Fabrication Techniques for Mems - Based Sensors: Clinical Perspective

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Lecture – 53
Introduction to Fabricated Sensors

Welcome, today we will see few interesting sensors that are that we have fabricated in our facility as also some few commercially available sensors to understand what all innovative methods we have used or people are using to may come up with sensors of extreme precision or of with cheap cost both spectrum we will see. So, to start of here we have a series of electrodes.

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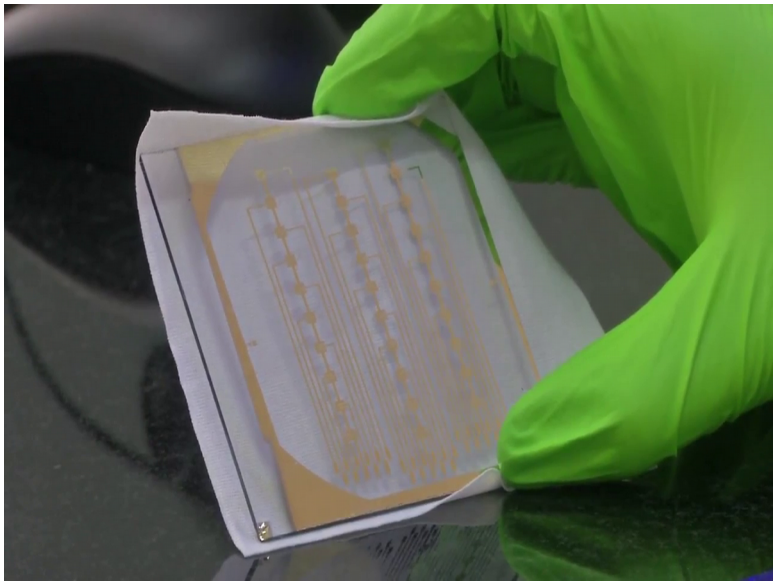

So, let us just see that now, we have a series of electrodes that have that have been formed on a glass substrate. Here, you can see a series of electrodes exactly 30 number of electrodes that we have fabricated here in our facility on glass substrate.

So, the material of the electrode, the material of the electrode is gold ok. So, the conduct pads are visible below bottom if you see this vertical structures so, those are the conducts. Conducts for sensing the electrode and the material is gold and the substrate is glass. Now, that you have covered so much portions in the fabrication goes you would know like very well how this would have been fabricated.

So, what we will do now is we will take a glass substrate, clean the glass substrate, then what do we do then we will deposit gold of some thickness. Actually not gold, if you remember correctly, we should deposit chrome gold some thickness of chrome and then on top of it a definite defined thickness of gold. This is done so that the gold can attach or other or stick on to the glass substrate properly.

So, the gold is deposit thoroughly ok, then we have to pattern the electrodes, right. So, we have to make a mask first; mass plate will be made. So, the mask plate will be a, we will quota photosensitive material we are on top of the gold that was deposited if exposed this photosensitive material with the mask that we make for this electrodes, develop the photosensitive material correct. I think this passes us you would have learnt develop the photosensitive material. Then what do we do then we will have to edge out the gold that is not required from rest of the places only where the electrode is there, there only we need the gold and in all other places we will edge out the gold using gold hn like potassium, iodide and chrome hn also.

So, we will remove the chrome and the gold. Then finally, we will end up with this beautiful structure. So, in the structure if you see, you can see small squares square like patterns one by one those are the electrodes. So, within them, actually we have made 10 micron spacing electrodes. So, there is like 20 micron width electrodes and 10 micron spacing between them. So, those electrodes we have made as IDE structures in this and then in 1 column, there are 10 electrodes and there are conduct pads for each of them, like that we have 3 columns.

So, total 10 into 3, we have 3 electrode, 30 electrodes deposited on this 3 inch glass substrate so, this is a 3 inch glass substrate ok. Now, you were know I as I have told it is 10 micron 20 micron features, you might not be able to you would not be able to actually see this here. You can only appreciate the overall structure of the electrode. Now, let us actually look at it in the microscope, I will just put it on the metallurgical microscope which we have covered before and see how the electrode structures are looking. So, I will just load it onto the microscope.

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So, before we see anything on the microscope, first we should start with the slowest lowest to know the features properly ok. So, let us look at the screen now so, I have kept before looking at the screen. So, the sample is loaded I have kept the 5 x magnification microscope focused it on a electrode structure now, let us look at the screen.

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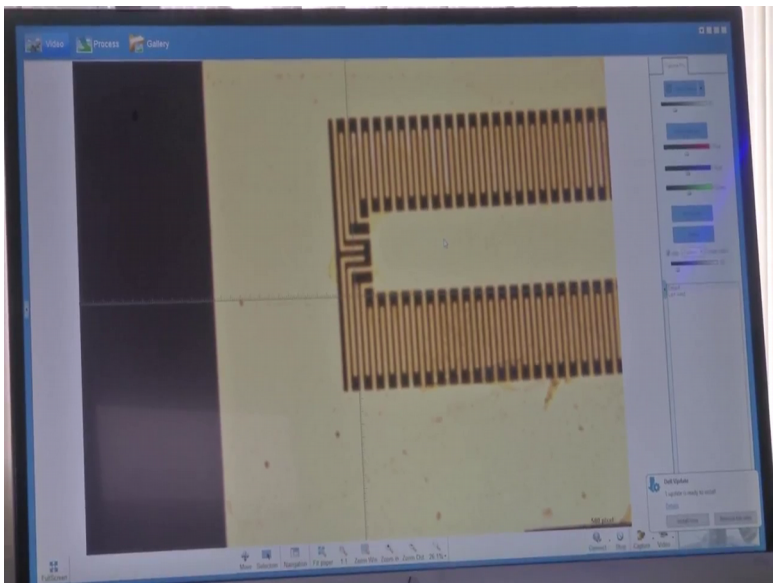

So, you can see in the screen, this is at 5 x magnification. So, this is the electrode the square shape that you had seen where I told there are inter digitated electrode structures.

So, these are the electrodes at 5 x magnification. Now, we will go zooming, I will go to 10 x magnification so, we have to fine tune it again ok.

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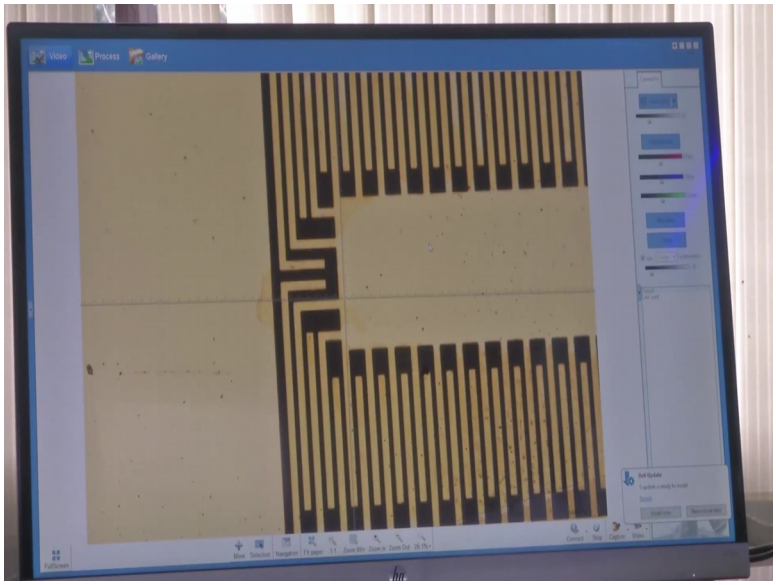

So, I am adjusting the focusing so, now, the focus is adjust, adjusted. So, now, you can see it is at 10 x magnification. You can nicely see the electrode pattern; I will just move the sample around so that you can appreciate the features ok. So, these are the electrode structures if you want to see in much more detail, can go to the next level of magnification which is 20 x.

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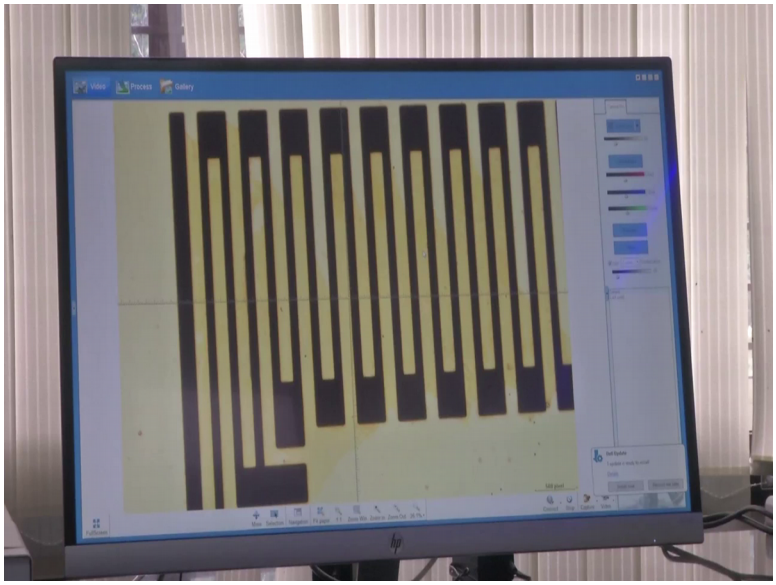

So, this is 20 x magnification ok at 20 x magnification, you can see the exact finger like pattern of the electrodes correct, how the inter digitated structure which we have covered in the course, how they are structured see one pattern of electrodes are coming from top, one set of electrodes are coming from bottom, but they are not in conduct they are like this, they are not in conduct.

But, once something have that has to be sensed it kept on top of this electrode structure, the conduct will be made correct and then we will be able to sense it with the conduct pads which will be there. So, like this we have made 30 electrodes on the single 3 inch glass substrate. So, we have made so many electrodes because the gold deposition process is itself is a quiet an expensive process. So, if you want to do short loop experiments with just the electrodes and do not want to integrate the electrode with some microfluidic channel or heater or anything and you want to just try out how the electrode will work, you need to have as many electrodes as possible in smallest area possible.

So, that is what we have done because we wanted to do some preliminary experiments with this electrode structure. So, we have made 30 electrodes on the glass substrate. So, this is one interesting us micro fabricated component that we wanted to show today. So, now, let us next let us just see, now let us see another interesting sensor microfluidic chip in fact, I hope it is visible to you now.

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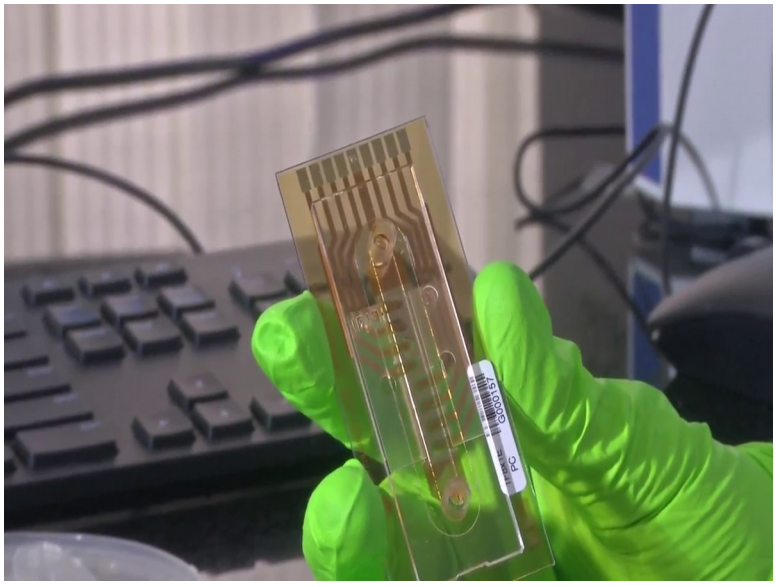

So, this is a microfluidic chip, this is not something that we have fabricated, it is made by company called applied biophysics. But, they wanted to show it to you because this is a very interesting microfluidic chip which is actually fabricated at very low cost, it is made of plastic and it is flexible. See I am flexing it, nothing happens with there we saw the sensor made of glass so, this is made of plastic, everything is made of plastic actually.

So, the top surface that you are seeing, top surface that you are seeing is also made of plastic and the microfluidic channel is on this top surface and the electrodes which you usually see are screen printed by method called screen printing, they are screen printed on the bottam plastic surface I will just tilt it.

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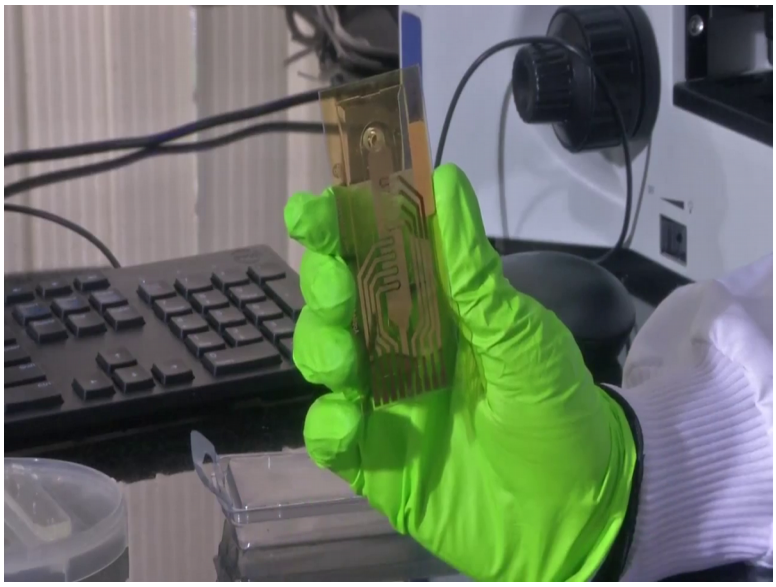

So, when I tilt it, you can see the screen printed electrodes, you can see the screen printed electrodes here see. So, if you see if you observe, these are not very micro dimensions, electrodes are actually even 1 mm thick electrodes. If you see the these are also again interdigitated structures, if you see this is the first electrode and these are sub interdigitated structures, this is from applied bio physics.

So, these are like 1 mm features so, this can be done with less expensive processes. So, they have used a something called screen printing to print the electrode structure and the electrode is formed and then they make the microfluidic channel. So, these are the inlet and outlet ports and there are some sample input ports and there is a microfluidic channel running inside. You may it not be able to see it very clearly, but there is a microfluidic

channel running inside. So, you will load your sample like this and the sensor below will sense the changes. The idea is they are try to sell it as a product so, when we are making is we should look at how these companies are making this chips.

Because, when we are doing research, we should as I have explained before we should also look at how it can be made translation, how you can actually make it sell; not necessary for monetary purposes. Selling in the sense, we should be able to make impact to the society with our research. So, we should be able to reach to the masses or to the clinics or to the doctors and if possible make sure that at least on a weekly basis or a monthly basis, they are able to use our research outcomes to help patients or help people in general.

So, to do such things you need to have cost effective ways of fabricating stuff so, this is one way. So, this is plastic through plastic they have made this, they have bonded plastic to plastic. So, these are all very interesting concepts and how they have made this very cheap use this a use and throw, it is very light, it is hardly I think 10 grams. So, they are made as use and throw microfluidic chip with very not very fine electrodes just macro level course electrodes.

But, so long as it senses differences between your control experiments and you are able to come to a diagnosis, it does not matter whether you are having 10 micron electrodes or 1 mm electrodes, but you have to be very careful about what is your actual application. If your application demands that you need to have it in microelectrode, then we do not have any other option, but to go ahead with the previous sensor that we showed where we had 10 micron electrodes. But, if your application inwards micro sensing, then you can go ahead with such electrodes such big electrodes.

So, there is always a trade off involved within cost, design constraints, material used like you want gold or platinum or you want to use PDMS or plastic or glass. So, you should look at it in a very holistic manner and see what is your exact application and where you can compromise and where you cannot. In places where you cannot compromise with the design, you should not worry about the cost because functionality is a is a core or the heart of your design. Unless it does not function with good accuracy, specificity, selectivity and all even if you make it cost effective, it does not it is not useful. First

functionality be have first functionality be has to be met with good faithfulness then you look at reducing cost and size and other form factors.

So, this one chip we wanted to show it show you today. Now, just a quick thing so, in a previous session, we have seen PDMS molding right, we made PDMS and molded it using silicone masher and all that time we have told that a PDMS will be bonded to glass, correct.

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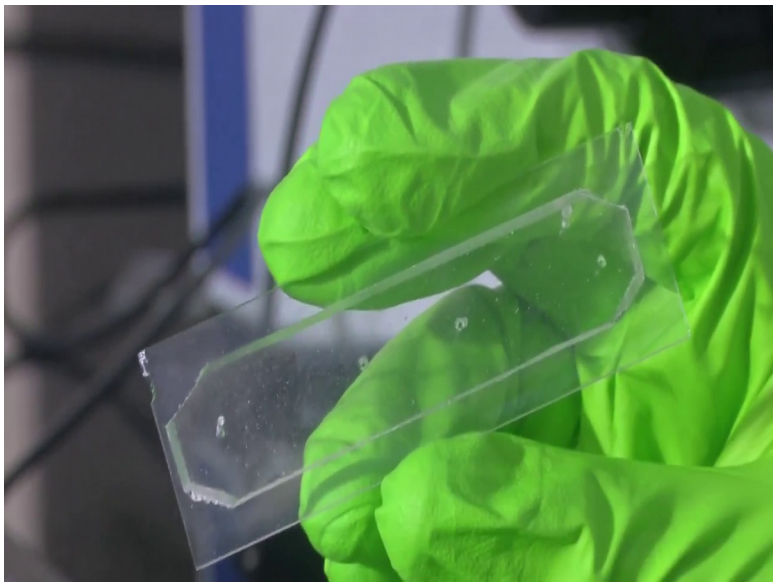

So, we have a PDMS membrane which does not actually have micro channels. It has only holes; you can see the punched holes here which are been punched first using a bioxy punch. So, this is the thick, it is almost I think 1.5 centimeter 15 mm thick PDMS membrane see top membrane. It has been bonded onto the glass slide the standard glass slide which are used in biology experiments they have been bonded on to the glass slide and if in if you try to pull it out, they would not come out because, they are chemically bonded or like their atomic level at molecular level they are bonded to the glass.

So, this is done using method called oxygen plasma so, this way you can bond PDMS to glass. So, this I wanted to show you because that time we had not shown you how we have bonded to glass. So, this PDMS membrane has been bonded to glass using oxygen plasma, you can see a one more chip, same design is there.

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Now, we saw these things, we saw electrodes, fine electrodes, course electrodes, different materials, glass, plastic PDMS, glass mounting and all. Now, let us go back to the basics; by going back to basics, what I mean is we have one very unique sensor that we have made we can see.

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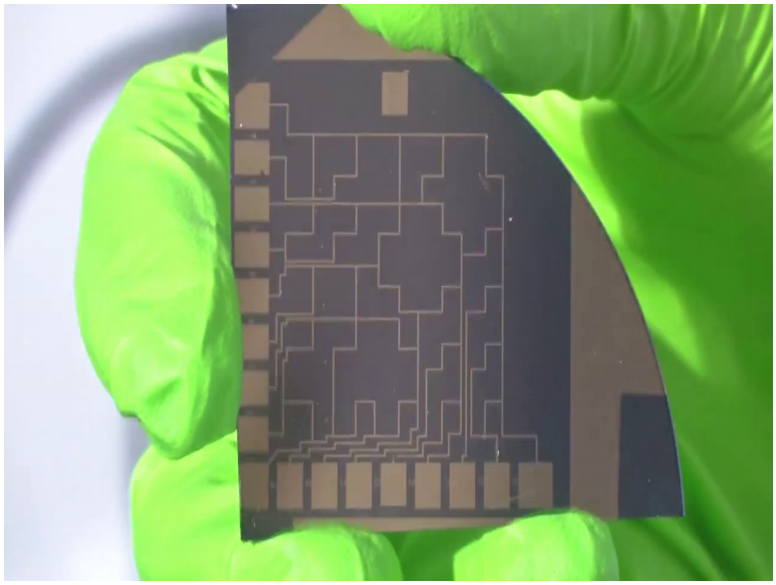

So, this this sensor is made for sensing biological interaction between; biological interaction between molecules of very small size like under 10 microns ok. and what you see is not what is all about. So, this sensor has been made with multiple processes so,

you have might have known that there is something called photolithography correct. We made the electrode patterns before using photolithography, but photolithography has it is limitations. In photolithography, we use UV light to expose patterns correct, but UV light is limited with this wavelength because of that, there is a finite limit to which it can go to maybe around 1 micron or maybe some nanometers it can like 800, 900 nanometers it may be able to go as features. But, what happens if you want like 200 nanometer or 0.2 micrometer features, for that you have to use something called e beam lithography.

So, this sensor has electrodes that have been fabricated using e beam lithography at the centre at different parts within which you will not be able to see and then on top of the electrode, we have made coastal structures mac bigger structures which are in the micron scale, which are in the micron scale using photolithography. So, we have used photolithography; photolithography on the outside features and e beam lithography to make the exact sensors at the inside. So, this is how this sensor has been made and the conduct pads are here. Because, in microscope if you see might not be able to see, it very clearly so, I am not showing exactly in microscope in this, but this is overall idea about this.

So, you can see that how we can engineer such devices. So, we have used multiple processes e beam lithography photo lithography, gold deposition etcetera on the silicon wafer oxidized silicon wafer to make this extremely versatile chip that can be used to measure interactions of biological molecules at sub 10 micron level. So, that is so again what is this is again coming back to what I told just now.

Look at what is your design constraint, what do you want to actually sense, you are making fabricated sensors, what is it that you want to actually sense, what is it is dimensions, what is the electrode that you need to make; you need to make. So, that it is sensitive to such interactions, then you fix your electrodes and depending on that, after you fix that that will be a fixed criterion then you change other things to reduce your cost or material consumption.

So, this is how you should approach your design so, this is another sensor which we wanted to show. So, we have seen series of thirty electrodes on glass substrate, we have seen very interesting microfluidic chip macrofluidic chip that is made using plastic, we also saw how a PDMS membrane was bonded to glass. Now, let us go back to the PDMS

membrane that we have molded in our previous session. The channels we are made that time we told, we had told you that this PDMS membrane will be bonded onto a glass substrate with electrodes deposited on it. So, we are actually done that so, we wanted to show that to you.

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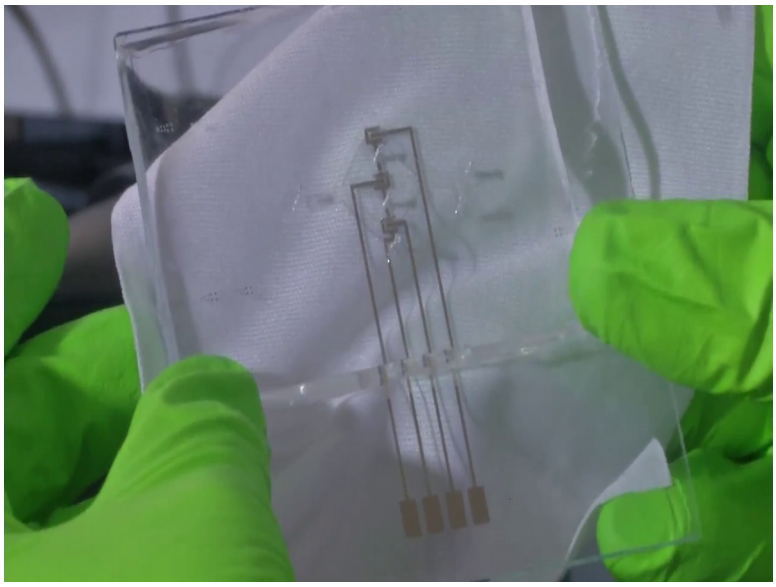

So, we have the glass substrate below, the electrodes are there you can see it right, the golden colour electrodes are there electrodes are below and to that glass substrate with the electrodes, we have bonded the cut nicely cut PDMS channels. So, channels are there visible here hope you can see may not be able to see, but you know that you have seen this before. So, there are channels here so, the channel the PDMS is bonded onto the glass with the electrodes.

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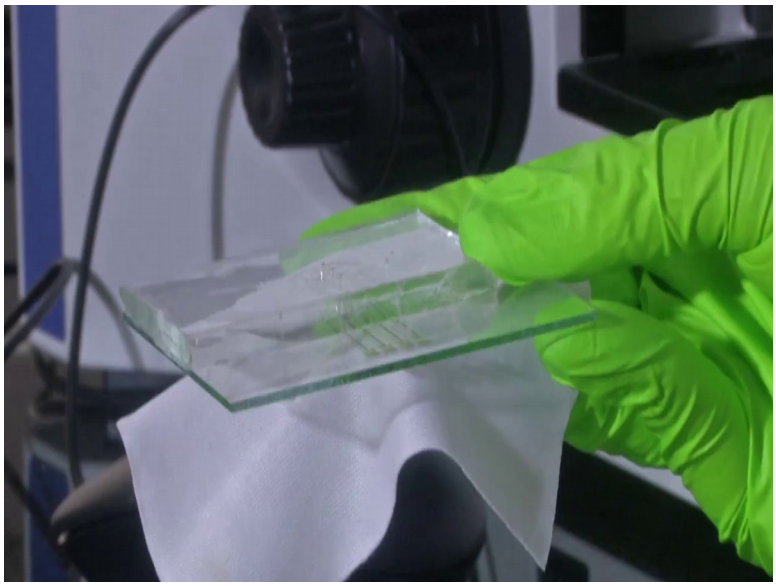

If you see from side, we can see that this PDMS layer is bonded on to the glass is bonded using oxygen plasma. With this process, this device is actually ready to be tested fully ready. We have punched holes, if you see here we have punched holes for the inlet outlet of the microfluidics and also for loading reagents, holes are punched, the electrodes are in place so, the device is complete. This is how you complete the fabrication of a device ok. So, these are few devices that we wanted to show.

If time permits, we will be showing you more devices and course duration of this course; otherwise, you should have an idea that this is how device fabrication is done and what are the different constraints that that you should take care design constraints, cost constraints, time constraints. So, that you are able to make your sensor in the most robust manner and also package it using methods like 3 D printing so that it can reach the end user and have a society impact.

Thank you.