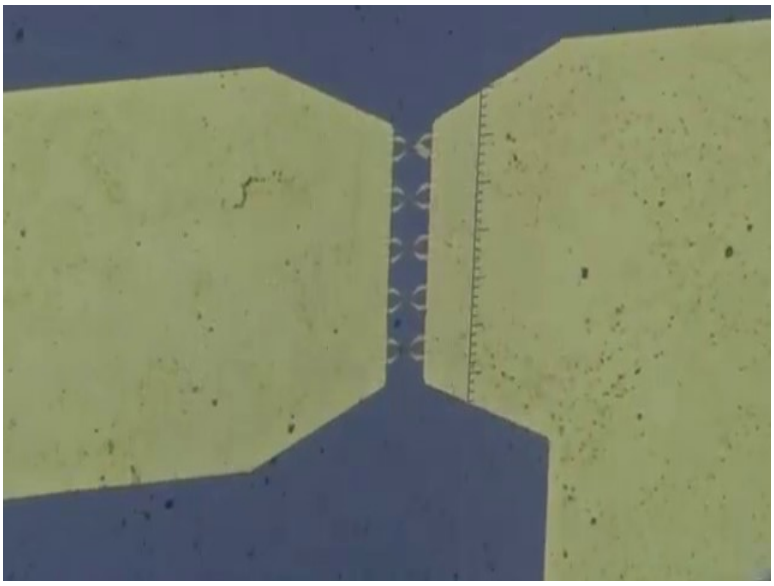

So, you can clearly see it. Now, I have adjusted the auto exposure. So, this was seen originally as a continuous line, but you can see that there is a discontinuity where there are electrodes correct, here you can see, very nicely. Now, let us go to a higher magnification. Just look at the keep looking at the screen, we will go to higher magnification, 20 x magnification.

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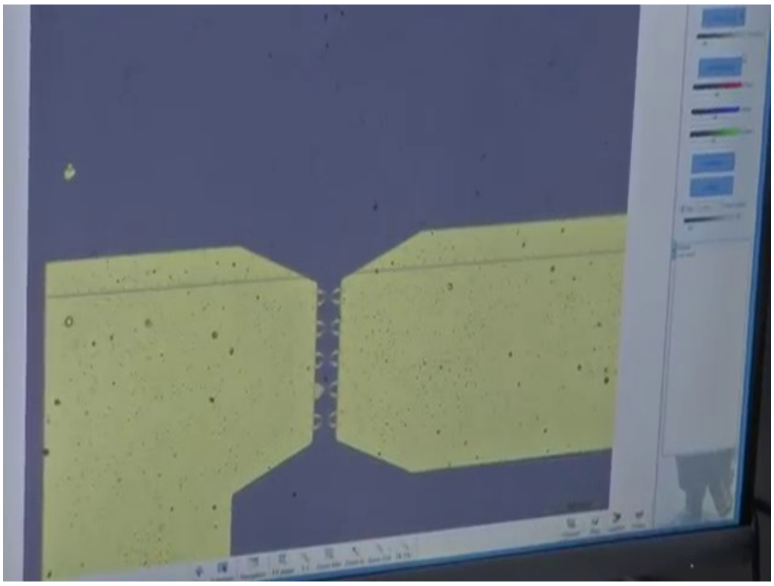

So, I have gone to a high higher magnification on the same device. So, you can see it more clearly that finger structure. Even now it is not very clearly visible. So, let us go to 50 x magnification.

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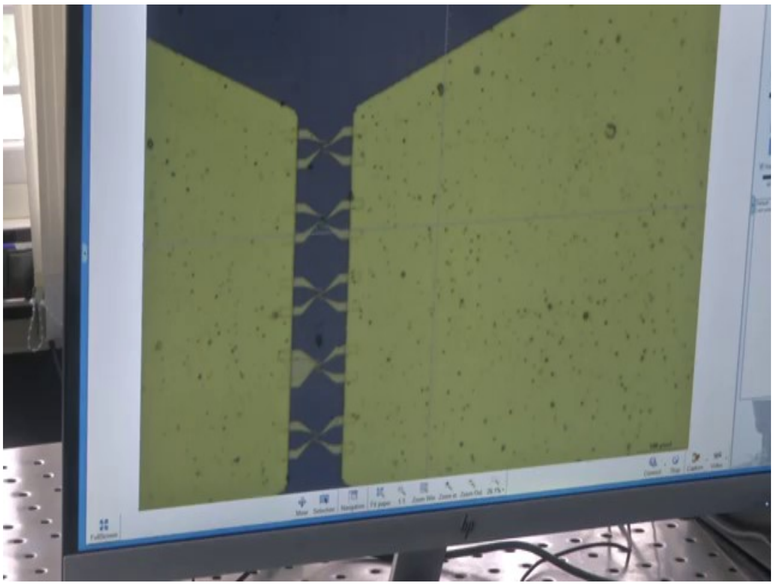

I am at 50 x magnification and I am adjusting the focus. Now, you can see the interdigitated electrode structure here. These are the main electrodes; you can see the interdigitated electrode structure at 50 x magnification. Very delicately, we have to move the substrate. So, you can see the electrode structure. I can even go to 100 x magnifications and show you. I am going to 100 x magnification now.

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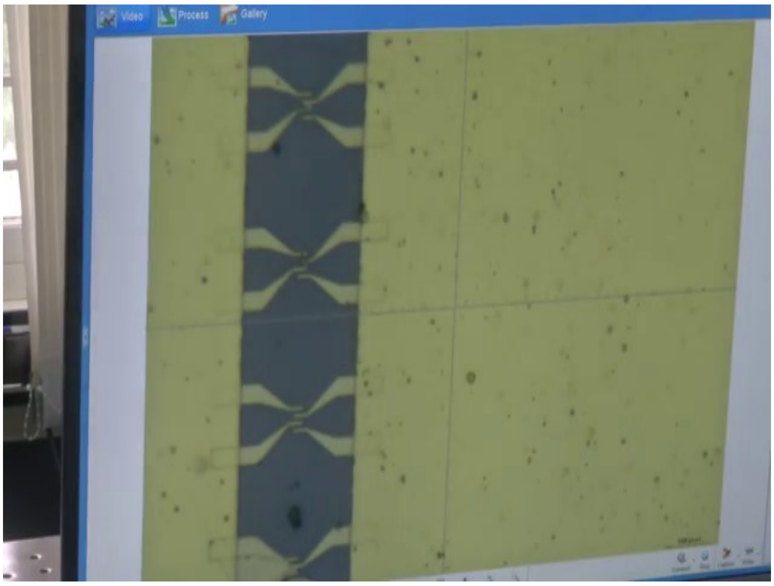

This is 100 x magnification, let me focus it. So, I have focused it 100 x magnification. Let me increase the exposure. So, I have focused it. So, you can see it now very clearly. So, this is main electrodes. You can see in the interdigitated electrode structure very clearly, inter digitated, digits are there know, inter digitated. This we have explained a lot before. So, this is very very small, you observe.

We started at 5 x magnification. Now, we have come down 5 x, 20 x, 50 x to 100 x magnification to look at this. So that means, how small the feature is you can imagine. So, these are all 200-nano meter thickness and 200-nano meter width and spacing interdigitated electrodes. You can on; this can only be made using e beam lithography. That, this, this sensor was fabricated using a very special process where we have combined both optical lithography and e beam lithography.

So, these major big lines right, these big lines were made with optical lithography, these small lines were made with e-beam lithography. Why because optical lithography transfers the pattern fully onto a substrate in one go, e-beam lithography has to go and write that pattern. So, if you try to do the whole thing using e-beam lithography on a 4-inch silicon wafer, it will take days to finish the lithography that is why major lines we use with optical lithography and these fine features, only those fine features, we will direct writing using e-beam lithography.

So, I think you understood a very beautiful and concept of different lithography techniques and actually saw a sensor here. Like this we will see a few more sensors. And later on we will see how these sensors can be tested with biological samples. So, as you have seen, you have seen a unique sensor which is kept here which was fabricated using a combination of optical lithography and e-beam lithography. We have seen how we have seen up to what magnification, we have to go to see the sensor itself. We have to go to 100 x magnification.

So, in another, in other modules, we will see other few more sensors, I think at least two or three more sensors we will see which are again unique structures. And then also we will see how the sensors like what is a biological preparation that is required to test with sensors, like I will show you about deparaffinising of tissues, because tissues will be used with the sensors to measure their properties that will almost complete the lab section of this course.

Thank you.