Advanced Neural Science for Engineers
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Lecture Number - 47
Neurosurgery-based MEA Implantation – II

Hi welcome to this module again it is on the rat craniotomy and we are looking at the MEA. This is video number 2. In the last video 1 you have seen if you recall you have seen what you have seen how the anesthesia is done locally anesthesia is done and how we are looking at the craniotomy and how we can see different regions. I hope it gets more and more interesting over a period of time.

The brain surgery is the most difficult surgery compared to other surgeries I am not saying other surgeries are not complicated and in fact I have no right to say which surgery is better, which surgery is complicated, but in general because I have seen the way the brain surgery is done it is really, really trickier, but that does not mean that heart surgery is easier or a liver transplant is easier everything requires a skill set.

Brain is something which is really unknown whether you talk about the degenerative diseases, whether you talk about curing Parkinson's whether you talk about how the memory and attention degrades as you grow older particularly for geriatrics patients, you talk about epilepsy and then the sleep disorderness, you cannot get good sleep then different waves that are generated during the sleep time.

Whether it is alpha, beta, gamma and then so the theta and what are REM cycles and what is a dream phase. So, it is really mesmerizing because we do not know until we do not know in detail each and everything about brain it will still remain area of exploration. If you have recently understood how we can use digital VLSI to an extent and analog VLSI or mixed signals to develop this neuromorphic chip.

So, neuromorphic chip is very interesting concept of using your VLSI and to develop a chip that can mimic a part of the brain same thing goes for the olfaction if olfaction is smelling then you small what happens, which part of the brain gets activated, memory when exactly the memory is stored, how it is stored you can think about when you are 4th, 5th grade and you can still have that memories.

So, it is an amazing organ you can say or a part that is still unknown for all of us to explore. Now, when I say unknown does not know mean that we do not know the anatomy, but why things happened how the decoding happens, how can you encode it back, can you replace certain part of the brain with a coprocessor. Suppose, if you have the brain and certain part of the brain which are non eloquent areas if those areas are being surgically removed.

Can you replace those area by a chip not to make a person or super human just to regain what he or she was that skills that motor area the visual, the speech, the memory anything that has been affected can you regain it that will be a very interesting concept. However, we come back and see the video number 2 and in video number 2 what we will be discussing would be the following things.

Then there is very thin layer which is called dura, how the incision in the dura is made, understanding how the localization of the region happens by using wire electrodes then we implant the micro electrode array after confirming the localization of the target area then we will show you the drilling for ground and reference electrodes because when you implant the micro electrode array.

You need to also see which one will be my ground electrode, which one will be my recording electrode, which one will be my reference electrodes. So, what you can do for ground for reference how we will perform the drilling. Next is how we can fix the printed circuit board that is your electronic module with the stitching so that for arresting the moment that means that if the rat moves the whole electronic should not move because it will generate lot of noise.

Of course rat moves electron goes with it like a bag pack, but how well you can attach the bag pack to the rat's back is also a matter of importance because removing any shocks while the rat is walking or any other activity is very important and that is why the fixing of PCB is really important. So, these 5 different points we will be looking in the video next one.

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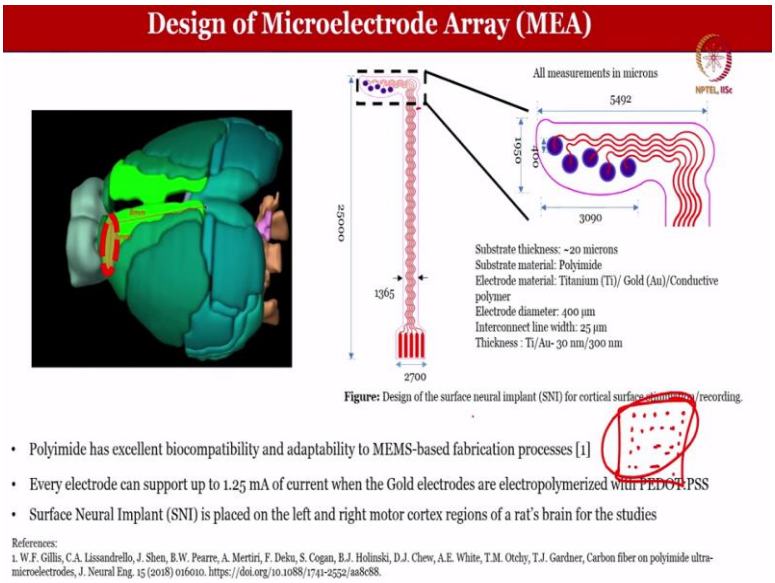

But let me just show it to you how we are going to implant this electrodes and where actually we do the implant. So, we will still stick to something that we have been looking at in the electrical stimulation MEA for electrical stimulation. So, in this case if you see these are the microelectrode array and how many numbers you can see there are 5 numbers. If you zoom in here is 1, 2, 3, 4 and 5; 5 electrodes are there.

These are your recording electrodes. So, everything else has an insulating over it except the contact area and except this circles that you can see 1, 2, 3, 4 and 5 where there is no insulating material. All the other region has the insulating material so that when this region touches the brain surface and in fact any region like this also, here also that will not have an effect on those electrodes because this is covered like by a insulating layer.

Only the electrodes that are touching the brain surface is that your recording electrodes we will be able to capture the signal from the brain and the contact electrode will help us to connect into the further electronic module so that is how it is. Now, the way to place this thing inside the brain after you do the craniotomy and then you open the dura is in this region one and in second region is here so 2.

So, require how many electrodes now? We require two numbers of this devices. One 5 electrodes on one side and another 5 electrodes on the other side. So, now you can do the surface stimulation you can substrate thickness about 20 microns extremely thin. I have told you during one of the class that the human hair is about 50 to 60 microns, 50 to 80 microns.

We are talking about 20 microns that means that half of the human hair even lesser than the thickness half of the thickness of human hair.

That is how thin the devices are that can be placed on to the cortical surface. The substrate material the substrate is any material on which you are going to fabricate a device, substrate material is your polyimide, the electrode material is this blue colour thing that you can see here I am sure that it is blue colour here 1, 2, 3, 4 and 5 this material is nothing, but titanium and gold.

Titanium is used to improve the aeration of the gold on the polymer porous polymer is there it is the polyimide. So, now you have the electrode diameter, what is the electrode diameter? The electrode diameter is about 400 microns that means that if you take this one circle one circle is close to 400 microns. What is the line width for interconnect line width this line width this one this wavy line you can see in red colour this line width is about 25 microns, electro diameter is 400 microns.

Line width is 25 microns and thickness of the titanium and gold, what is the thickness? Gold is about 30 nanometer and titanium is about 30 nanometer. So, these are some of the parameters that we have used to fabricate the surface, neural implants we also called as the SNI for cortical surface stimulation and recording again for recording this can be easily used for stimulation you need to understand what kind of material you need to use so that the stimulation is proper.

The reason of using polyimide is that it has an excellent biocompatibility and adaptability to MEMS based fabrication process. Second is that every electrode can support up to 1.25 milliampere of current when gold electrodes are electrode polymerized with PEDOT PSS you see that only gold will not have that much of capabilities, but if you go for electropolymerization than you can go and apply around 1.25 milliampere of current from each electrode.

So, this SNI which we called as the surface neural implant is placed in the left and right motor cortex here just between the primary and secondary we put this implant and left and right motor cortex regions of rat's brain for the particular study. So, now when you see there are different way of implanting we can use either this one or you have a chip or you have a flexible device with 32 electrodes.

When we look at an epilepsy we are looking at there are some flexible devices which were having 32 electrodes. So, if I just do like this then you have 32 electrodes and this 32 electrodes will be touching the brain. So, this is also microelectrode array so with 32 electrodes here we have used only 5 because of the region of interest is you can see very clearly it is very, very small about 3 millimeter this length is 8 millimeter.

And you have to place the device right in this circle that is how the size of the device is also measured, you have about 3.1 or 3090 microns which is about 3 millimeter close to 3.090 millimeter. If you want to be precise this slant is about 5.492 millimeter, this one is 1.950 millimeter and each electrode as I told you is about 400 microns in diameter. So, what you will see in this particular thing.

In this particular thing you will look at how the incision of the dura will be there, you will look at where is the localization of the region is made then you will see how the implantation of the MEA is done, MEA can be anything like I said it can be 32 electrodes, it can be array of electrodes which is single needle or it can be your flexible device or implant made using polyimide which is the 5 electrode it can be anything.

So, how it can be done then we will look at the drilling and ground as I have told you at the start and finally we will look at the fixing of PCB and is stitching and other things. So, during this time we can also look at the characterization. Characterization of the electrodes are very important.

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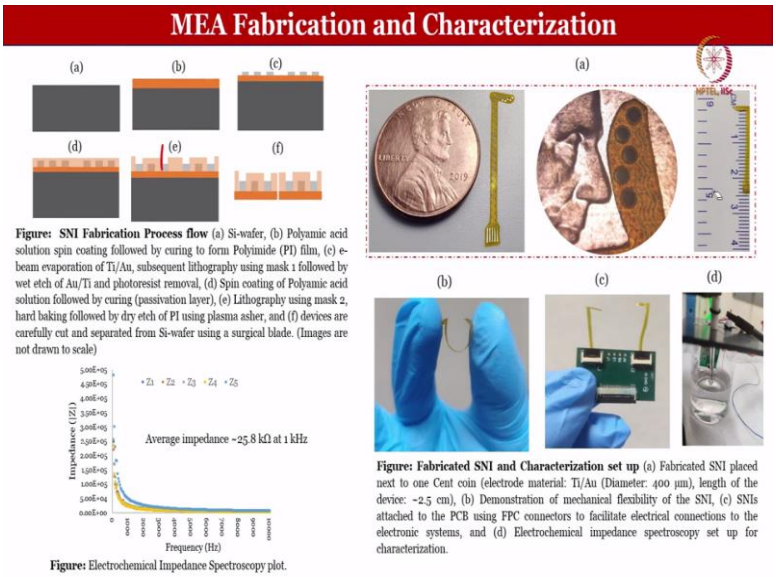

Figure: SNI Fabrication Process flow (a) Si-wafer, (b) Polyamic acid solution spin coating followed by curing to form Polyimide (PI) film, (c) e-beam evaporation of Ti/Au, subsequent lithography using mask 1 followed by wet etch of Au/Ti and photoresist removal, (d) Spin coating of Polyamic acid solution followed by curing (passivation layer), (e) Lithography using mask 2, hard baking followed by dry etch of PI using plasma asher, and (f) devices are carefully cut and separated from Si-wafer using a surgical blade. (Images are not drawn to scale)

Figure: Electrochemical Impedance Spectroscopy plot.

Figure: Fabricated SNI and Characterization set up (a) Fabricated SNI placed next to one Cent coin (electrode material: Ti/Au (Diameter: 400 µm), length of the device: ~2.5 cm), (b) Demonstration of mechanical flexibility of the SNI, (c) SNIs attached to the PCB using FPC connectors to facilitate electrical connections to the electronic systems, and (d) Electrochemical impedance spectroscopy set up for characterization.

So, if you see this particular slide now what we have seen so since this slide is there I will be anyway I have talked about this in one of the class, but I will also teach you again. So, you have here the silicon wafer and on silicon wafer you have your polyamic acid solution which is spin coated as you can see from here and then you can cure it and then on that you can deposit titanium and gold using your electron beam operation is nothing.

But your physical vapour deposition using one mass followed by wet etch of Au Ti so you can get what you want which is this particular design followed by spin coating of again the same polyamic acid solution followed by curing which you can see in d and then lithography using mass 2, hard baking followed by dry etch of PI using plasma etcher. Why because you need to open the contact pads and the region of our interest which is of the electrodes.

And then finally the device are carefully cut and separated from silicon wafer using a surgical blade. Once the device is there we can do the electrochemical impedance spectroscopy study and from that we can understand what is the average impedance of the electrodes which we found that it is about 25.8 kilo ohm and 1 kilohertz which falls with the literature that is available with us; available with us means is available on the different platforms.

So, we have here Z 1 to Z 5 there has been impedance from one electrode, impedance from electrode second, third, fourth and fifth. When you average it out it is close to 25.8 kilo ohm. This is an actual device again we have used 1 cent because the diameter of that 1 cent is constant, it is not for any other purposes and I will tell you a very interesting story regarding this using 1 cent is that I have my Postdoc from Maryland, College Park.

And also a 1 year Postdoc or you can say a fellowship from Harvard Medical School which is in Boston, Maryland, College Park also is in US and when I joined and I started using 1 cent and placing the device next to it then the question was that oh why do not you use Indian rupee, why you want to use American cent. You are in India now that was the comment you can say or advice that was given to me.

Now guys it is nothing to do with the currency. If you see our rupee you take the rupee and you see over a period of time you keep on changing the diameter not the rupee that I have it looks similar to like 50 paisa that I used to have earlier. I do not know how many of you have even seen 50 paisa, but the point is we do not have a constant diameter of our currency, the coins are not constant.

There are several reasons why it is not constant let us not go into the finances. The reason of using the coin is to show you the device size that is it. So, we put 1 cent it is same diameter from years. So, it is easy to understand the device dimension compared to one cent then there was the only reason why we are still using the cent just to show you the diameter so that you can understand that how small your device can be.

But sometimes lot of us may not have seen cent actually. So, we will now know and that is why I also have a scale bar here. So, when you zoom this much area just this much area and you put this device as you can see here and what is the size the size is close to like this. It is a scale bar. So, the point that I am making is that sometimes we need to make sure that what are we representing and how well we are representing our device.

So, for people who understand what is the diameter of 1 cent for them it is easier to look at the cent and say oh this device is tiny, for people who may not understand we can always show with a scale bar or a ruler. So, whatever is easier. So, let us see in this video all these things and then we will go to the next video which will be little bit further about once you do the craniotomy and once you implant the device how you are going to seal the brain of the rat. So, I will stop here quickly we will move to next video as a part of this module and that will be video number 3. I will see you in the next video till then you take care, bye.