Advanced Neural Science for Engineers
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Lecture 45
Microneedle Electrode Array

Hello everyone, this is the third session if you recall and this session will be on the implantable MEAS. So, third session on the implantable micro electrode arrays if you recall the second and the first session then you will remember that we were talking about epilepsy as a model and in epilepsy we were talking about rodent because animal model would be rodent the disease would be epilepsy and the idea is to acquire the signals from the brain and those signals, we called as a ECOG signals or electrocorticography signals.

In the first session what we have seen is we have a flexible micro electrode array with 32 you know recording electrodes and we placed it on the rat's brain and then we can create epilepsy by using the convolutions like bicuculline and then we can recover the baseline by using different anti-epileptic drugs.

And from that we can see what is the efficacy of those anti-epileptic drugs or AED's. Then in the second version what we have seen is that how about we fabricate a bioresorbable flexible microelectrode array and the application is still same which is to understand the efficacy of drugs.

In that we have seen that once you implant the device and you record the signals after few days the device will absorb or it will be it is biodegradable and in the experimental procedure, we have seen that how we are using it in the in vitro situation or in the lab situation where we place the device in the pH 7.4 and look how it is degrading across period of time.

We have done the same experiment on the animal model which is by implanting the device in rat's brain and looking at how it is degrading across period from three days to seven days. At this point in time, we were not having access to the animal MRI otherwise we can also look whether this in terms of the MRI image how the chip is degrading across period of time like that one day, two-day, three day and so on.

So, the alternative way of what we understood whether it is absorbing or dissolving in the brain is by looking at the signals that we were able to acquire on day one versus day three

versus day seven. Once the signals are gone, we assumed or we presumed that this is the way to look at the methodology to look at the bioresorbability we assume that it is dissolved but a better way would be to look at the animal's brain in animal MRI and see how the device is dissolving with respect to time.

This is a third session where we look at the implantable microelectrode array for recording neuropotentials from rodents and in this case, we will be talking about micro needle base microelectrode array.

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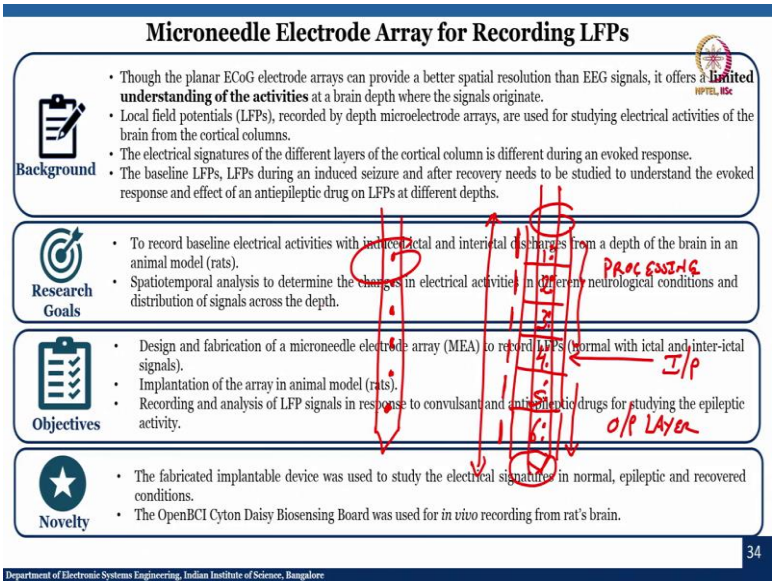

You all know about needle and you all know about microelectrode array how we are integrating those electrodes recording electrodes onto a single shank or a micro needle electrode let us see that. So, as usual we start with the background we do the we understand the research goals we look at the objectives and then we look at the novelty factor.

The first is background. Background as you can see that though the planar ECOG electrodes that is you can place on the surface can provide a better special resolution than EEG signals it offers a limited understanding of the activities at a brain depth where the signal originates and that is very important.

Because, you are looking at the surface and acquiring the signal, what happens in the in the deep down the brain we do not know but if we have the micro neural arrays, you can integrate those or you can place those in depth at of the brain and can understand or acquire the signals so that you can further study those signals.

Now, what we call is as a local field potential recorded by depth micro electrode arrays are used for studying electrical activities of the brain from cortical columns. Very important term came now which is cortical column. So, the array of cortical columns you can see the cortex area of cortical column and each column if you just take it in the brain each cortical column will have six layers. 1 2 3 4 5 and 6 all right.

So, second third fourth fifth and sixth this is a column you can do look at this it look s like a column. So, this is a column now we are talking about rat a rodent model. Now, fourth the layer fourth is an input layer, layer one two three is processing layer, layer five and six are output layer all right.

So, we if you want to go inside the brain deep inside the brain, we need to create a electrode that can fit in this particular column and can measure the changes from each column, what changes you can measure or acquire the electrical signals. Now, to penetrate it we make it like a needle all right.

So, this each electrode would be a recording electrode we will see how to fabricate those according electrodes and each electrode or group of electrodes will fall with the same within the same layer. So, to acquire signals from each layer, so can be one electrode can be two electrodes so if there are two electrodes like this then how many electrodes we require, we require 12 electrodes because two per layer we have six layers so there are 12 electrodes.

So, your device should be like this where it has 12 electrodes and then from the brain, we can acquire the signals from all these 12 electrodes. Or if you want to be easier you can have only six electrode one two three four five six one from each layer you can have one electrode that will acquire the signal this much easy. So, what we understand is that now we need to understand the local field potential at different depths.

Depth is from layer 1 to layer six. Now, let us move to the next point, the next point is that the Baseline LFPs Baseline local field potentials, local field potential during an induced seizure when the epilepsy is going on and once you load the anti-epileptic drug or you administer the anti-epileptic drugs the recovery of the signals this all things creation of the first is a baseline then the ECOG during the induced seizure and the signals that you obtained when the recovery has been occurred.

So, this all needs to be studied or to understand the evoked response and effect of anti-epileptic drug on LFPs at different depths correct. Because, then only we will know that how

the AEDs are effective or not. So, you still understand that the goal is still epilepsy but, in this case, we are looking at the depth of the brain other than the surface by using the depth electrodes.

So, what should be the research goals then, the research goals are following, the first one is to record a baseline electrical activity which induce ictal and interictal discharges from depth of a brain in animal models that should be the first baseline electrical activity. And, and once we can do that for doing that we need to anyway fabricate a device.

Second is that this special temporal analysis to determine the changes in electrical activities in different neurological conditions and distribution across the depth that is another thing that we need to identify or measure or acquire. Now, this changes in electric activity you can again understand once you have the micro electrode array and, in this case, we have to go deep down that is why I told that we are going to use the needle kind of electrodes.

So, in terms of objectives one is the design fabrication of micro needle electrode arrays MEA to record the local field potentials normal with ictal and interictal signals during the scissors and during the admissions after the administration of AEDs. The implantation of the array in animal models how to implant it, where to implant it, how deep it should go there is another thing.

The next thing is recording and analysis of LFP signals, local field signals in response to convolution and AED's for studying the epileptic activity. Now, this is the three different objectives, let me go to the novelty factor. Novelty factor is the fabric implant device was used to study electrical signature in normal epileptic and recovery conditions but there is there any change in the design that we have made which can fall in the novelty.

And of course, there was before what we propose or what we have done or how we have acquired the signal this Open Cyton Daisy biosensing board was used only for acquiring signals from human brain it was never tested on animal model. So, so we were, we tried it to acquire the signals from the rat's brain.

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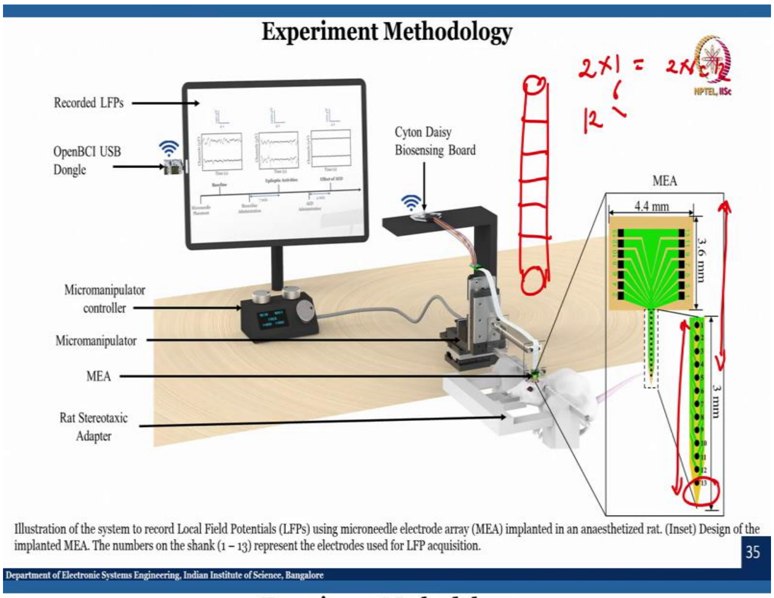

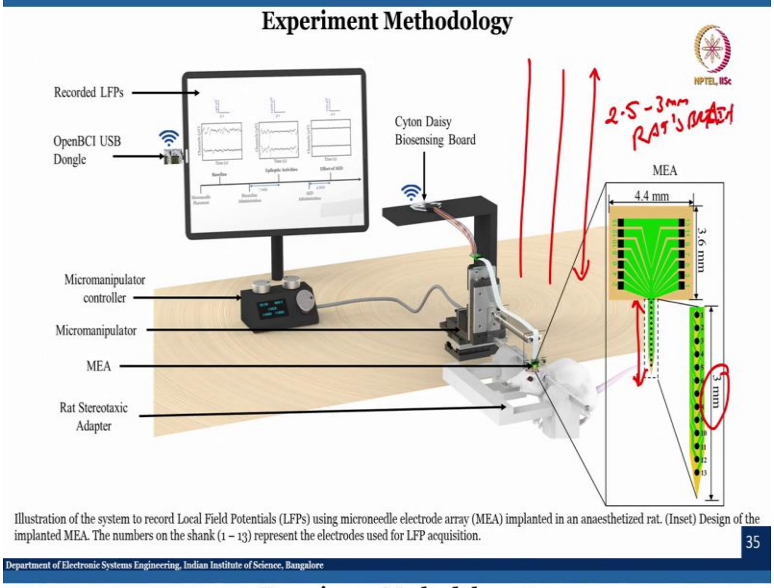

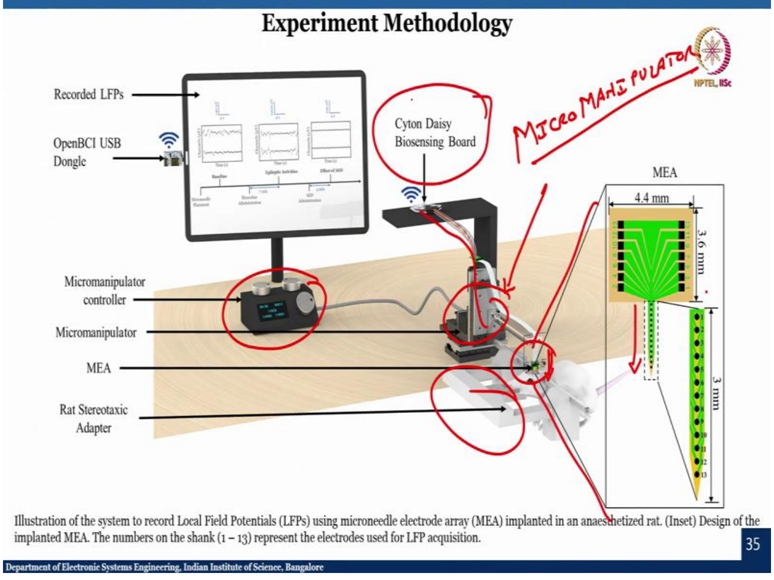

Here is the figure you can very clearly see a beautiful schematic where how we are going to perform the experiments. So, the micro needle that we are talking about has many electrodes as you can see here about 13 but I told you that there are six layers in a column six layers and why there are three electrodes.

If I have two per column then I should only have I should only have 12 electrodes two per column two into one column how many columns were there, there are six columns. So, 2 into 6 becomes 12 simple math but here you see there are 13 electrodes. So now, can you tell why the 13 electrodes, think about it why there are 13 electrons instead of 12 and we require only 12.

So, if you know the answer it is great, if you do not know it is absolutely fine. We require one electrode for ground and also the remaining so with respect to that electrode we are going to measure the signals. So, one extra electrode is there and now the size of this particular needle the depth that can go is 3 millimetres.

You can see the depth this depth is from this one this depth. Now, why 3 millimetres? Because, most of the time the, the length of this cortical column is 2.5 to 3 millimetre in rat's brain, what is a length, 2.5 to 3 millimetre in the rat's brain. And that is why we have the we have the length of this needle as 3 millimetres. What is the width of this chip? 4.4-millimetre 3.6 millimetre this is your micro electrode array but, in this case, it is needle which the MEAs or electrode array recording arrays are integrated onto the needle.

Now, we have this particular stuff and this is nothing but your micro manipulator, micro manipulator. This micro manipulator we can integrate the micro needle as you can see here, we perform the craniotomy and then you place this needle inside the brain of the rat. Inside the brain of the rat, it is Micron Precision.

So, we can we can control it with the help of the micro manipulator controller which you can see in this case here micro manipulator I already told you that this is shown here then microelectrode arrays are here this the zoom in version is here and then rat's stereo adapter is right over here so we have everything ready the signals that you acquire goes through the cyton bio sensing board, Cyton Daisy biosensing board and these are transferred to the OpenBCI USB dongle via Bluetooth.

And what you can see on the screen are the local field potentials from the from baseline when there is epileptic activities and when there is a AED that is administered in the rat's brain. So,

it is administered rat's body. So, the, the efficacy of AEDs can also be again measured using this particular technique.

So, if you if you read it is a illustration of the system to record local fill potential using micro needle electrode array implanted in the anaesthetized rat it is under anaesthesia the inside shows the design of the implanted MEA. The number of Shanks are 1 to 13 different electrodes using for the LFP acquisition.

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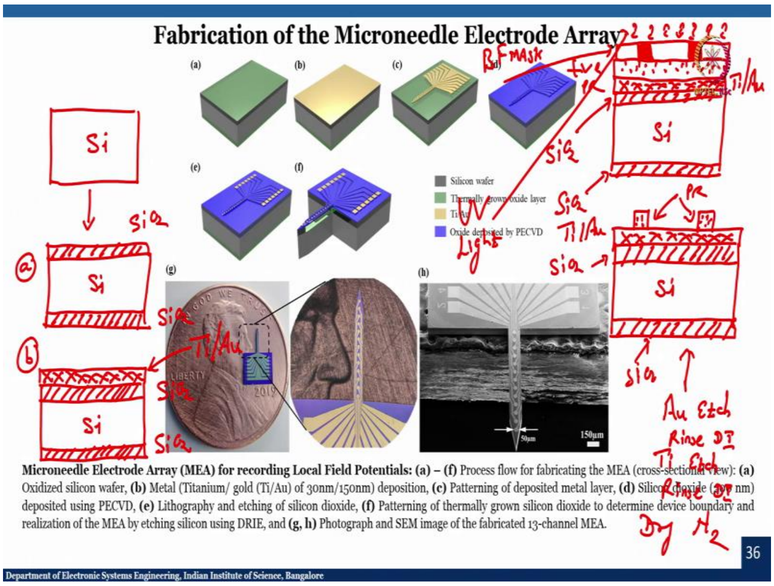
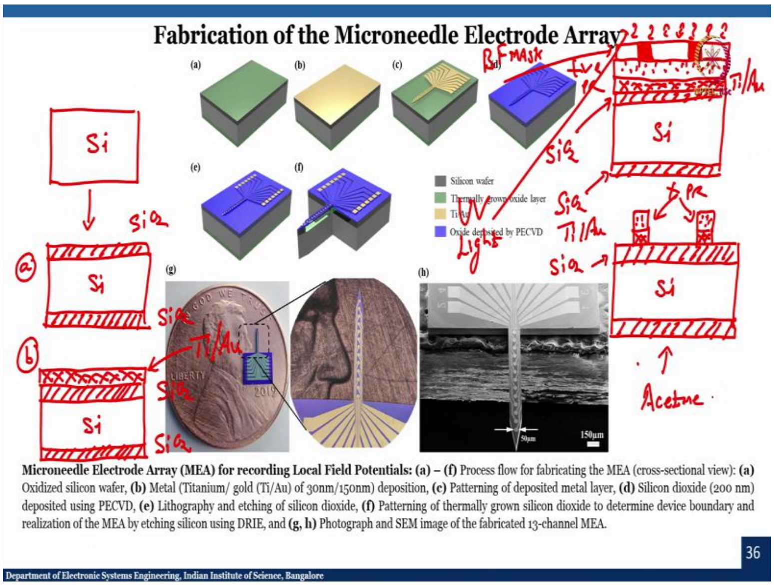
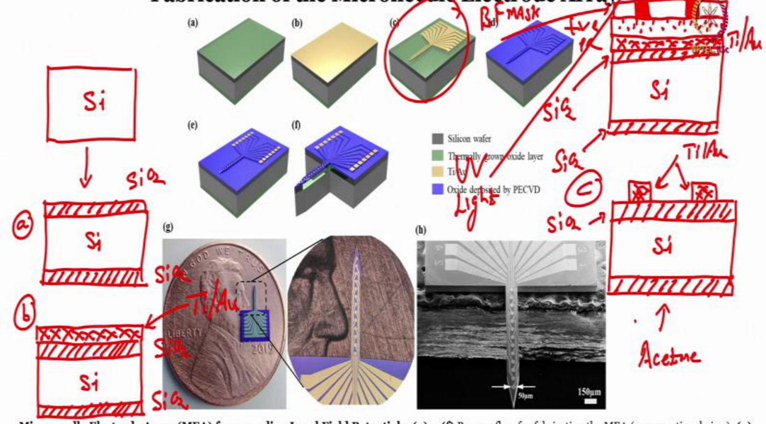
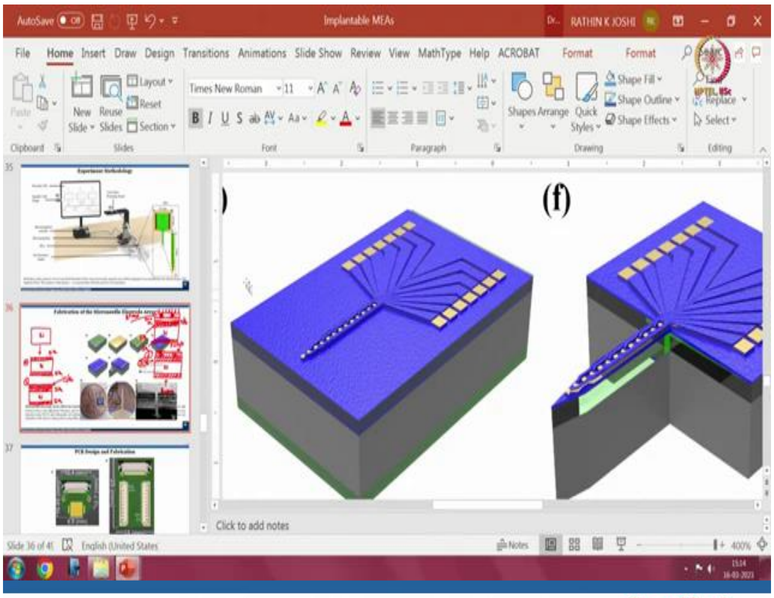




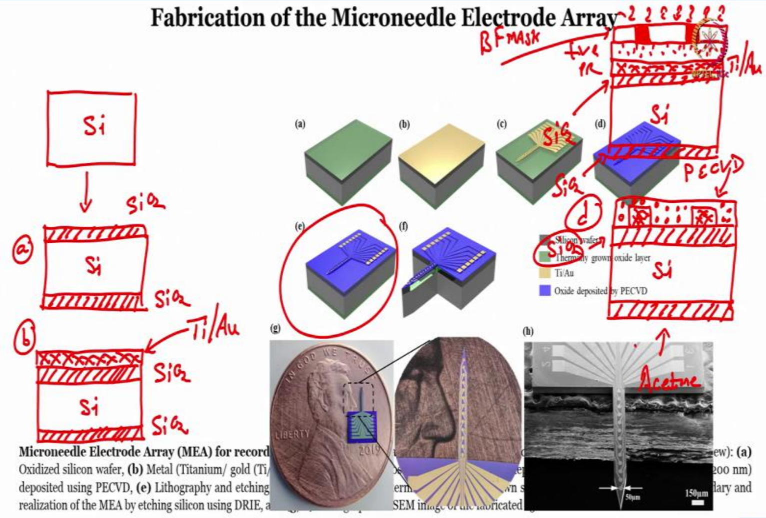
Fabrication of the Microneedle Electrode Array



Microneedle Electrode Array (MEA) for recording Local Field Potentials: (a) – (f) Process flow for fabricating the MEA (cross-sectional view): **(a)** Oxidized silicon wafer, **(b)** Metal (Titanium/ gold (Ti/Au) of 30nm/150nm) deposition, **(c)** Patterning of deposited metal layer, **(d)** Silicon dioxide (200 nm) deposited using PECVD, **(e)** Lithography and etching of silicon dioxide, **(f)** Patterning of thermally grown silicon dioxide to determine device boundary and realization of the MEA by etching silicon using DRIE, and **(g, h)** Photograph and SEM image of the fabricated 13-channel MEA.



Fabrication of the Microneedle Electrode Array



Microneedle Electrode Array (MEA) for record ... ew): **(a)**
Oxidized silicon wafer, **(b)** Metal (Titanium/ gold (Ti/ ... 200 nm)
deposited using PECVD, **(e)** Lithography and etching ... dary and
realization of the MEA by etching silicon using DRIE, a ... SEM image of the fabricated ...

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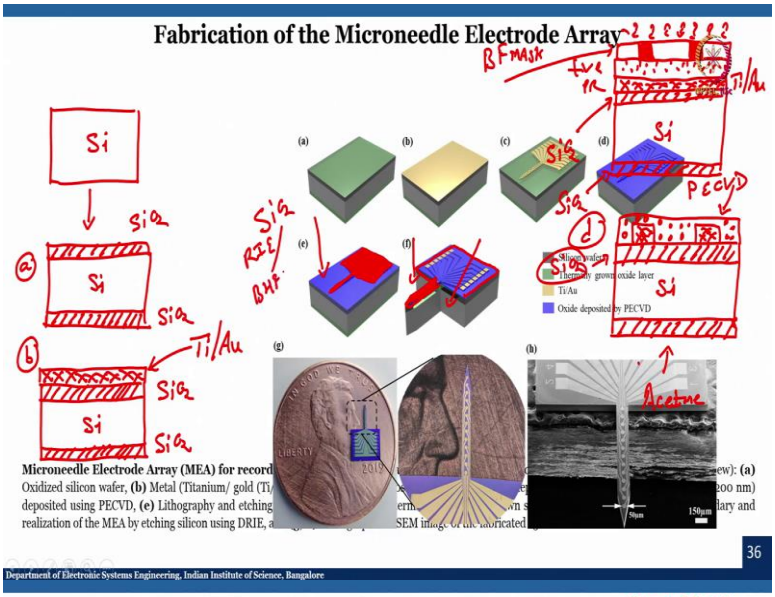

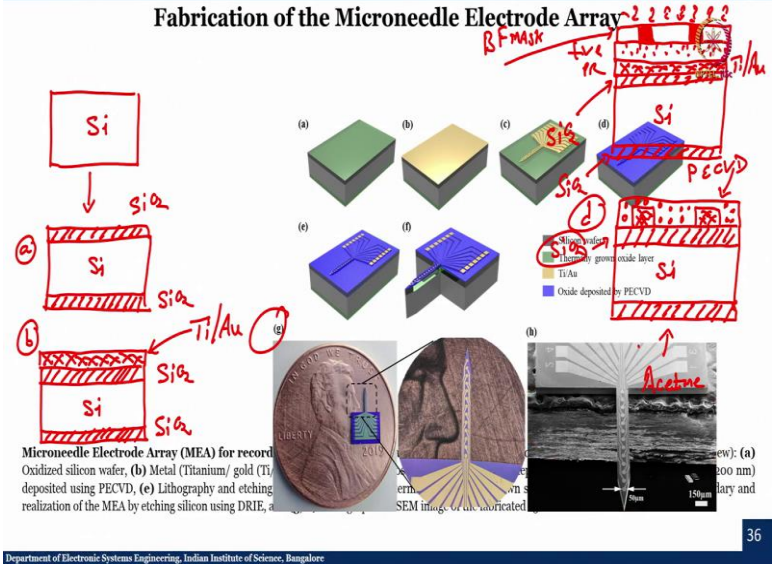

So, the favourite part, what is favourite part a fabrication. So, let us see how we can fabricate this particular needle. Now, what is this particular stuff you see here the grey colour is silicon, green colour is SiO2, gold is Ti Au and blue is oxide. Just to represent it oxide which is by PECVD.

Plasma enhances chemical vapor deposition this is a technique by which you can deposit the silicon dioxide or insulating material like Silicon nitride and silicon dioxide at a lower temperature. The reason of having lower temperature I will tell you in just few minutes. So, first you take a silicon wafer now this everyone understands very well how to fabricate device, is not it, then you take and then you grow silicon dioxide on Silicon wafer with help of the thermal oxidation technique.

So, you can grow silicon dioxide you can see here and we have it here so what is it SiO2 here also we have SiO2 this is silicon. So, then we have this particular a, is not it. Now, what you

do is once you have this one then you deposit your titanium and gold, titanium gold because chrome gold chrome is known to be a toxic for the implantable devices that is why we go for titanium gold this is again your SiO2, SiO2 silicon and then on Silicon you have a layer which is nothing but your titanium and gold Ti/Au, Ti/Au.

So, this is your b now so where is it this is your a and this is your b easy everyone. Now, what we do, we pattern this you see we pattern this so patterning everybody knows I am just showing you to some cross section of this electrode like this. So, so do not worry about how exactly the top view looks like, this is the side view across external view. So, you have your SiO2 and you have your titanium gold and now I have to pattern this.

So, I will spin caot my photoresist our favourite part of photoresist positive PR what is this one Ti/Au titanium gold. SiO2 silicon SiO2. Now, on this we have the mask, where the mask just to represent the electrodes we just draw like this and this will be our bright field mask. There is our bright field mask. So, this one will be your bright field mask after that so positive PR you have to do soft bake load mask and then expose with what is this one UV light, expose with UV light.

And after that you unload the mask and develop the wafer, unload the mask and develop the wafer. So, what develop the wafer means develop the photoresist on the wafer then what will I have I will have my oxide and then on my oxide I will have Gold, Titanium gold, titanium is used to improve the addition of the gold. And then I would have my photoresist in these two areas.

Why because positive photoresist the same pattern that is there on the mask will replicate on the wafer or on the water resist or in other terms the unexposed area will get stronger and the exposed area will get weaker. So, this is my positive photoresist remaining things you know Ti/Au SiO2 silicon SiO2.

Now, what I will do, I will dip this wafer I will dip this wafer in Au etchant then rinse it with Di then dip the wafer in titanium etchant then rinse it with Di and then dry it with nitrogen sorry, dry it with nitrogen. So, first gold etches because gold is on the top then we rinse it with the Di water then we dip it into titanium etchant and again rinse it with di water and finally dry it with N2.

If you do so what you will get, if I do so what I will get, like this is not it, the area which is protected by the positive photoresist will not get etched the area which is not protected will

get etched simple. Now the next step you dip this wafer in, dip this wafer in acetone if I dip this wafer in acetone then my positive photoresist will be stripped off photoresist will be stripped off and I will be left with my titanium and gold, is not it.

I am left with my titanium and gold because my photoresist has been stripped off. So, if you have this then this will be your, this will be your C this one, I hope we all are understanding and we are on all on same page. So, for a is an oxidized silicon wafer using thermal oxide for b we have titanium and gold for C we have performed photo lithography technique to pattern in the design that we want which is our micro needle array after this the next step so I will just draw it here.

So that we do not miss what we have to show next step is to grow silicon dioxide using so I will just show some different symbol for silicon dioxide. Let us say like this this is your silicon dioxide but why I am drawing like this and not the pattern which is similar to SiO_2 like this one.

So, because this silicon dioxide is grown using plasma enhanced chemical vapour deposition. Now, let us understand why we have to use the oxide which is reposited by PECVD and not thermally grown in this case why I have used PECVD and not thermally grown oxide the reason is that for thermally grown oxide for thermal oxidation we all have understood and seen that the temperature is about 900 degrees centigrade to 1100 degree Centigrade.

And this is extremely high temperature for the material which is below it that mean in this case it is Ti/Au but if it is Aluminium, it is it is nickel if it is nichrome or some other material that cannot withstand this temperature then it will then we cannot get our device we cannot get the pattern the metal will be affected the material will be affected.

And to avoid that effect, the affection of the material the because of the chemicals or because of the temperature in this case that is 900 to 1100 degrees Centigrade we go for an alternative technique of growing so this 900 to 1100 degree centigrade is for thermal oxidation is for thermal oxidation. And we have wet oxidation, we have dry oxidation in both the cases you require this temperature but we cannot have this temperature because the metal below it may not be able to withstand the material on which you are growing this silicon dioxide may not be able to withstand.

So, what is an alternate alternative technique, the alternative technique is to use, alternate technique is to use plasma enhance chemical vapor deposition to grow your oxide because

PECVD you can use 100 to 300 degrees centigrade to grow your SiO2 or even silicon nitride you got it now the reason of using oxide deposited by PECVD. Yes. But if there is no metal if there is no material then you can grow for the thermal oxide where the thermal oxide always has a better quality of oxide compared to a PECVD oxide.

So, after this now once you have this what is the next step, next step if you see on this is becomes very easy that once you have this PEC oxide which is your D, this is your C and then now it is it becomes D that means that is PECVD oxide is there what is the next step we have to open the contact pads and open the recording electrodes you can see here the in this micro needle you can see dots, this dots are so let me just try to zoom in further.

I do not think I can zoom in but let me try, you see here now you can see very clearly what you can see is that the that the oxide from the recording electrodes from the recording electrodes and the contact pads so you can see the my pen moving these are the contact pads, contact pads and these are the dots are the recording electrodes you can see that blue colour is gone from there that is because we have performed, we have performed photo lithography technique to remove the oxide only from those electrodes, contact electrodes and recording electrodes.

Now, what you do is you save the front side and by protecting all the region except this needle region you see a protecting only sorry, protecting only needle region except a needle everything is exposed, everything exposed that means that only on this region and on this one you would have your photoresist.

So, in this case I will have a photoresist which will cover my needle and this part like this and everywhere here. I will coat photoresist and pattern it using lithography like this. Now, if I do this and the photoresist is only in this area the next step what I do is I will etch silicon dioxide silicon dioxide etching can be done using RI reactive and etching or using BHF buffer hydrofluoric acid.

If I do that then I can I can expose my silicon, is not it, I can expose the silicon. The next step is I will use DRIE once SiO2 is removed I will go for DRIE deep reactive etching it will etch this silicon completely from all the area which is not protected by the photoresist. If you do that then what you get is f which is here after DRIE you get this one and also this is just a representative like I said but in reality so yeah so once you etch completely you etch completely then you get this one.

Now, why we do not have to do front to back because the wafer that we start with is only about 100 microns, the wafer that we start with is only 100 microns in this case so the thickness of the cantilever can be hundred microns sorry, not this is not a cantilever I am sorry micro needle is only 100 microns.

So it looks like cantilever but here it is not released it is thick so it is a micro needle so micro needle the thickness is similar to the thickness which is here of the silicon and like I said it is 100 microns why the thickness 100 Micron is used because when you when you go for this needle and then you implant it then this one would be somewhere around 200, 200 to 300 micrometre.

The diameter of the quad column would vary from 200 to 300 micrometre 100 micrometre will go in and can record the signals that is the reason of using 100 micrometre thick wafer. So, that finally the micro needle thickness will also come around 100 micrometres the g shows the actual micro electrode arrays or the electrode arrays on a micro integral and this is the zoom in version of the same.

Where you can we can see that how the very clear titanium gold patterns can be seen everything is covered by an oxide except the recording electrodes. Now, you will say that I cannot see the oxide you cannot see the oxide because the oxide is about a micron or so and or even less like half a micron and oxide is always transparent. So, silicon dioxide since is a transparent you can you can still see the as if there is nothing on the other area but all this area actually has oxide.

And only the recording electrode and the contact electrode does not have any oxide this is an SEM of the same, the SEM of the micro needle.

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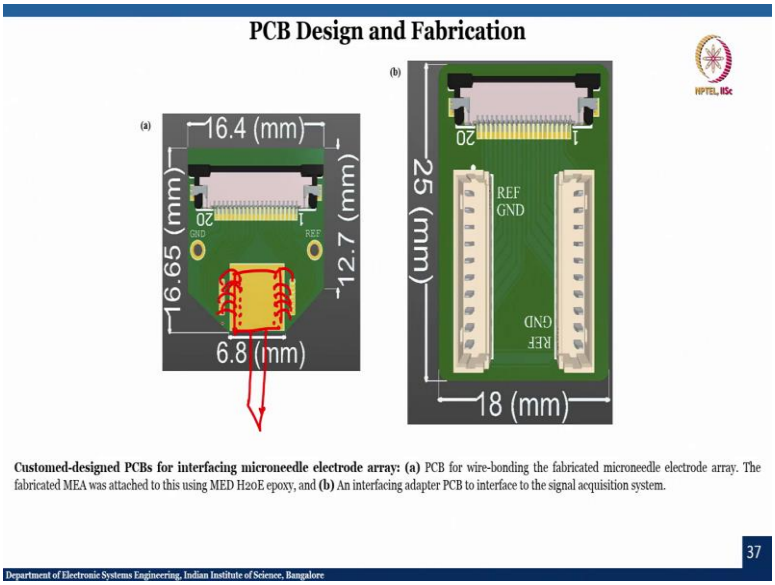

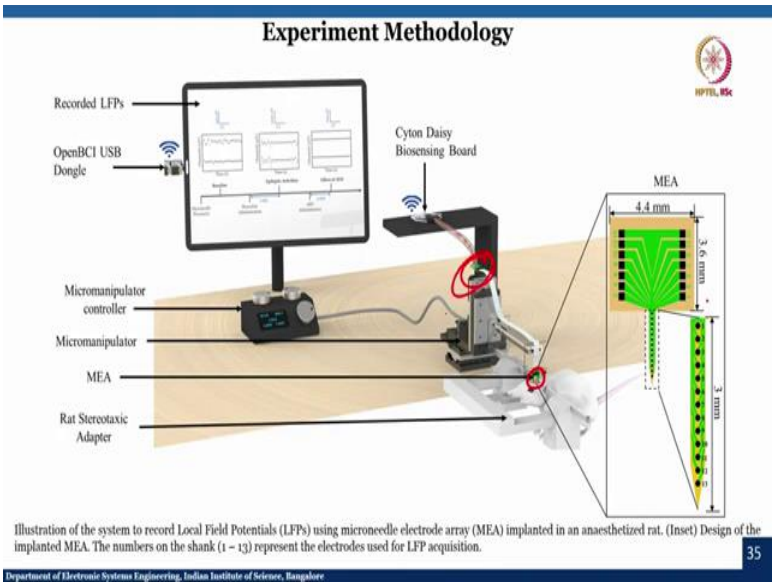

Now, once you implant it you need to also attach it to the electronics you can see here this this needle is there but finally it is attached to the electronics so that it can be further used for acquiring the signal. So, for that we have a PCB for wire bonding the fabricated micro needle you can place the micro needle in this area and then it goes like, like this and the pairs of the micro needle can be wire bonded onto this like this.

So, that is how the PCB can be utilized and this comes under packaging, electronics packaging the b is interfacing adapter PCB to interface the signal activation system. So, a and b's are very clear.

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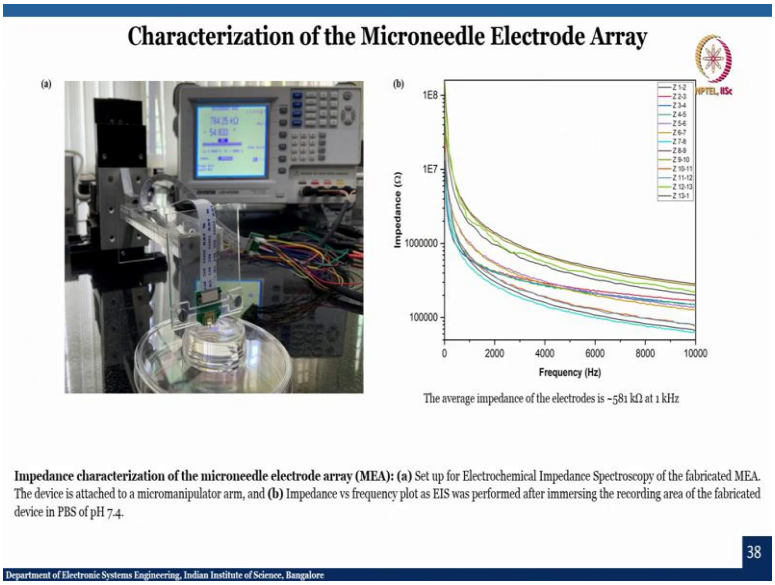

Like any other electrodes that we have fabricated till now we also have to perform the characterization of this particular micro electrode array micro needle electrode array so for that we have done the experiment using electrochemical impedance spectroscopy and the device is attached to the micro manipulator arm as you can see in the figure a.

While the impedance spectroscopy data is shown in figure b is impedance versus frequency plot after immersing the recording area of the fabricator device at pH 7.4.

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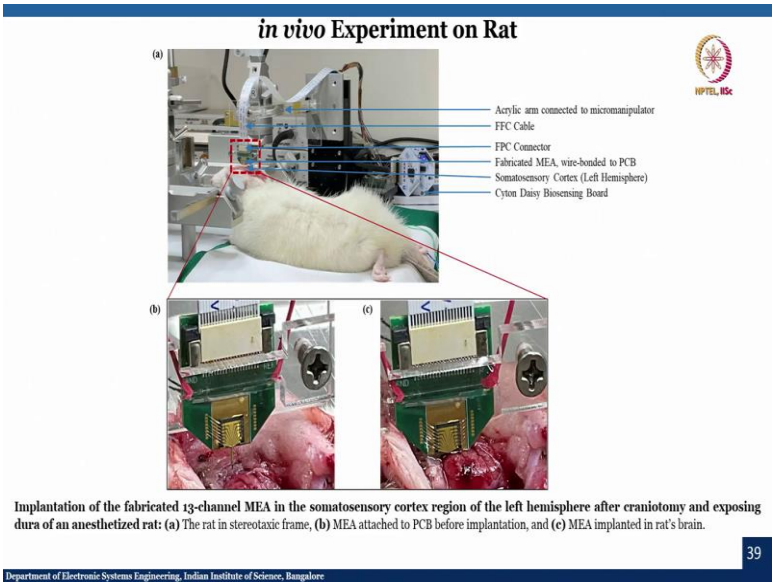

In this case what you can see is that an actual image or photo of the rat during the experiment and you can very clearly see that how the acrylic arm is connected to the micro manipulator to which there is an FFC cable it is there is an FPC connector and to which there is a

fabricated MEA wire bonded to the PCB and there is a somatosensory cortex on which the device needs to be placed or implanted and then there is a Cyton Daisy board.

Now, in this case the b shows that we are ready to implant the c shows that the needle is inside the rat brain,

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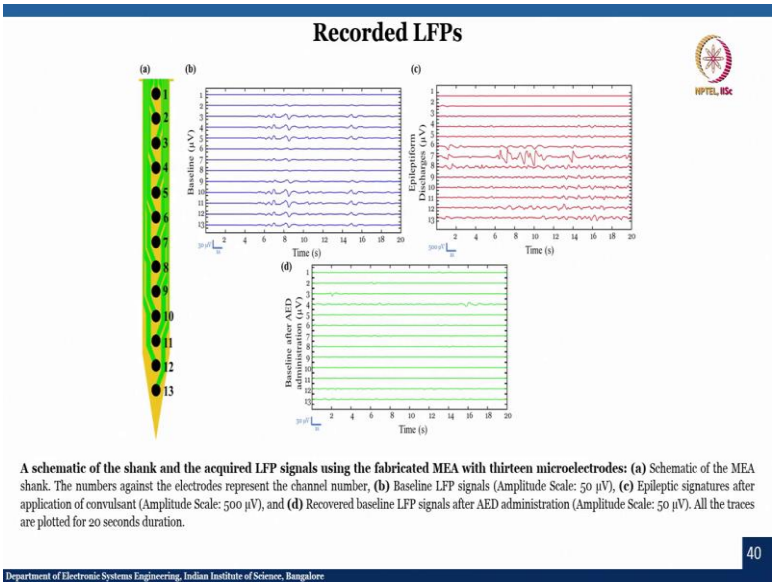

So, when you record the local field potentials how it will look like. So, you can see that the recorded channels are 13 one I as I told you with respect to the channel, we keep on recording the signals so the y axis is baseline micro volts also the number of channels and the in terms of voltage and then and the on the x axis you have time and its time is for 20 seconds.

So, you can see that how the voltage would vary with respect to time and in case of baseline signals the amplitude max amplitude is 50 micro volts while in case of epileptiform discharges you can very clearly see that the signals has the strength has increased to 500 micro volts in that range while in case of administrating the AED through the rat's tail what we can observe here is that the baseline is recovered and the value amplitude value is close to 50 micro volts.

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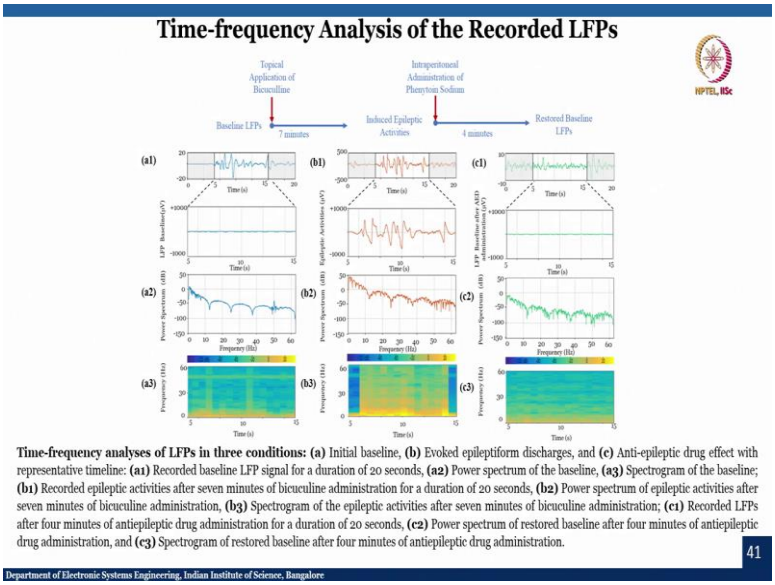

When we perform the time frequency analysis you can see that when the when we get the Baseline values and as you can see from a1, a2, a3, a1 shows the LFPs baseline then a2 shows the power spectrum analysis and a3 shows the corresponding frequency with respect to time the power spectrum analysis and all this a1 a2 a3 will show the baseline form as soon as you apply the topical the topically the back equivalent which is a convolution and wait for seven minutes you can start seeing the episodes of the epileptic activities.

And it can be clearly visible also in frequency spectra, power spectra and when you apply the inter peritoneally the phenytoin sodium which is the anti-epileptic drug after four minutes the baselines are restored here also you can very clearly see the LFP is reflected after administrating the AEDs. And same thing power spectrum and the frequency spectrum.

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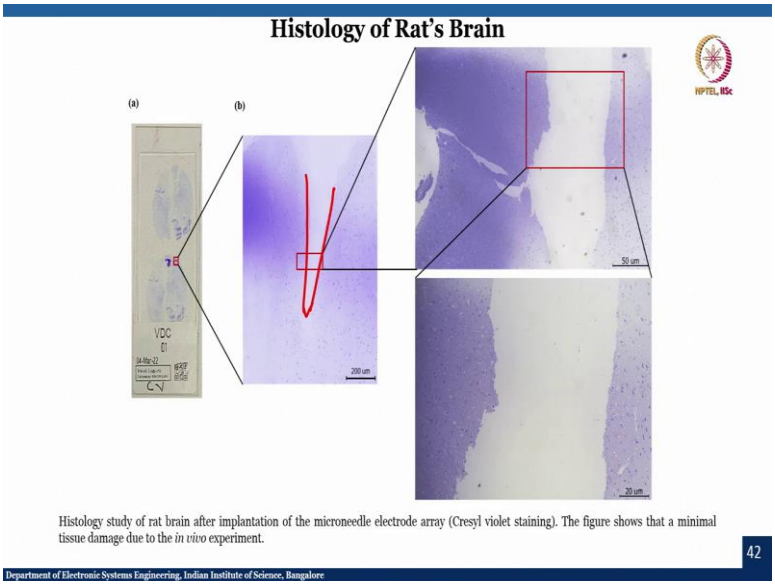

So, this is the histology of the rat's brain you can see that how the needle has penetrated inside the rat's brain and it is a Cresyl Violet staining the figure shows that a minimal tissue damage due to the in Vivo experiments has occurred to this using this particular what you call the experiment methodology.

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We have some fabricated, we have some patterns and some publications around this area now let us not worry about it now let us see the last part of it which is the last session. Now, what I want to show until that now what we have seen we have seen an implantable flexible micro electrode array then we have seen bioresorbable implantable micro electrode array then we

have seen single shank it is one shank one needle one shank integrated with micro electrode arrays.

Now, in this session what I want to show it to you that what happens when you want to acquire the signal from multiple regions in that in the same area of the brain. So, for that you need to create more than one macro needle it can be two three four depending on what is the area of interest. So, for hippocampus the way to design the electrodes would be different compared to the motor area compared to the visual area and different regions in the brain.

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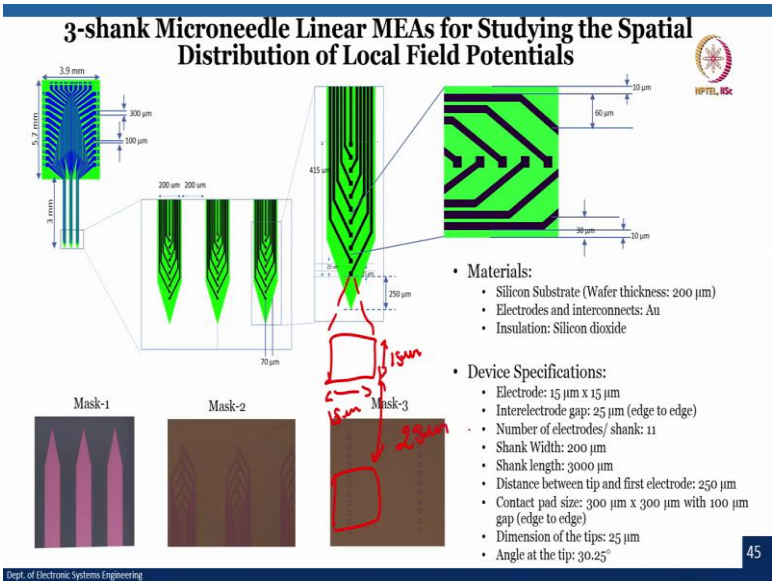

So, let us see what are the different kind of micro electrode arrays that you can fabricate, here you see that there is a three-shank micro needle linear MEAs for studying the spatial distribution of the LFP's and here the again the depth is close to three millimetre the distance between two electrodes or two shank is about 200 microns.

The each recording electrode as you can see here each recording electrode is close to 15 micrometre and the spacing between each electrode is 25 Mega meter means that if I zoom this one I zoom this one then I have this so this is my 15 micrometre by 15 micrometre. And the distance between two so, I have one more electrode then the distance between two is about 25 micrometres. So, that is where we are from the understanding the electrode size, recording electrode size and the it will record somewhere from 415 Micron area what else, what else, yeah, the width this width, this width is about 10 microns, 10 micrometres and the there are three masks is a three mask process.

So, mask 1 mask 2 mask 3 the materials are silicon is a substrate we have a thickness come close to 200 micrometres like I said you can convert, you can change the thickness from 100 micrometres to 200 micro meters if you really want to have only 10 micrometre thick wafer then there is an alternative technique then what I have been showing it to you which will not take as part of this particular course other otherwise it becomes more like the fabrication and the less than the application.

So now we have the electrodes and interconnects which are made up of Au when you say Au that should be always an addition layer which is your Titanium or Chrome, I told you that Chrome is bio not biocompatible that is why we go for the titanium gold and the insulating layer in this case is silicon dioxide. So, these things are absolute clear with all of us now let us look at the device specifications.

So, electrode size is 15 by 15, interelectrode gap is 25 number of electrodes or shanks are 11 is your current number of electrodes per shank, per shank, so let us understand this is 1 1 2 2 3 4 5 6 7 8 9 10 11 this is 11, this is 1, 1 to 11. So, there are 11 electrodes on the particular shank on each shank.

The width is about 200 microns, length is 3000 microns which is three-millimetre distance between the tip and the first electrode is 250 micrometres the contact pad size is 300 by 300 micrometres which is the contact pad is this one. If I have a then this one 300 by 300 that is a contact pad size here and with 100 micrometre gap that means that between two contact pads there is a 100 micrometre gap.

This is about 300 these contact pads, dimension of the tip is 25 microns, angle of the tip is 30.25 degree. So, this is what are the specifications of this micro electrode single chain now we have three shanks here so we can cover a larger area.

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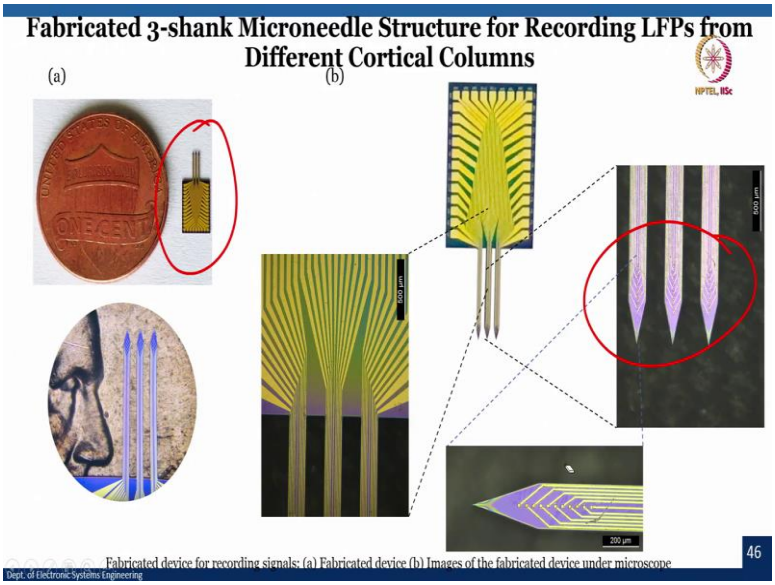

This is an actual photograph as you can see we have place the micro electrode structure 3 shank electrodes against the one cent to see the size and you can you can appreciate that how small these needles are when you when we if you have ever seen one cent then you will really know that this is really really tiny.

And then you can see different photographs of those micro needles including the one here and if we zoom in it looks like this a beautiful you can see very clearly here is a purple colour, the purple colour it should be grey even silicon but purple because there is a silicon dioxide that is grown on the on the gold or deposited on the gold and then only gold contact pads and the recording electrodes and so and the contact electrodes in the record electrodes which is the these are the recording electrodes the oxide is removed from this region and then finally the DRIE is performed to realize the micro needles.

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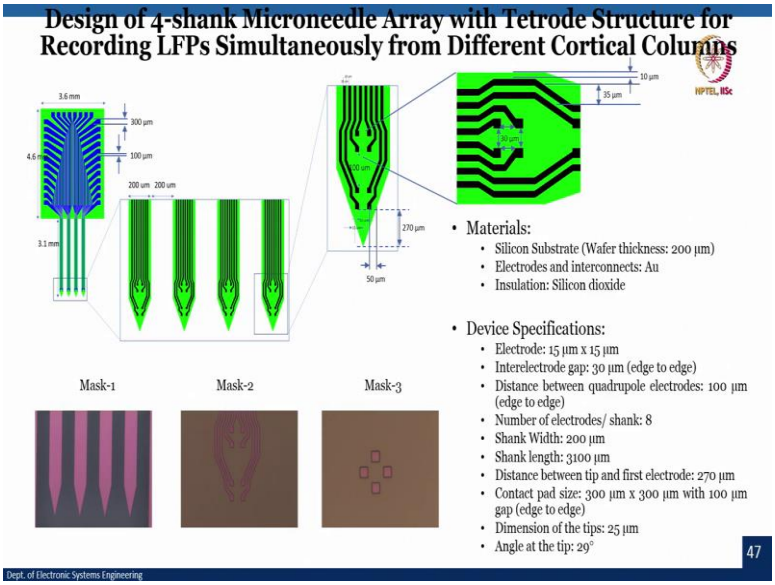

Now, in the area of Neuroscience we use four tungsten wire and fuse it together, fuse it together like this. So, that you have in on the tip you will have four electrodes like this, these four electrodes are at the tip you can understand like this the tip is there and 1 2 3 and 4 and these 4 electrodes will be able to measure the signals from the surface or from the depth these are called tetrodes.

Because, there are 4 in numbers so they are called tetrodes and we can have two different tetrodes on the planar structure. So, in this case you can see that there is a device with four shanks and each shank has two tetrodes, tetrode 1 and tetrode 2. So, we have total eight tetrodes.

So, the materials are silicon substrate wafer thickness is about 200 micrometres electrodes and interconnects which is made up of gold insulating layer which is silicon dioxide, device specifications are again given in this particular case where the electrodes are of 15 micron by 15 micrometres the interelectrode gap is about 38 30 Micron micrometres which is the edge to edge and then find and then distance between quadrupole electrodes or quads are about 100 micrometres.

Number of electrodes are 8, distance this one is 100 micrometres, 100 micrometres. And then number of electrodes are 8 on each shank the length of shank is 3.1-millimetre distance between tip and the first electrode is about 270 microns the contact pad size about 300 by 300 microns with width of 100 Micron with 100 Micron meter gap between two contact pads.

These 100 microns we are talking about is edge to edge finally the dimension of the tips are somewhere around 25 micrometre and the angle of the tip is 29 degrees centigrade.

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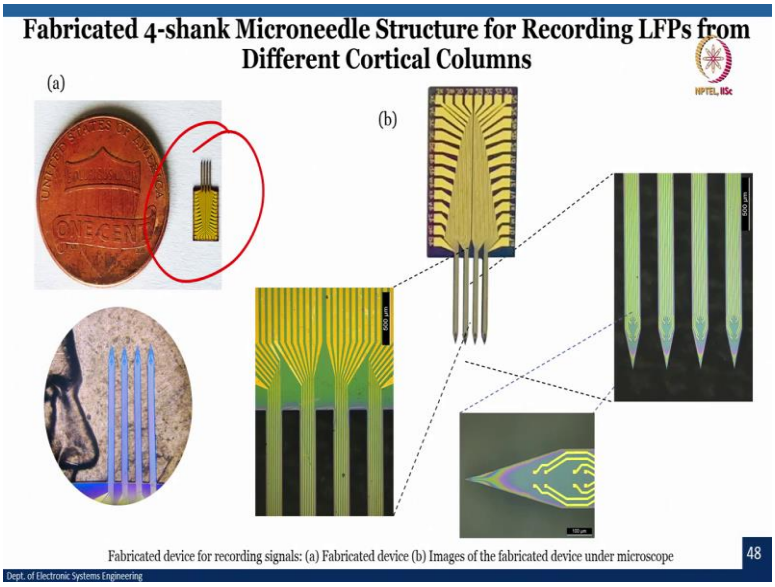

Our actual photo not just simulation or theory it is an actually fabricator device and when we say fabricator device you know it requires you to design requires you to design the mask to the simulation and then to fabricate. So, there are actual fabricator device done right here in in the Indians Institute of science using the facilities we use laboratory facilities that I have in the department of electronic system engineering is a is a nano Fab Lab with lot of interesting important equipment.

And for some of the processes we use the mother facility, so mother facility is what I have coined it, we have a nano fabrication facility which is CENSE and there we use all the CVD and RIE techniques. Here we can use PVD techniques deposition thermal e-beam sputtering, we can use photolithography, wet etching, optical microscope and so on.

There we use PECVD, LPCVD, RIE, DRIE and some characterizing like SEM and so on so forth. So, if you see the screen again, we are almost at the last few slides about the micro needles we talk about lot about the epilepsy and brain so I am sure that you want to move to next kind of topic.

But I just wanted to tell you that we are now in the capability of fabricating our own implantable sensors and recording electrodes, until now we used to buy and we still are buying and we are now trying to make everything within our country. So, there is a like I said is the last slide and we are finishing the session four at this point with a point that these are

not just what I am showing it to you and we are done but I will also show you the recorded video which we have done as a part of the experimental laboratory and for each video I will first introduce to you what you are going to see and then you will look into the processes.

The next session would be on the electrical simulation that we are going to use for the application in case of the deep brain stimulation, deep brain stimulation is nothing but the Parkinson's disease and how we can use this deep brain simulation what kind of experiments we can do or we are planning to do and again everything comes in the advanced stimulation. I hope that you appreciate the title of the course.

It is not just talking about the EEG signals and ECOG signals and different electrodes but also to fabricate those electrodes and implant it and record the signal and simultaneously we are going one step further of applying the electrical stimulation and correspondingly recording the signal.

I have told you about two different models, one is acute experiments one is the chronic experiment, acute experiment is where the animal is used and utilized you can say because we do not sacrifice animal without any purpose the we take the animal we implant the animal with the electrodes once the work is done the animal is euthanized while in the chronic experiment, we let the animal live for certain days till we acquire the signal.

For everything whether it is animal model or human model you need to have a clear ethical clearance to use those many subjects whether number of animals or on a number of human subjects like in the case of the neonatal hearing screening, so with that I will stop this discussion about microelectrode array.

But, one more topic we will be talking about where we will see that how the electrical simulation can be used for and very important disease other than epilepsy which is Parkinson. So, let us meet in the next class and we will talk about that till then you take care, see you then bye, bye.