Nanobio Technology Enabled Point-of-Care Devices
Prof. Gorachand Dutta
School of Medical Science and Technology
Indian Institute of Technology, Kharagpur

Lecture - 31
Self-Powered Biosensors

Dear all last few classes I thought many problems how to solve like many tutorials. So, let us again I wanted to teach you some new technology like Self Power Biosensors is really one more topic I will add in this course.

So, let us learn this after that again I will start some few more tutorial that will help you for your exam preparations. And as I told this all the tutorials I just taught you this is not just the solutions of your questions and answers this is also kind of new concept you are getting.

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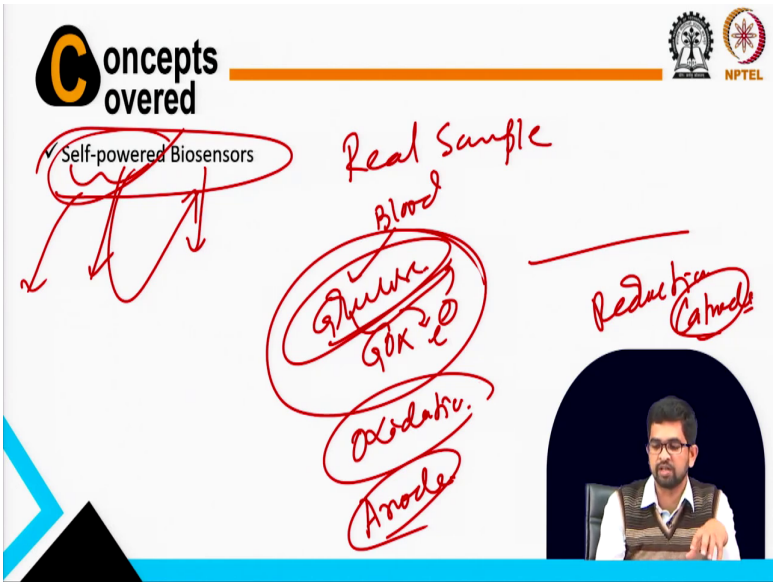

So, today I will cover mainly the self power biosensors. So, why we need the self power? So, let us first discuss this issue. See from the name itself you can understands right your biosensors its is self power and it do not need any extra power from outside. Generally, battery operated your one since and means its needs some energy you know to get, but to suppose we are applying some potential 0.3 volt I am saying or you are running a cyclic voltammogram you need some energy that energy you are getting from battery.

When you see your potentiostat your electronic circuit everything they need some energy that is battery operated, but this thing somehow you visited a very rural area and that area is very far from like your advance all the facility you do not have much power also. Or maybe some situations it may face you do not have for few days the power then what happened then your sensor surface will not work.

Now, for that purpose you can develop a self power biosensors means you may have power backup you may have battery, but still this can help you to generate some energy and that energy can provide to either sensor and it can use without any battery. Let us come this our real sample we are using for diagnosis know suppose blood sample.

So, it content glucose right this glucose also has some energy we can convert it with the help of like glucose oxidase right. We can oxidize the glucose and that we are getting the electron. So, here oxidations happen right maybe we can choose another electrode where you can try the reductions. So, one is the anode and another is the cathode.

So, if you have the anode and cathode means your battery means one battery you have. So, you can use your real sample and one component of your real sample like the glucose can help you to generate the energy that is the topic for today's lecture. So, anyhow you can, but you have to generate one electrode where oxidations happen or another electrode where reductions happen that I am going to show you.

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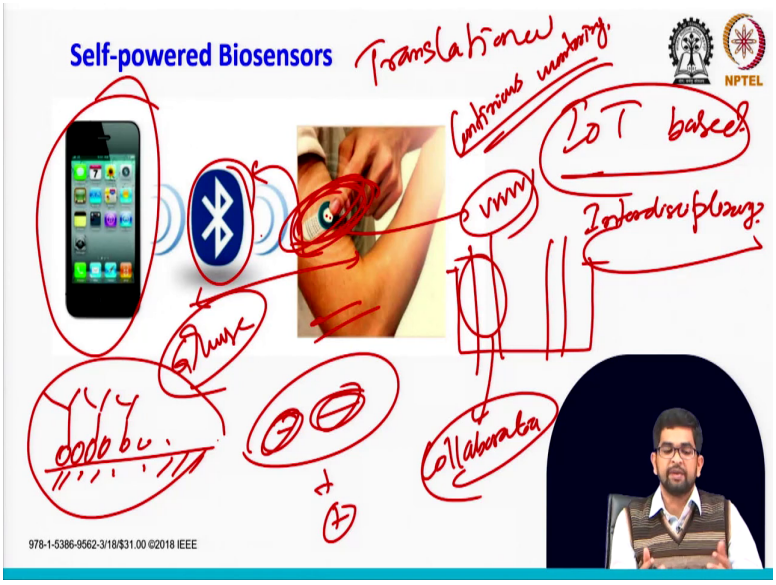

So, it cannot basically help you a cell power sensors and also it can help you like continuous monitoring just see in this case here one kind of design your smart phone integrated systems. Suppose you have like a like a banded kind of very simple a biosensor chip.

Suppose it can detect the glucose also, but it can detect the glucose at the same time it can generate the potential difference between the two electrodes like anode and cathode it can you can you can develop. And based on this is kind of a small battery like then you can integrate many this kind of cathode anode cathode anode many step by many.

Then you may get the sufficient power. A sufficient potential difference between the cathode and anode and you can now get the enough power or enough energy to run your potentiostat or run your electronic device that actually helping you to measure the your biosensor target.

Suppose in this case here targeted the glucose here it target glucose. So, you are going to derive the glucose.

So, in this case you can see in this simple sensor chip where it will get the glucose maybe it can get from the interstitial fluid it its it may have some small small micro needle and through this micro needle it will get the interstitial fluid and it content glucose from there it or maybe from the other real sample you can think. I mean they just for a concept I am saying. So, any solution that contained the glucose you can try for potential difference and for cell power biosensor development.

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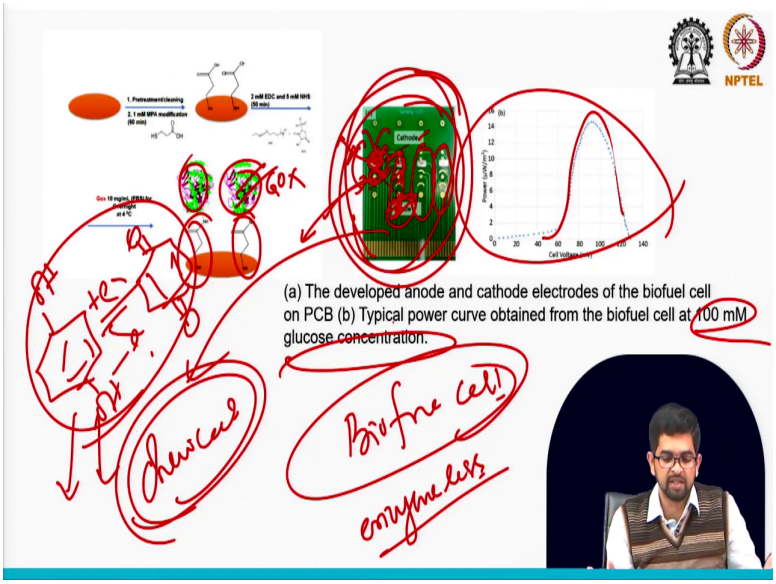

See here the design this is a PCB based cell power device PCB. So, here you can see the cathode and anode. So, anode here actually what we did see first we use some linker based on this linker we immobilize the glucose oxidase they are the glucose oxidase enzyme. So, in the

anode you can immobilize your glucose oxidase and cathode you can use some like platinum or something you can I mean there you may get oxygen reduction.

So, one surface glucose oxidation another surface oxygen reductions you can see in this diagram. Like here we can obtain a cell power biofuel cell and when we use like a 100 millimolar glucose then we may get this power versus voltage like how much power we can generate this is a kind of a battery right. That we can use for cell power biosensor development.

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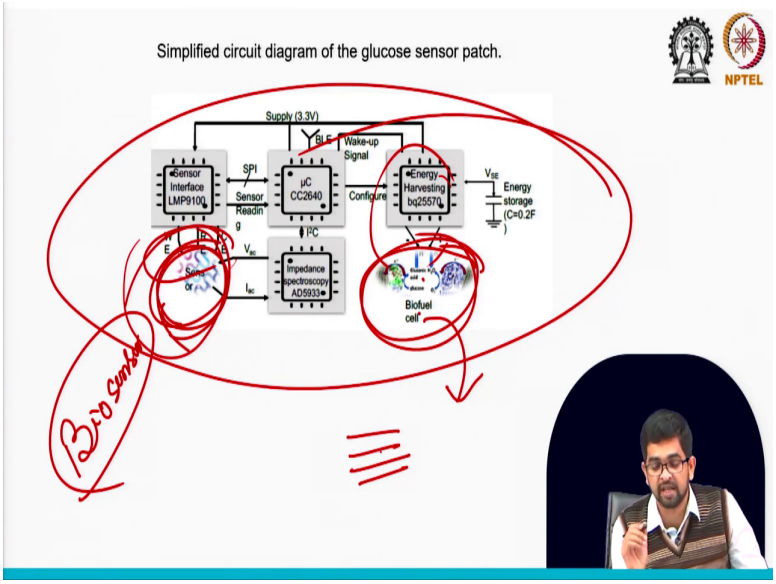

That see one thing here I actually I wanted to show you a very simplified circuit design. You can see here actually see here a biofuel cell that just last slide I taught you like this biofuel this is biofuel cell. So, this biofuel cell actually help generate the energy from glucose and

here you can again develop a like working electrode deferential current to counter electric you can see your sensor.

So, your actual biosensor here and actually your biofuel cell here. So, this is a complete circuit where one part you can use your biofuel cell another part you can use your biosensor. So, biosensor now means it will get the enough energy from the biofuel cell it will harvest the energy. That energy actually we will use for the sensing applications this technology will use.

And then finally, we will try this wirelessly we can transfer the data for that also you need energy that is amplifications also we can do here in the circuit design who are actually from the electronic background I will recommend them to think about this kind of the circuit design.

So, this is because this is very much specialized for them. So, that is why I do not want to go very deep inside the circuit design? Because mainly I just want to tell you the very generic concept if you want a cell part device that is possible. So, one you can develop biofuel cell. So, one is the cathode development the anode development based on the oxidation and reductions and another part the different biosensor ok. That is the design here in this slide.

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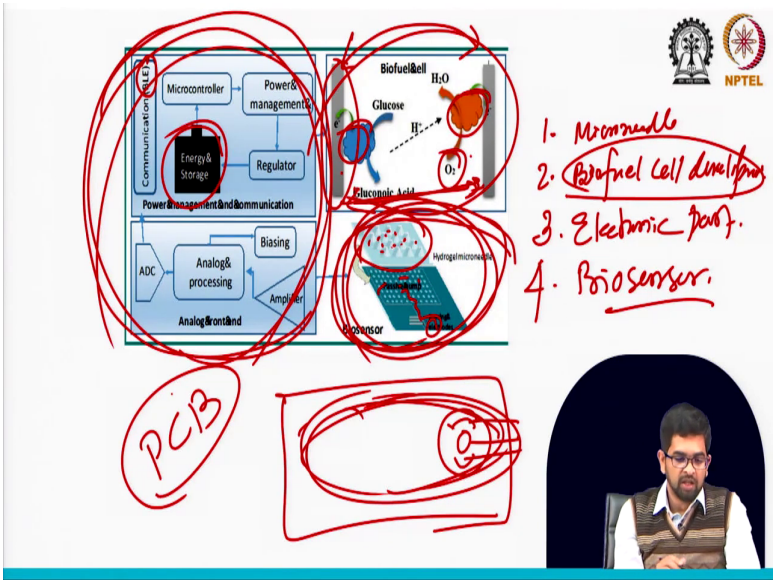

So, as I told you that we have to design a biosensor for cell power. See how we will start step by step. Here I will take some time to teach you how to design and how to develop a cell power device. So, first what you will do you have to use see here some micro needle. So, micro needle based biosensor I taught you already. So, they can help to collect the sample. So, from there micro needle from this micro needle surface here you may get all the like your real sample it will go to your sensor surface.

But at the same time this micro needle held to get the your real sample that content a glucose and it may come in this case. So, here you have the glucose oxidase in anode and here you have the like some other enzyme like reductase kind of things where, oxygen will reduced. So, there will be some potential difference this is just I am summarizing this biofuel part. And you will differentiate the potential energy and here is this total circuit diagram.

So, you may need some light analog processing amplifier. So, that is things we need for the because it is very small amount of potential you are developing. So, you have to amplify basically and you have to store this all the energy and that energy you have to help that energy will help you to run the full your biosensor.

So, 1 point is your like a micro needle this micro needle development that will help to collect the sample then your 2nd part will be your biofuel cell development right, biofuel cell development. 3rd step after biofuel cell development you have to integrate them in cells and you have to amplify you have to store the energy right.

So, you may need this also you may need the Bluetooth control like communications you can communicate the data via Bluetooth. So, these all the electronic things you can design. So, electronic part that you have to take care of then last thing is the biosensor ok.

Biosensor means where you can sense your analyte. One very important I mean in this case is the PCB you can choose is very important and good substrate for design the whole thing. What you will do suppose you have the PCB. So, here you have the working reference counter electron right.

So, this is your sensor surface in the back side of this PCB you can design this electronic whole part. Where it can generate the energy and front side you may have this sensor and then on the top of this sensor you can use this passive pump or microfluidic and all the hydrogel based needles everything you can use the top of the sensor.

So, the top of the sensor this is a one part will be your like micro needle your microfluidics everything in the top of the your PCB. Then in the in between middle you will have the biosensor like for the glucose testing or maybe for any other target marker that you want to detect from the real sample. And back side of your PCB you may design the whole electronic part then your sensor will be ready for detections. So, this biosensor you may try ok.

See this is as I told you the cell power sensors it is very smart technology it is also IoT based and here it is very much interdisciplinary. You know this part is very interdisciplinary. So, I taught you until now like very very basic biosensor maybe some of you like who knows the biology basic or very chemistry background they can easily understand they can easily fabricate.

But now you have to collaborate for the full device development yes, some these questions may come for this advanced biosensor advanced biosensor of full device development things. Because our whole translational research you can remember or this kind of research is the translational research right translational. So, we can easily translate also from easily bench to bedside applications.

See and there is a main two pillar I taught you know one is the collaborations the one of the main pillar is the collaboration. So, maybe your expert for the sensor development right you can easily develop the like different nanomaterial then you may you can easily conjugate the antibody. But you may do you do not know maybe the circuit design.

So, what you will do just develop the sensor you have to collaborate with some basic electronics or we you are expert in the electronic because for this IoT enabled for through the transfer the data through the Bluetooth you need some this kind of design that definitely you have to first optimizations required how many biofuels cell you have to use to get the accurate potential difference that also you have to think there is so many factors ok.

And in the biofuel cell where maybe if you are the basic biologist or chemists here maybe you can take part right like which material you can use for the cathode which material you can use for the anode. See sometime maybe you may not get the potential difference that you can take part also let us try to avoid the using the enzyme like glucose oxidase or other bilirubin or other oxidase kind of you know reductase they are enzyme they may denatured easily right.

So, it is preferable if you can try some non-enzymatic generally, we prefer here some chemical many chemicals is available. So, you can try here in the oxidations where you need

the oxidation and where you need the reductions then easily you can make the potential difference between cathode and anode. So, something like this like hydroquinone easily convert to the benzoquinone so, quinone based compound. So, here is also electron transfer right.

So, this kind of reactions also can help to generate the potential difference. So, this so, next class maybe I can show you the more reagent. So, in this class I cannot show everything let us try to understand the first principle today and then next class I will show you the many other reagent that is enzyme less enzyme less or non-enzymatic. So, one basic things you can try some very simple chemicals that can help you to generate the potential difference.

Also, at the same time you may think like here is your like you are all the battery right small small battery and maybe near you can try here biosensor. So, your battery and biosensors are very near and they can help each other for the development. And these things just is really really important in the current situations like the it is called continuous monitoring right.

Why we need the continuous monitoring? Because sometime specially for the glucose consideration depends on your exercise depends on your food habit right. In the morning one different after taking some food it will be different and really means you need some insulin or not when the diabetic, they may need the insulin right just before the meal.

So, you may have the continuous data for the whole day and then you can decide your food habit you can decide. So, that is why this kind of device is really really important the cell power biosensor this is the advanced technology. So, you can apply ok. And this is this slide just I taught you a very basic scheme, but this is kind of the plan you can try that is my goal actually today in this lecture.

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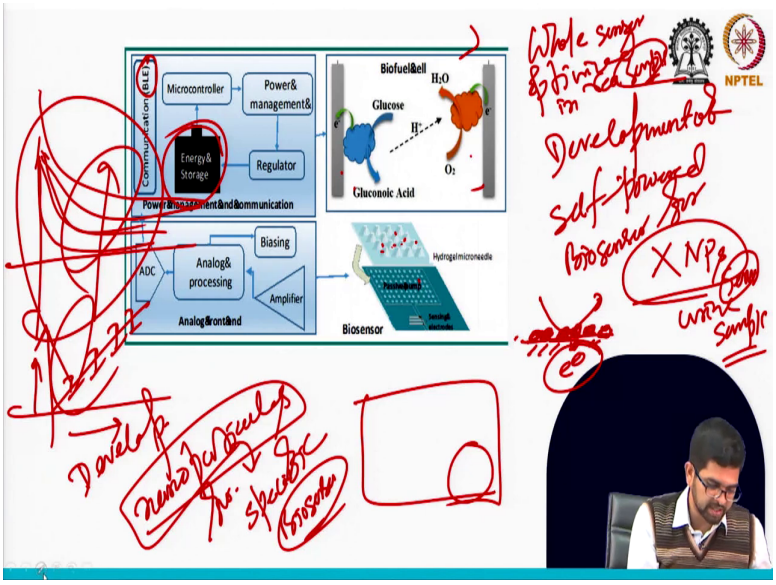

That, how to design is cell power biosensor and say because in this class maybe some of you are the very use in the UG background maybe PG background who want to go for the higher study. You may think some kind of project like this development of development of cell power biosensor for. So, last cases I tried the glucose directions right. You may try this one suppose if you try in the urine sample.

So, you may think that creatine detection creatine that is this it cause the like problem for kidney like creatine detection also you can try creatinine. So, that is also very important factor. So, that you can think like I am just giving some another project like this way. So, same way so, what you will do you can think about the creatine detections on a biosensor and there is a different enzyme available for the creatine or maybe some others, but I will recommend let us develop some nano particle for like creatinine.

But thing is there while although it is very easy to say by let us develop some non-enzymatic biosensor. Like nano particle they are the non-enzymatic biosensor, but development of a nano particle and getting the specific data is really crucial factor what the specificity specific or specificity specific biosensor is really important.

Suppose I developed a nano particle NPs suppose X nano particle I developed. So, I fabricated on the sensor surface this X nano particle and I tried the creatinine. And I got the very good electron transfer rate and I changed the concentrations once you change the concentration creatine suppose you are getting the chronoamperometry like this you are getting the changes right.

Different different creatinine you are getting the current also changes and you got the very good calibrations curve also like very good straight line also you may you got like a creatine reduction here is the suppose current. And here is the concentration of creatinine right.

But when you check the actual real sample suppose you are using the urine sample right or maybe you are using serum sample. See the serum and urine it may contain some other species if those species also react with this nano material, then your whole sensor actually you will become useless. So, whatever suppose you need your serum sample content the glucose your X nano particle also reacting with the glucose and it is also showing the current change.

So, suppose in your real sample content like 10 millimeter glucose other than content with 12 millimeter glucose. So, because of 2 millimeter glucose change you may get the different current. So, it will miss guided it will it will miss guide you that is why the specificity means yours this nano particle should not react with other interference species present in the real sample.

That is why we always recommending once your concept done means suppose you developed a nanomaterial some new nanomaterial and your creatine reacting very good you are fantastic that your first work is done, but you cannot say that your means. Now you can make the device before making the device you just make a real sample and check the data.

And if you see the now actually real sample other component also reacting then you have to go for the optimizations this is the very common problem for development non-enzymatic biosensor it may react with your target it may react you may get very good data you may get very good sequence everything done.

But if you see that your other component real sample is reacting then let us optimize your whole sensor your whole sensor should be optimized in real sample, how? So, just check real sample which component present those component is really reacting on the on this sensor surface or not then, which potential you are applying actually may be see you because you are applying some potential know.

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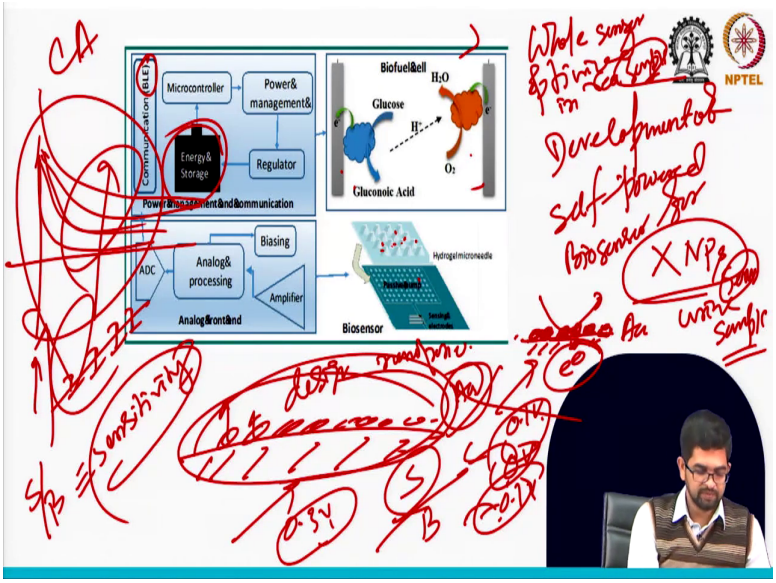

I am showing this one suppose this is your sensor surface you have some specific you are thinking your nanomaterial is very specific. So, here you are applying 0.3 volt for the

chronoamperometric case, but in that potential if it is showing the glucose oxidations in your real sample content let us apply like different potential.

Let us go to the near 0 as I told you know like 0.1 volt you can try, 0 volt you can try, minus 0.1 volt you can try then let us find out which potential is the best for the real sample. Then use that potential for the curing detections and still after this potential say once you decrease the potential ok. Then your background definitely will decrease, but signal also will decrease that also a problem because if you signal to decrease then your signal to background means you are getting actually your sensitivity.

So, if you lose the sensitivity then also it can cause a problem for you sensor development what you can do you just think about now the design of the nanoparticle now. So, you can design nanoparticles with some different metal base different metal here maybe you have tried like gold now here you can try with a gold with some other decoration. Or maybe some other alloy type or maybe change the gold is something else try and then check again the same way the creatines reacting or not.

Then again, the same way use the real sample let us get that all the interference data that we are getting with the other nanoparticle here also you are getting a similar way or not. See many I think you may ask this very common questions. So, we can go for this biosensor development these things.

But as you are asking the real sample whether we can go for the final optimizations, but handling real sample there is a one you see the ethical clearance. Ethical clearance that you have to very much cautious because you are developing biosensor right.

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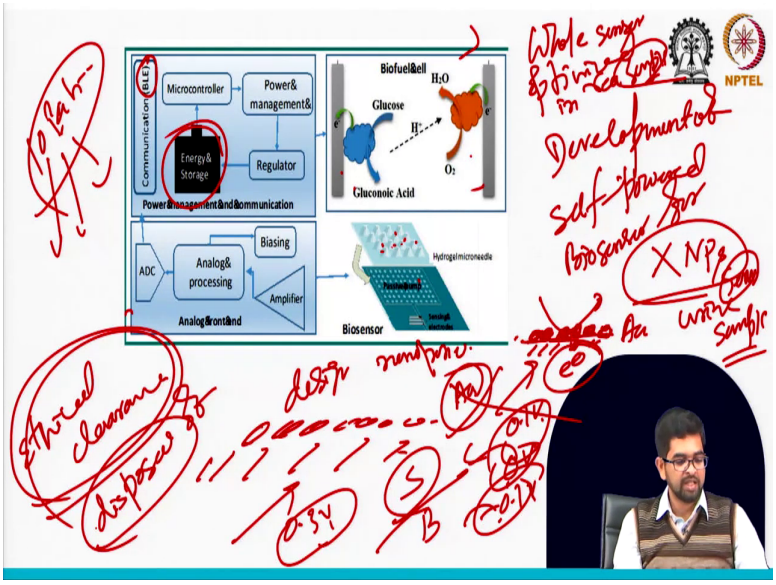

So, one day maybe I will show you again what is the ethical clearance the ethical clearance you should have; ethical clearance suppose you are using blood samples you are collecting from maybe may be from 10 patient some patients they may have some infectious disease right. So, in a laboratory they may be affected right.

So, you should have you should follow the proper protocol of the handling of this all the real samples this is one factor and how to dispose maybe you handle properly the real sample, but you are not disposing properly. So, there is a one committee always there that is ethical committee they will help you or they will give you proper guidance or they will check you are following the proper guidance or not.

Means the disposal of your sensor waste means after use in your waste you are throwing your all the component like is randomly. Otherwise see if you throw in just randomly means some

someone also can be affected with some infectious disease may be can it can comes to other patient you may use like some like some saliva sample. That saliva may contain some COVID or something it may again spread to someone else right.

So, we have to check properly that who will handle this real sample he or she will be very much cautious about this and he should or she should know how to handle this. Then he should not dispose right randomly he should properly dispose it that everything controlled by the ethical committee.

And that is why we will take the approval from the ethical committee that is when you already that is why when we have done our sensor development and finally, at the end of the time we are thinking let us use the sense real sample let us value edit.

Why it is not the good plan you just think from the beginning of the real sample. So, once you almost suppose you already made a made a nanomaterial surface that is very specific and you already get some data. Let us now immediately try some real sample let us see there behavior on the sensor surface sometime real sample is behaving a fully different than whatever you are optimizing with your buffer sample.

So, that so, you should have some plan use at the very beginning otherwise at the end of the development again you may come back for your whole sensor development you will start again from the beginning. So, you should have some information if you use the real data.

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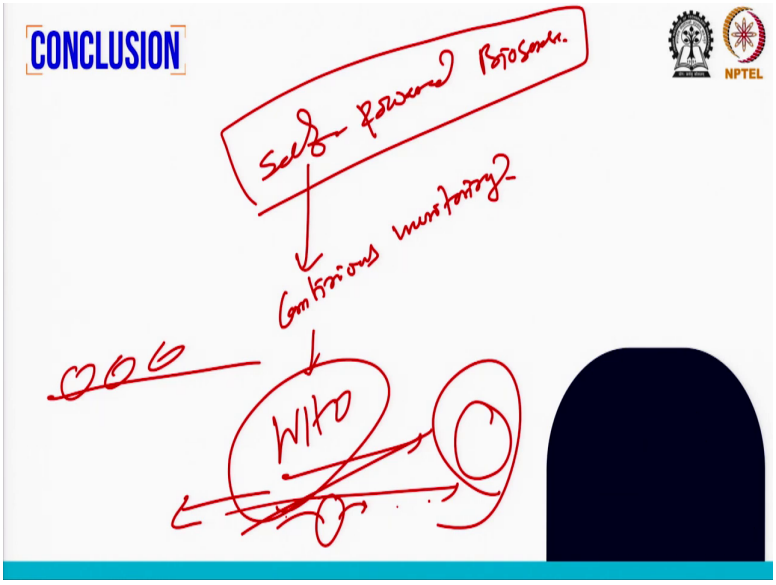

So, this is the conclusion for today's that today I taught like self power sensor self power biosensor. So, this is really important because where you do not have really the power supply, but in the very usual area, but maybe somewhere you went you may not get the power for the longer time there you can try. And this is also very much useful for continuous monitoring that I taught today.

So, continuous monitoring and another things today I taught you that is the how to use the real sample and who can guide you may be if you go any good institute they have their own ethical committee they will guide you. So, you have to go through proper guidelines.

WHO also the World Health Organization they have very good proper guideline once you already developed your biosensor. So, who which biosensor develop some target suppose some COVID virus related some biosensor you develop. Please go to the WHO protocol let

us check how they may what is their advice and let us follow this and then go for the real sample handling.

But that should come actually not at the end stage of the sensor development you have to think this one in the middle because you may need to change so many parameter. So, that is I tell once you develop something let us try to use this real sample ok is done. Then again complete the sensor development then finally, validate the whole sensor with real sample ok.

So, that is the main concept you please try to remember and next class again I will show you some new technique some new tutorial also again some new problems I will give and you will learn something new design and you can think independently ok. That is all.

Thank you very much for today's topic, thank you.