Fabrication Techniques for Mems–based Sensors: Clinical Perspective
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Lecture – 32
Smart Catheter Flexible Force Sensor contd…

Hi, welcome to this particular module. In the last module what we have seen, we have seen how to fabricate a flexible force sensor right using a PDMS and P dot PSS as a strain gauge material. So, strain gauge P dot PSS we are using P dot PSS is a conducting polymer and it has a very high gauge factor compared to a metal.

So, how to pattern P dot PSS we have seen, then how to create gold context for the strain gauge that we have seen. And, then how to create a bump and attach a bump and finally, realize the sensor by peeling off the PDMS from the substrate, the substrate was silicon right. Now, once you have this sensor ready then you have to attach the sensor on 5 sides of a bead and that bead we have connected to the catheter.

Now, how to calibrate it? How to get the values? At, when you are applying a force right, how the sensor performs? What is the output of the sensor? Right, for that we will see the some of the experiments today.

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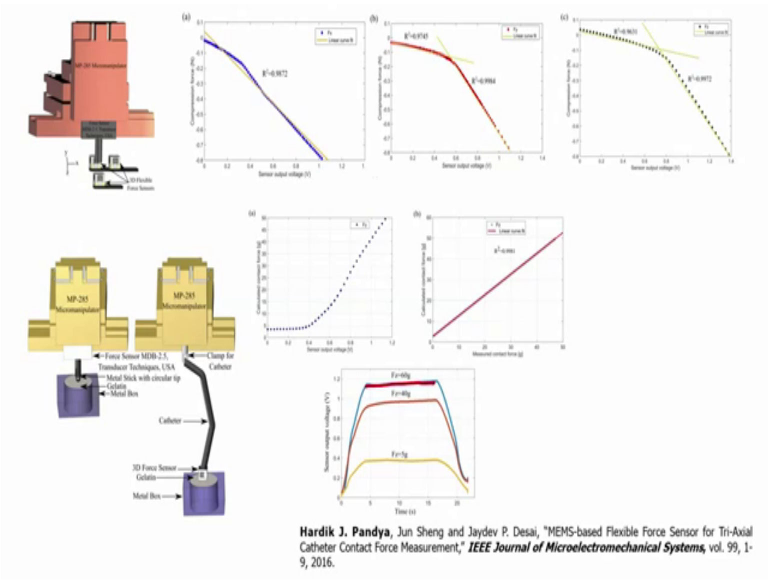

So, if you see the screen what you see is there is a micro manipulator, this will actually see when we will have a tool to the Fab lab and I that will be part of this particular course, where you will be shown micro manipulator, its performance, its operation in the laboratory. And, it is extremely important tool because we have to indent the tissue or we have to indent the force sensor to get to evaluate its performance right. It is used in many applications, we will see, we will talk about it when we go to the Fab lab. It is a class 10,000 non-conventional clean dome for characterizing the sensors that we fabricate in a actual conventional clean dome environment.

So, we have the series of lectures for you guys to see how to work in a class 10,000 clean dome. What kind of precautions you should take? What kind of equipment are generally there in the clean dome? What is biosafety hood? What is a peristaltic pump? How the manipulator can be operated? How the impedance analyzer can be operated? Right, How are the how is own operated? How we can form the PDMS from the silicone mold? So, this everything will be covered as a part of this course and we will we will show it to you in reality how it looks like right. So, it is very important to connect your theory to the experiment part so, that you can correlate what we are learning here and how the system looks like right.

So, since all the things that I have talked we will be talking in our course whether it is micro manipulator or it is your impedance analyzer or it is a peristaltic pump or it is your incubator or it is a bio-safety hood because, everything we will be using right. So, we will see when it when the time comes right. Now, if you see we have a commercial force sensor connected to the micro manipulator and then with that commercial force sensor we are moving the micro manipulator down like this and we had this flexible force sensor.

So, when we apply a force here right there, the sensor would change its output right sensor would change its resistant because the strain gauge. So, we have developed an electronic module; so, that the value of the strain gauge can be converted into voltage. And, that is why wherever you see the plot that we have the plot that you can see here is compression force versus sensor output voltage right.

So, you can see here the compressive force and versus the sensor output voltage. Here you can also see that we have use the we have fitted the curve and the R square value is close to 0.9872; that means, the sensor output is linear right, it is a linear result. Same way we have used when it is F x that is the x direction when we are forcing in a y direction so, you can see here x y and z right.

So, x direction when we force an apply force when we apply in y direction and we apply in z direction. For all these 3 forces we have corresponding results from the output of the sensor you can see sensor output voltage for your F y right, and again you can see R square value 0.9984 for your F z right. Again, you have compression force versus your voltage compression force is given in Newton's.

So, there is one thing, now calculated contact force versus sensor output voltage. So, now, if I keep on applying force what is the on how the sensor output would change. So, you can see here from 0 to about 4 close to 4 or close to 3 grams the sensor will not is not able to you know it is almost like point from 0 to 4 or 0 to 3 the sensor is not so sensitive right, above 3 and above the sensor will start showing the change in output voltage, you can see here 0.2 volt from 0 to 4 it is almost like minimum right.

So, and we do not worry we do not have to worry about this particular force. In fact, until this force we do not have to worry because the optimum forces 40 grams right, optimum force is 40 gram during surgery. So, what we see is until 5 grams of force we have 0.4 and is not really linear, but you consider from 5 grams and above it is linear right. So, as you increase the force the sensor output voltage is and there is a linear relationship between the force and the sensor output above 5 grams right or 5 grams and onwards. So, that is one thing that we can see here, second thing is calculating the contact force was is measure contact force.

So, if we already know how much force we are applying because we have a commercial force sensor here right. So, we know what is the calculated contact force and correspondingly what we are measuring. So, for 10 gram is it matching you have to see like this close to 10 gram right 20 grams somewhere here right. 20 grams is there as you can see here right and 30 grams like this. So, calculated force versus measure force you can again see a quite linear relationship with R square value of 0.9981 right. This is we can see that it works very well.

Another thing that you can see here we have used a force sensor MDB 2.5 with a transducer technique from United States and there is a metal stick and this is a gelatin box right is a gelatin material box. So, we are pressing this force sensor against gelatin and getting the results same thing what we are done we have connected the catheter, we have connect to the catheter and we are forcing the catheter against the gelatin and we are collecting the results right.

So, we have comparing our results with the commercially available force sensor right and when we apply different forces let us say 5 gram force right; if we start applying 5 gram force and then we stop at certain point it will come back to its original stage. But, the there is a for 5 grams the output voltage is different for 40 grams is different for 60 grams is different; you can clearly see that the sensor can be used from 5 grams to 60 grams.

And, it shows on off time it can show on off time and it is when you apply a 460 gram it becomes saturate, it is not continuously increasing. Continuously increasing then it is very difficult to get the understanding and they performance of the sensor. So, here what we can see is the sensor can be utilize to understand it's performance by calibrating it with respect to the commercially available force sensor.

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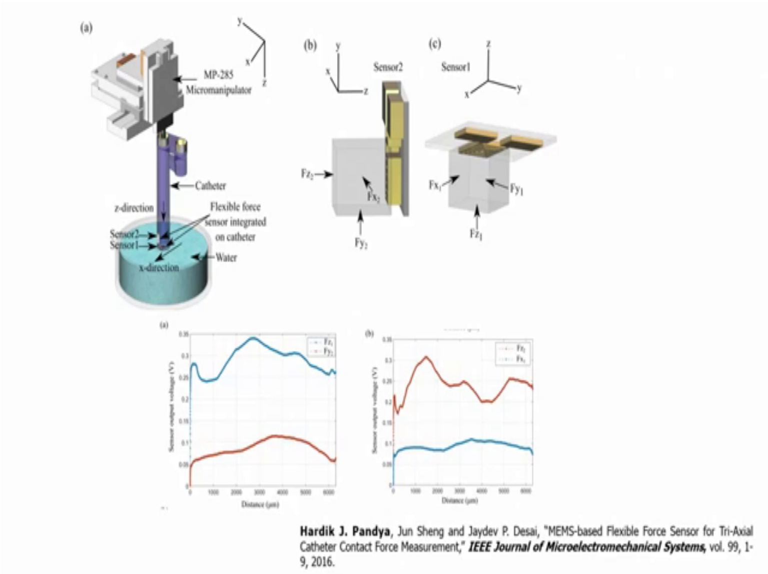

Now, there is another thing that we have measured and that is what I told you is in reality the catheter would be inserted in the body and there is a flow of blood right. So, it data that we obtain from the flow of blood should be neglected and the data that we get only from the sensor, only when the sensor is touching the tissue should be taken into account.

So, for that we what we have done is we have sensor 1 here sensor 2 here. There are 2 sensors here and then there is a water this is a x direction and then there is a z direction you can see here right. So, what we have done we have moved the sensor in x direction and z direction. So, we have we have dipped the sensor in this direction and we saw what are the results.

So, if you see these sensors there are two sensors attach right; one sensor is in this particular it is at the bottom of the catheter bottom of the bid and the second sensor is and the side of the catheter bid. So, if you see for sensor 1 and sensor 2 we have different results; however, just looking at the results what we see is F z 1 and F y 2. So, F z 1 is here F z 1 is this 1 and F y 2 is here this one right; because for this one is z, but for this one it will be y right. This is a normal force to this strain gauge it is a y directional force or a shear force to this particular sensor right. What I mean is you apply a force like this normal force, but if a force is coming in this direction is kind of shear force right.

So, we are measuring the normal and shear forces our force in different direction to be precise. So, F z and F y 2 we have the results right, we can clearly see that when there is a F z force this sensor would be more sensitive compared to this sensor. Same way F z 2, that is the when we apply the force in this direction which will be directly pressuring the sensor here right. It is very higher compared to F x 1 which is the force in this particular direction. Thus, what we are just measuring is what kind of data we can obtain when the sensor is moved inside the water and what will be the flow when we actually put the sensor in the heart we have to study that, we have to also change the design of the sensor like I said right.

So, the idea of this particular module to show it to you was that we can design a flexible force sensor, we can obtain the data using flexible force sensor, but we have to optimize our design; we have to improve our design to actually use it in a in the surgery right. But, these are the primary results that we have obtained and from this we get a confidence that using the strain gauge and P dot PSS material as a strain gauge we can measure different forces right.

So, this is all about the using the 3 D MEMS based force sensor for catheter contact force sensing. So, what we have learned in this 3 modules is that you can design flexible force sensor or any other sensor using micro engineering. Second is what is atrial fibrillation, third is what is a tool to cure atrial fibrillation, fourth is how the surgery is performed, what is electrical mapping. And then how the another catheter is inserted when you are performing ablation, fifth is when you want to fabricate a flexible force sensor or any sensor you have to get you have to calibrate it.

And, then you have to see its performance by considering all the possible scenarios that you will be that you have to take into consideration when you are comparing the actual catheter when it is placed or it is used inside the body right. So, this is about the catheter contact force sensing for atrial fibrillation. Now, the topic is smart catheters. So, how you can make it smarter? How you can make it smarter? You can, we already talked about making it smarter by using electrical mapping because, there is a catheter which is lying inside that tome. When tome opens the catheter will come out it will do electrical mapping it can go in tome closes it can be used for ablation.

So, doing multiple things is smarter, it is smarter catheter for sensing ability will be a smarter catheter. Another ability would be tactile sensing, when a surgeon is operating this catheter can a surgeon feel the force right, that is a feeling of that force will be the tactile sensing. If you have tactile sensing on the force on the contact along with contact force sensing then this catheter operation would be easier most probably and of course, the catheter is smarter, because it can not only show you the force that you are applying, but also you can feel that force right.

So, how can you now develop a tactile sensor I leave it on you, now you know how to perform a micro fabrication. How to use photolithography and try a few ideas again in all these things, that we have discussed, if you are stuck somewhere, if you have questions if your queries you should and you I insist you to ask us using the forum right. Your queries would be answered to the best of our abilities and feel free to learn more right, feel free to learn more get a novel ideas and try to implement those ideas at least in terms of designing the process flow for fabricating a particular sensor right.

So, having said that we will be looking at other applications related to clinical research or clinical relevance of our MEMS based sensors of our micro fabrication. Till then you just go through this particular module and previous two modules to understand the complete concept.

I will see you in the next class, take care bye.