Fabrication Techniques for Mems-based Sensors: Clinical Perspective

Prof. Hardik J Pandya
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

Lecture – 01
Introduction to Microengineering Devices

Hi, welcome to this course, this course is about Fabrication Techniques for MEMS-based Sensors from Clinical Perspective. So, when we talk about clinical research right what does that mean? And how it is really useful?

So, there is a saying which goes like this that is solution for the big problems lie in small things that is true for our actual life as well as in case of research. When we understand the properties from the micro and nano perspective, we can really understand what lies what kind of problem lies and what kind of solutions we can design.

So, when you talk about micro and nano right what do you mean by micro and nano? And how it can be useful? So, in this particular course we will be understanding several devices that we can fabricate using a technology called micro technology right.

And in particular, we will focus on micro electromechanical systems based technologies as well as based sensors. This can be a microchip, it can be a flexible sensor, it can be a micro fluidic chip, right. It can be a device for drug screening it can be a device to evaluating the efficacy of the drug, right. It can be a device that can measure the weight of a fly a house fly.

So, how you can how we can design these devices? And how what are the process for designing these devices? So, we will take each device into detail right and understand from a research point of view how you can use this device to solve a particular problem in clinics.

So, when I talk about this kind of problems we should we should understand first that where exactly we are talking about and when what exactly we are talking about. So, it is not just from clinical perspective that we can make these devices, but these devices are used in several other applications.

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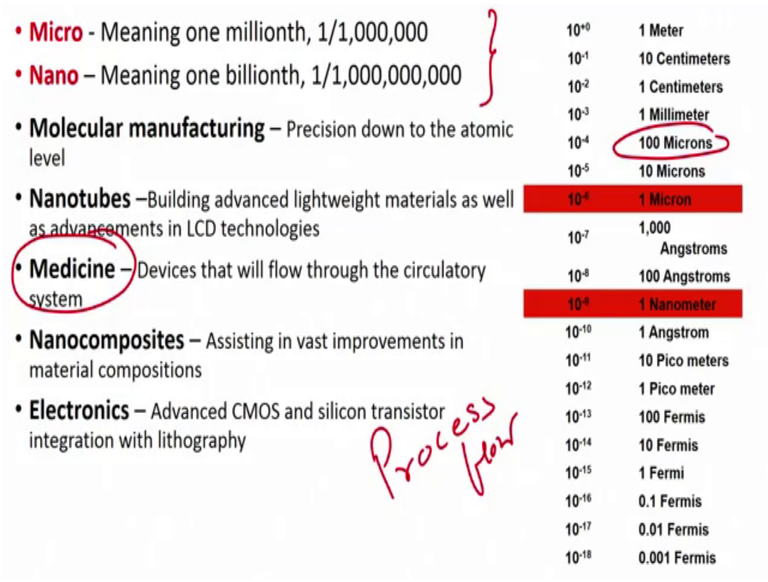

So, if you see the slide, if you see the screen what we see is that we are talking about 10 raise to minus 6 which is about 1 micron to 10 raise to minus 9, which is about 1 nanometer right. And if you talk about our human hair right human hair it is around 100 microns, it is around 100 microns you see this value right average human hair thickness is about 100 microns.

But, we are talking about one tenth of that we are talking about 1 micron. In fact, we are talking about 1 nanometer right; that means, a micro means a mean 1 millionth right you see 1 by 10 lakh. If I want to just say in terms of lakh it is 10 lakh right, 1 by 1 millionth or a when you talk about nano right it is 1 billionth right 1 by 1 billionth.

So, these are extremely small these are extremely small values. And it is extremely important to understand something called a recipe or process flow. So, it is very important to understand what is a recipe and what is a process flow.

So, when we talk about molecular manufacturing; molecular manufacturing what does that mean? Precision down to the atomic level, precision down to the atomic level, when you talk about nano tubes, we are talking about building advanced light weight material as an advancement in LCD technologies.

When talk about medicine we have devices that will flow through the circulatory system as well as devices that can evaluate the efficacy of the drug, as well as devices that can understand and help us to screen the drug right. As well as devices that can be used for for several surgical applications. So, we will see these devices we will focus more on this particular aspect.

Then we can also use this technology we can also use this technology for nano composites that is assistant assisting in vast improvement in material compositions. Finally, this technology is also used in electronics. When talk about electronics right we talked about MOSFETs, complementary MOSFETs, complementary metal oxide semi conductors and how we can fabricate this MOSFETs and circuits that are used in electronics.

So, you see that when you understand the concept of micro and nano, when you understand the concept of micro and nano and the technology behind it, then you can apply your knowledge into several fields. It is not just limited to clinical perspective, but is can be used for electronics, it can be used for robotics, it can be used for building novel materials, it can be used for understanding the molecular manufacturing right. So, it has a vast application it has the vast application.

So, today's lecture is focused on showing you few devices few devices that can be used in clinics or to solve problems which are related to medicine alright. So, let us see and we will talk about this devices in this particular lecture and we will take each devices and see how it can be fabricated.

So, when you understand fabrication from process flow to recipe of each device then you can use this device by using the clean room right. And understanding how the clean room can be used or how the equipment in the clean room should be used so to fabricate these devices.

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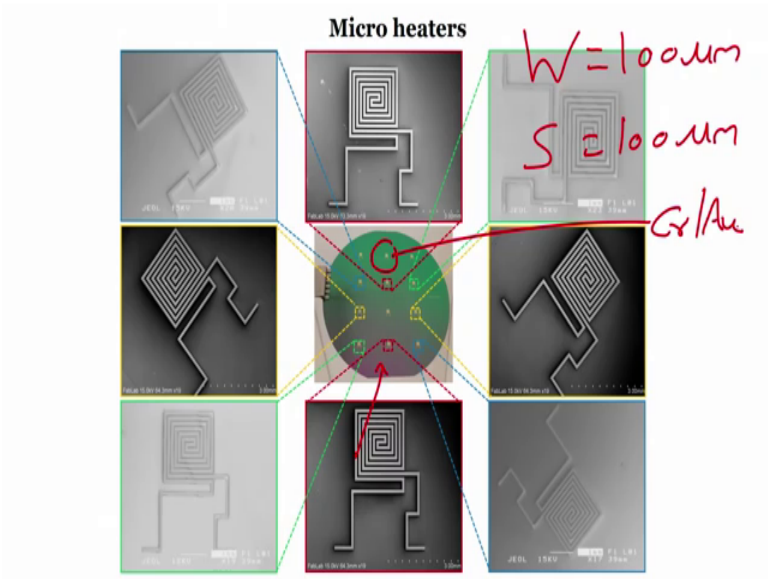

So, let us see this slide, the first slide that you can see here right what are these slides? It is showing micro heaters, this showing micro heaters right. So, when I when I talk about micro heaters you can see very clearly right that this is the bar is about 3 millimetre 3 millimetre. And the width of this line is about 100 micrometers is about 100 micrometers, alright.

The spacing is about 100 micrometers. So, width is 100 micrometers, width 100 micrometers, spacing 100 micrometers alright. And if you see this particular image this is a silicon wafer you can see right it is an oxidized silicon wafer, it is an oxidized silicon wafer, alright. And then on oxide we can if you see this part then it is chrome gold what is it? Chrome gold.

So, now the question is why we have designed this particular the heater in this particular fashion? Right, why we have designed the heater in this particular fashion?

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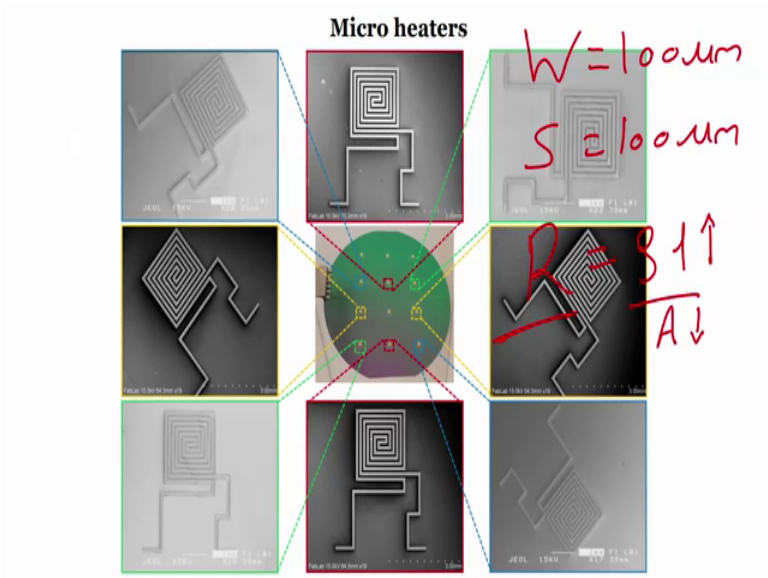

So, what is resistance? Resistance if we say R equals to rho l by A right; that means, if I want to have a resistance of a higher value, I should decrease my area and or I can increase my length.

For a given metal resistivity remains constant right. So, here by using this design which is a design of a coil right at angular coil we are increasing the length, we are increasing the length and hence the resistance. You got it? We are increasing the length and hence the resistance one thing. Second thing, second thing where these micro heaters used? Micro heaters are used in lot of applications such as sensors.

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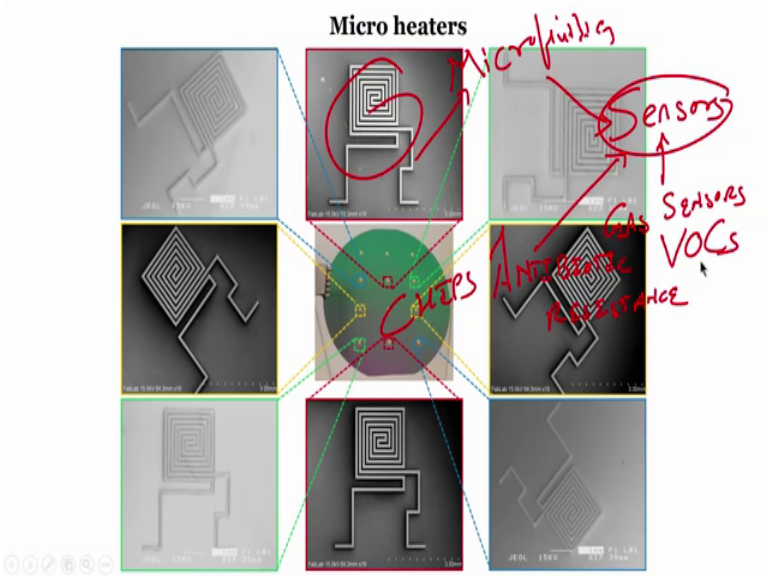

And when I talk about sensors these are gas sensors, gas sensors. Then this micro heaters are used in something called chip for antibiotic resistance antibiotic resistance chips. These sensors are used for micro fluidics micro fluidics right.

So, when you say the sensors when the sensors consist of heater and or directly heaters are used to micro fluidics, heaters can be used in a sensor that is used for antibiotic resistance. Heaters are used in sensors that is used for measuring different gases or measuring different volatile organic compounds volatile organic compounds.

So, when you talk about volatile organic compound that compounds what does a compound means? VOC means a compound that is organic in nature and that is volatile also in nature.

So, what are the example of VOC S when you talk about VOC S right.

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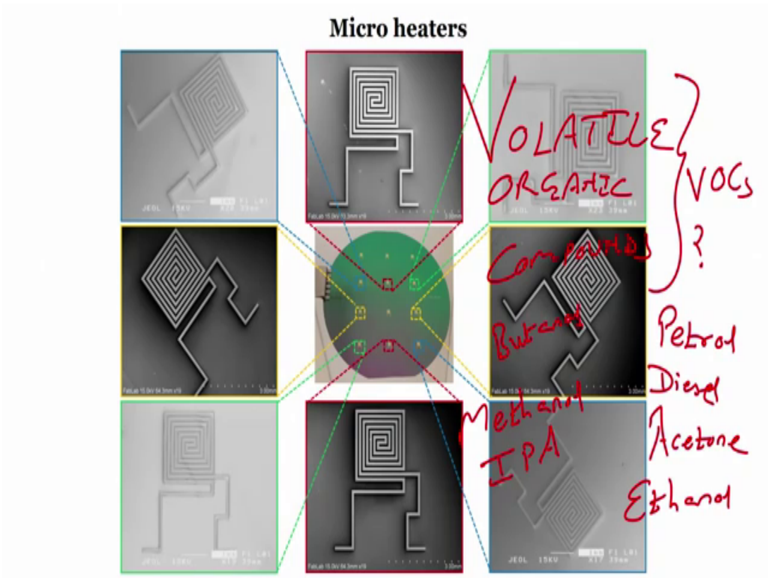

Volatile VO L A T I LE- volatile right, organic O R G A N I C organic, compounds c o m p o u n d s compounds. What are these volatile organic compounds? So, like I said it is organic about it is volatile good, but can you give me the example?

The example is gasoline so, we say here petrol, it can be diesel right, can be diesel, it can be acetone right that we use in nail polish remover. It can be ethanol, it can be ethanol, it can be methanol, it can be isopropyl alcohol, it can be butanol right. And if you want to detect this VOC S and we will see one application if you want to detect this VOC S, then you need to design a sensor and this sensor the sensing material works better at a higher temperature.

So, to raise the temperature of the sensing material we you have to use we have to use heater right. And the sensors are all micron in size or they consist of different patterns which are microns in size. And here we have to use heaters also in micro dimensions and that is why there is a importance of micro heater. So, we will see how we can fabricate a micro heater on an oxidizer silicon substrate.

The reason of using oxidized silicon substrate is that when we use silicon and directly if we deposit metal then we will not get actual value of metal because of semiconductor is because there is a semiconductor below it right. So, silicon is a semiconductor, we cannot deposit metal on semiconductor right. So, we have an oxide layer on silicon wafer and then on that oxide layer we can deposit a metal. And this oxide layer will act as an insulator right. So, oxide layer acts as an insulator.

So, now when we have to fabricate this micro heater right what are the process flow? And what is a recipe? We will see in this particular lecture series.

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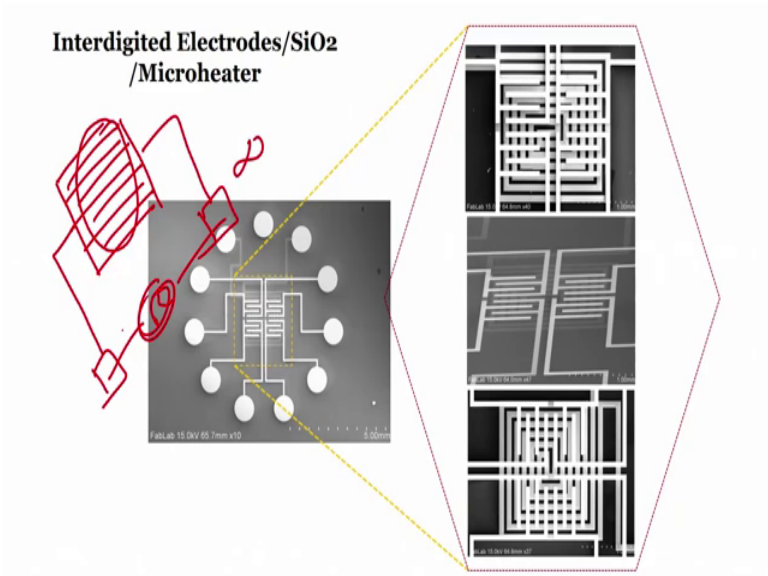

Let us see another device ok, let us see another device. What you see here? We see here there are interdigited electrodes right, it is called interdigitated. That means, you have digits this is 1 digit, this is 2nd digit, 3rd digit, 4th digit, 5th, 6th, 7th, 8th, 9. If digits are interlocked like this interdigited interdigited right and if I measure a impedance, if I measure a resistance or impedance across this it will be infinite correct because, there is nothing it is not touching.

But, if I deposit any material on this then I can see the change in the resistance. So, these are the electrodes that are used to measure the change in resistance or impedance of the material.

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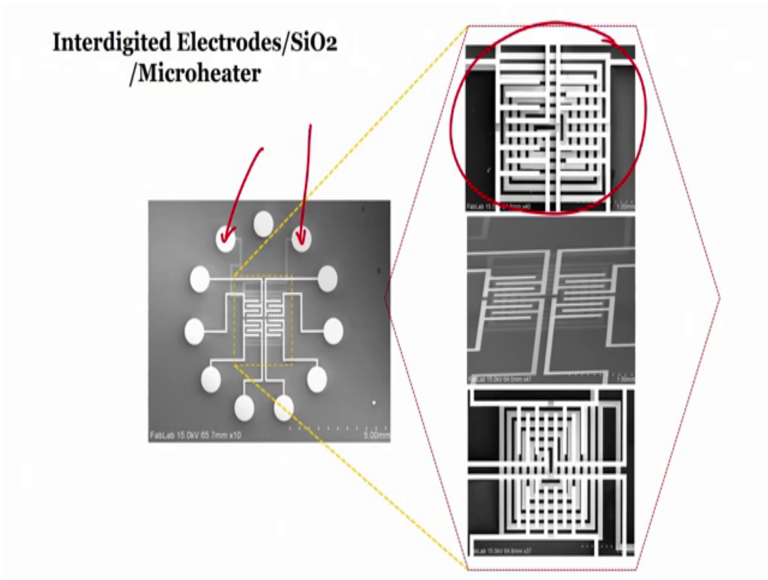

So, this particular structure if you closely see there is a micro heater here, this is a contact for micro heaters.

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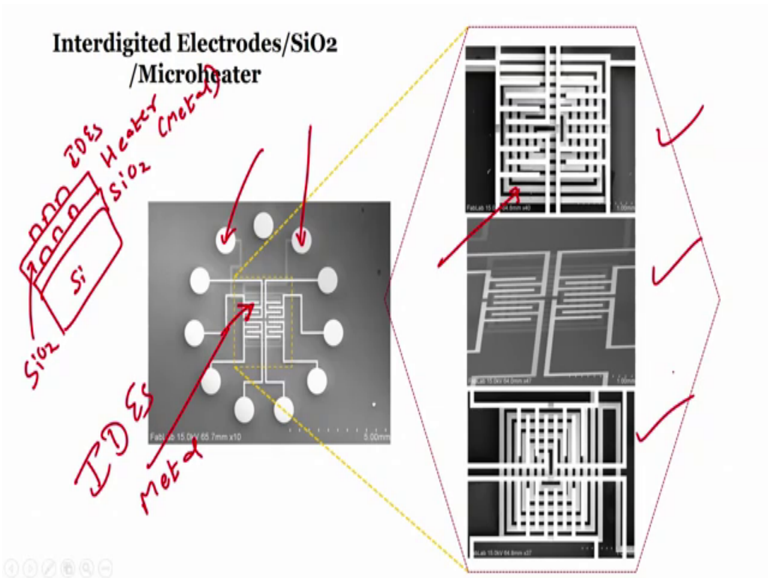

And if you see this particular diagram this one you can see micro heater right over here and then on that micro heater there is interdigited or there are interdigited electrodes. But, again you cannot have let us say this is silicon right this is silicon dioxide, then this is the heater. The heater is of metal right metal, interdigited electrodes this one inter digited electrodes also written as IDES are also made up of metal.

And you cannot have metal on metal; that means, that you should have a insulating layer on which you can design interdigited electrodes right. So, this one is where insulating layer.

So, if you see any of this device any of this one, this one, this one there is a micro heater at the bottom is a micro heater at the bottom on which there is an insulator which can be a silicon dioxide or silicon nitride on and on that we have patterned.

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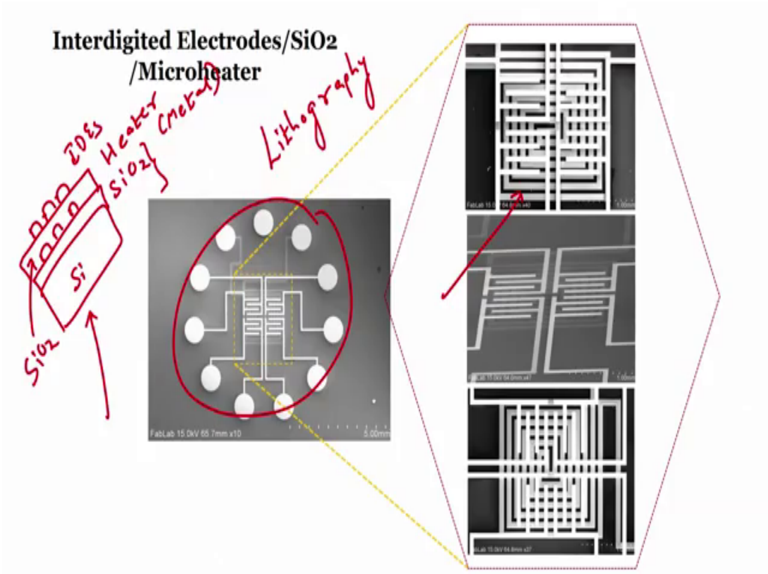

We have pattern interdigited electrodes right, you can see here in this particular diagram and there is oxidized silicon wafer on which oxidized silicon wafer is silicon wafer with silicon dioxide. Right, on which there are micro heaters or there is a micro heater here there is a single micro heater as you can see. On which there is an insulator, on which there is interdigited electrodes which are patterned which are patterned using lithography litho graphy alright. And we will see the application of these interdigited electrodes on SiO 2, on micro heater in few examples later on few examples later on.

So, now we are we are complicating the design of the sensor right. Earlier we have just seen micro heater, now we are talking about micro heater on that another layer of silicon dioxide, another layer of interdigited electrodes right. So, this will get on complicating when we design complex sensors. This very simple example micro heater insulator and interdigited electrodes, but there can be more complex examples that I will see.

If you go to the next slide if you go to the next slide what we will see?

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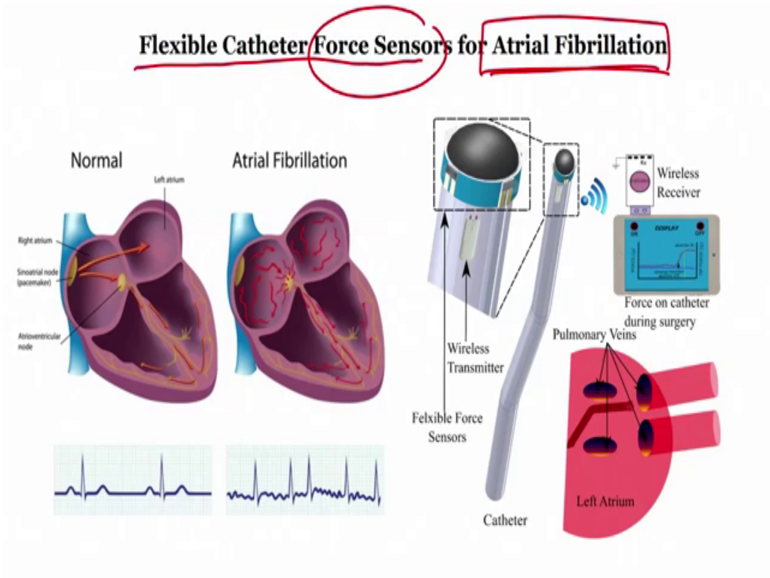

Another device and this is a flexible catheter force sensors flexible force sensors for catheter or flexible catheter force sensors for atrial fibrillation for atrial fibrillation alright. So, what is atrial fibrillation? What does atrial fibrillation means? And how we can design a flexible force sensor for such an application, right for such an application? What is the use of actually designing a force sensor for atrial fibrillation we have to understand that right?

So, we will understand what exactly atrial fibrillation means, we will see how we can design a force sensor and how we can integrate this force sensor on the catheter. So, that it can measure the character contact force. So, that it can measure the catheter contact force alright.

So, we will see how we can design this particular sensor and what kind of experiment that we can perform to understand the characteristics of the force sensor that we have designed. And this is again a medical application right because we are designing a force sensor for atrial fibrillation something to do with heart right.

So, if I know micro engineering, if I know micro fabrication I can design a sensor that can be used for surgical applications. You see it is used for catheters that are used for atrial fibrillation which is a disease in heart. So, we will see though this application.

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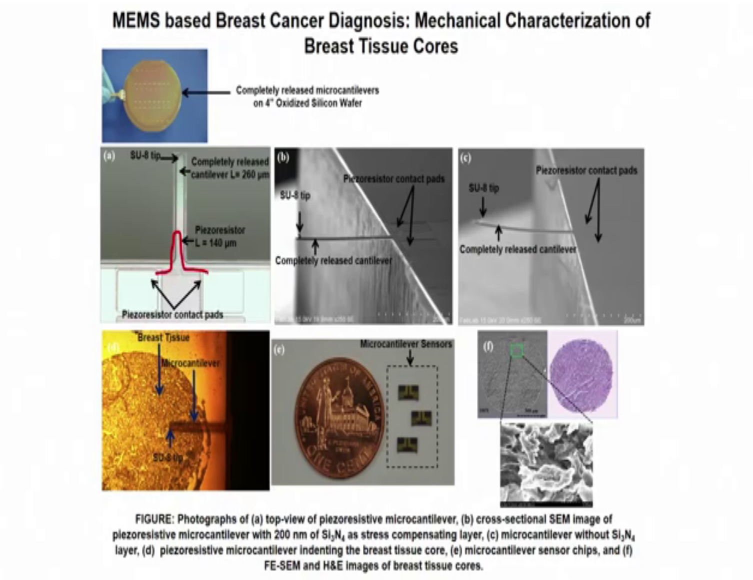

If I go to the next slide what I can see? I can see that there are cantilevers and if you closely see there is a piezoresistor piezoresistor embedded in oxidized silicon or embedded in polysilicon not oxidized silicon piezoresistor embedded in polysilicon.

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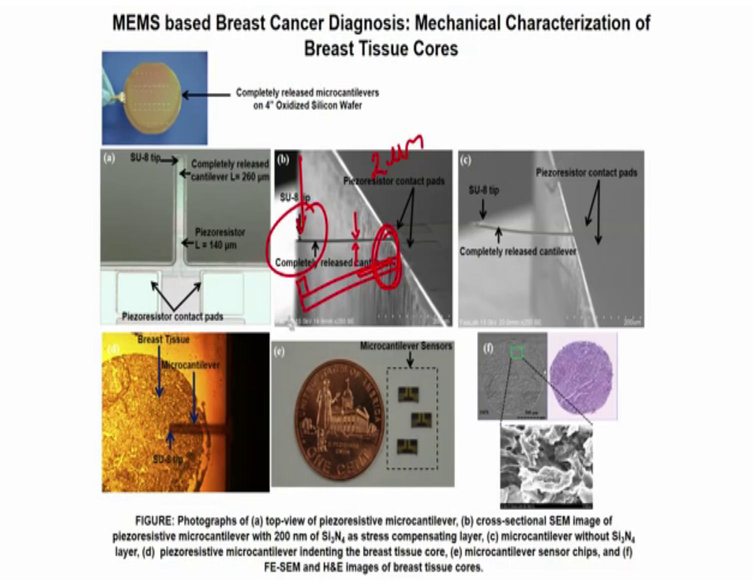

And at the end of the cantilever, at the tip of the cantilever or at the end of the edge of the cantilever in this side this one there is a SUA tip there is a SUA tip right. So, this cantilever the thickness thickness of this cantilever is 2 micrometer 2 micrometer right.

We are talking about human hair 100 micrometer thickness of human hair is 100 micrometer. We are looking at the cantilever which is about 2 micrometer and the reason of having piezoresistor is that when we press this cantilever there will be change in resistance. That is a property of piezoresistor right, when you apply pressure when you apply force there is a change in piezoresistors, because of the strain created in the piezoresistor.

So, because when we when we apply a force like this right it will bend in this direction like this right, then there is a strain in this area strain which causes a change in the which causes a change in the resistor embedded in the cantilever right.

Now, we can we can also see here.

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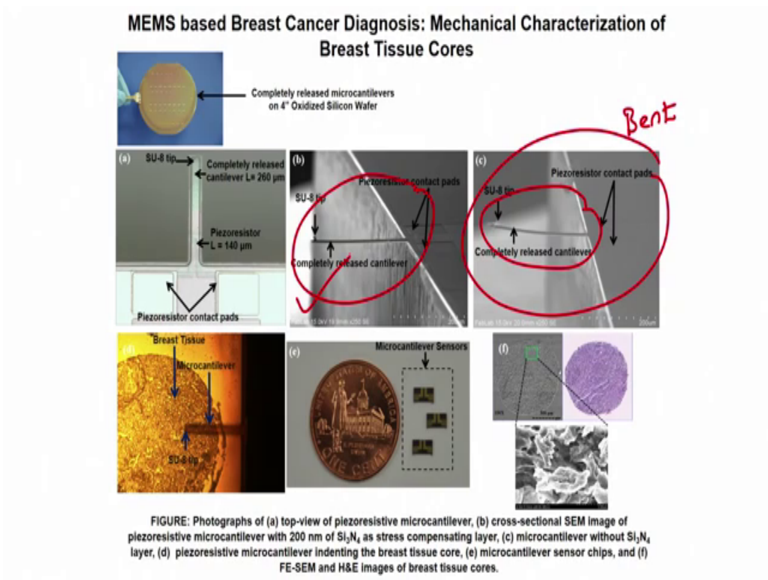

In this particular diagram that there is a piezoresistive cantilever once again which is bent which is bent right. What is the reason of what is the reason of bending? What is a reason of bending? Why it is bent? And why this is not? That is because of the recipe that I was talking about right.

So we should know; what is a recipe for fabricating these devices if the recipe is wrong then you will have this kind of device, but what we require is this one right. So, we will see how we can fabricate this piezoresistive micro cantilever and how it can be used for several applications including measuring the properties of tissue.

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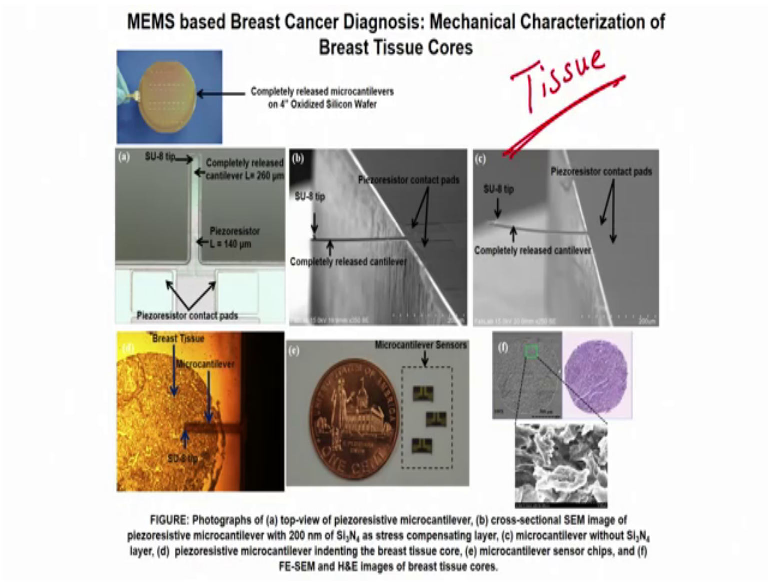

Including measuring the properties of tissue right; so when you talk about tissue right the stiffness of the tissue is different stiffness of the tissue is different. Can we measure a stiffness using piezoresistive micro cantilever? That is a question right. Can we measure the stiffness of the tissue using piezoresistive micro cantilevers? And if we can measure the stiffness of tissue then we can use this for disorganizing a case called breast cancer right.

So, we will see how it can be used for understanding the mechanical properties mechanical properties of the tissue let us go next.

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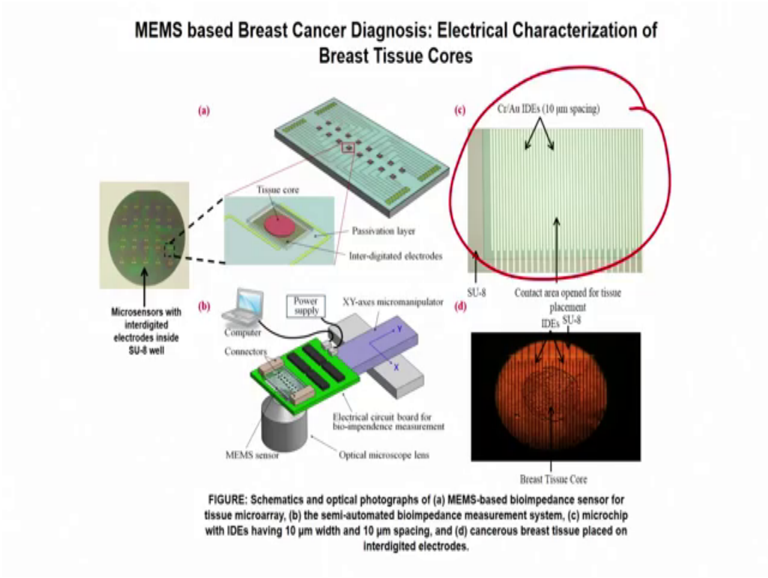

FIGURE: Schematics and optical photographs of (a) MEMS-based bioimpedance sensor for tissue microarray, (b) the semi-automated bioimpedance measurement system, (c) microchip with IDEs having 10 µm width and 10 µm spacing, and (d) cancerous breast tissue placed on interdigited electrodes.

Now, same example which is your interdigited electrodes, you can see here interdigited electrodes. And if I have an interdigited electrode what are the applications? I told you that one application of interdigited electrode would be measuring the resistance or impedance.

So, when you talk about resistance or impedance you require some mat material to be kept on the interdigited electrodes right. So, if we keep a tissue a tissue on the interdigited electrodes what we can measure? We can measure impedance. Why because there is a solution required to keep the tissue alive right and that is PBS is the silent solution.

So, if I have interdigited electrodes and on that if I place a tissue on which I have a solution then I cannot just measure resistance right because, there are several parasitic components that comes into play such as double layer capacitance right. So, now instead of measuring resistance what I will measure? I will measure impedance, I will measure impedance of the tissue.

So, now if your device or if you can design a device that can measure the impedance of tissue or it can measure impedance of cells as the disease progresses then you are measuring the electrical property of tissue or cell is not it?

So, what we will do by measuring electrical property of tissue? What we need by measuring mechanical property of tissue? Same thing will do by electrical property of tissue. That means that if I can see the change in the tissue properties as the disease progresses. And let us take an example of a breast cancer or oral cancer or any other cancer related tissue and my sensor can give these changes, can measure the signature, can measure the electrical and mechanical signature of the tissue or of the cell I can diagonize, I can use this device as diagnosing device for the cancer right.

So, now we are using interdigitated electrodes without any heater for understanding the properties of tissue and these are the electrical property of tissue. But, when I talk about electrical property of tissue right I need to first have interdigited electrodes. And when we are talk about that this tissue is there we have to load APB S that is a solution right. Then if I load this solution on the glass slide it will do not stay on the point right.

So, we had to create a well to hold the solution the hold the solution. So, we will see how we can create this kind of device there is a interdigited electrodes within an SU 12. That is another device that we can design from the biomedical application, from the clinical perspective alright.

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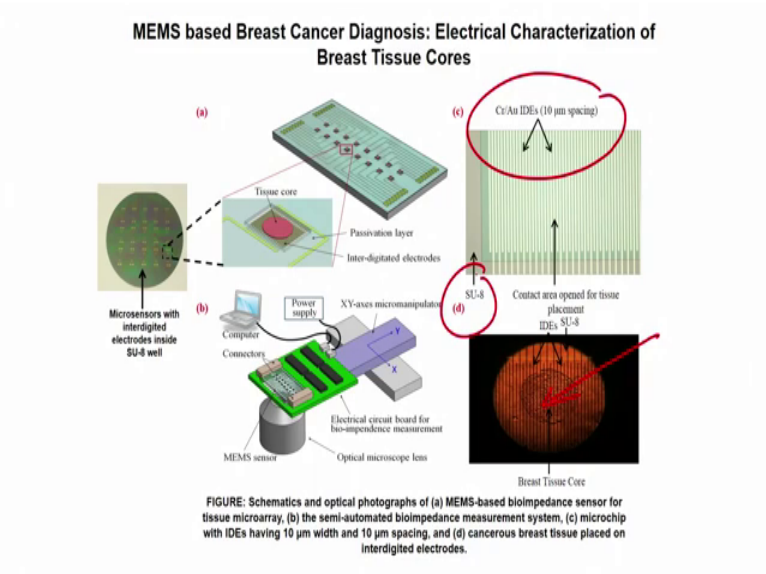

So, this is what we can see here on the slide this is you can see that the tissue is placed on the interdigited electrodes and you can see here the interdigited electrodes are fabricated using chrome and gold. And the spacing and width, the width and spacing of these interdigited electrodes is 10 micron. And the well is made up of SU 8, well is made about made up of SU 8 right.

So, we will see how we can use this kind of device for measuring the tissue property particularly electrical property of tissue electrical property of tissue.

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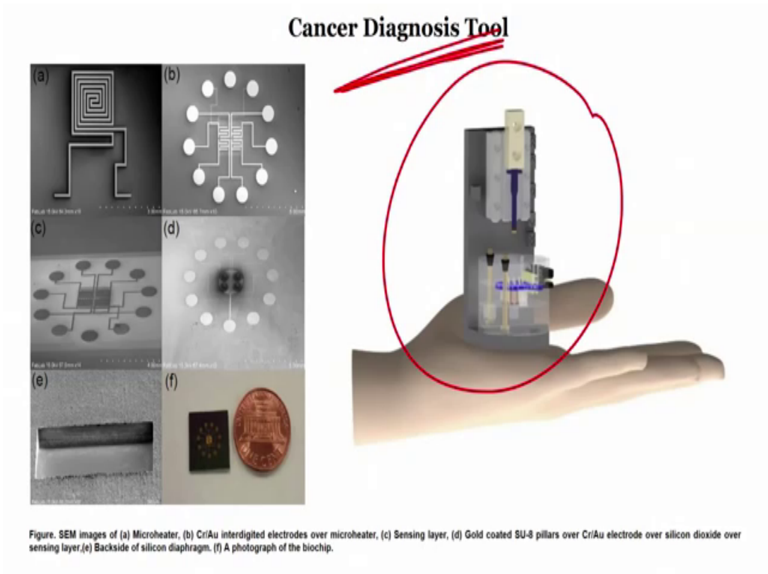

Let us move to the next slide now we will also understand how we can design how we can design a tool a tool that can be used for diagnosing cancer. And to understand the designing of this tool that can be used to diagonize cancer we again need the basic understanding of what we call micro technology micro technology right. So, here we will be understanding or we will be studying several modalities several modalities.

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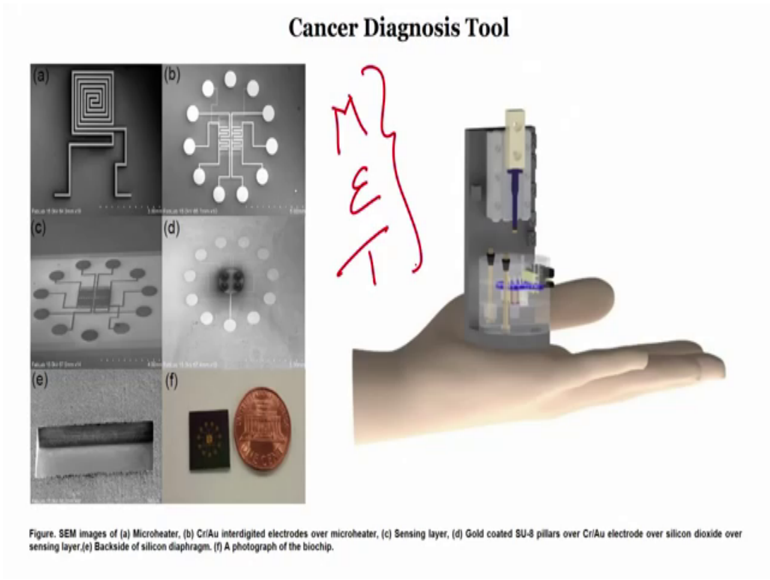

When I say several modalities one is mechanical, another is electrical, another is thermal mechanical, electrical, thermal. Thermal properties all 3 properties of a tissue if I want to measure can I design a sensor that can measure all 3 properties or can I design a bio chip that can measure all 3 properties of tissue, when I say all 3 properties the electrical properties, mechanical properties, thermal properties. And I do not want only one to design the bio chip, but I also want to integrate this bio chip in a tool.

Such that when the tissue is out the tissue is taken from the biopsy we will see how the issues are taken out. Once the tissue is out from the biopsy, I can place a tissue on this tool and I can just press a button. Or a pathologist if it is an pathology lab the pathologist will just press a button and he or she will be able to see what are the changes in the tissue properties. And thus this can be a aid to the surgeon, this device this tool can be aid sorry this can be a aiding tool to the surgeon right.

So, why we require aiding tool for the surgeon is the gold standard not enough right now how cancer is diagonized right. So, we have to understand these things and then only we can design a particular tool that can be used for understanding the tissue properties.

So, now we will see you as you see that right starting from the micro heater, then we come came to interdigited electrodes, then we make to cantilever and then we went to interdigited electrodes within SU 8 well. Now we are talking about a one more sensor that can be integrated and that is thermal sensor.

So, a thermal sensor can be micro heater we can use micro heater for thermal sensing, we have to use a piezoresistive material that is the we can use any piezoresistive material example is P DoT PSS which is a conducting polymer, and then we have to use a electrical sensor to measure the tissue properties. So, all 3 sensors integrated on a biochip. How we can do that? Right how we can do that? So, we will see in this series of lecture how we can fabricate such kind of device alright now.

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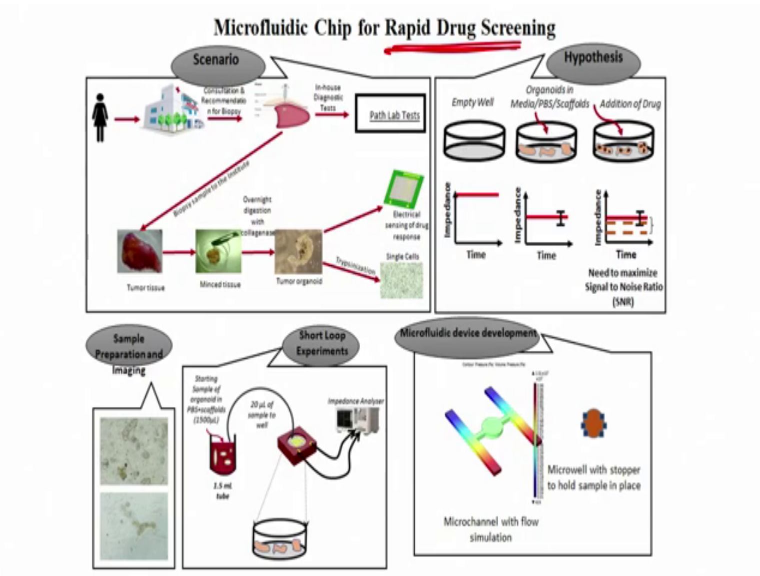

Let us see another another device and this device is used for drug screening right drug screaming. So, how we can design this drug screening device? And what is the use of this drug screening device right?

So, now if a patient has to be given a particular drug, which drug will be more effective from a patient point of view right? Every drug and every patient responds to the drug in a different way. So, can we design a device that is patient centric? What is it? Patient centric right such that we take the cells from the patient and we load in the device and we pass different drugs next to the cells and see the response of the cells or tissue with respect to different drugs then we can understand which drug is more effective.

So, to measure this response either we can use impedance or we can use the fluorescence technique fluorescence technique right now is used in bio labs right. So, what I was saying that if I take a cell; let us say if I take a cell from my hand let us say from here right I take a tissue.

I take a tissue I place the tissue in the micro fluidic chip right I slice the issue place the issue in micro fluidic chips. Pass the drug and if the drug is effective tissue will start dying. That the death of the tissue if I can measure by using some sensor that is integrated within this micro fluidic chip right. Then I can understand which drug is more effective for my body.

Now, we are not talking about just if I get sick and I had to dig out the tissue right, we are not talking about that kind of device. We are talking about device when it is cancer and when the drug that is administered to the patient or drug that is given to the patient is extremely important. Because, it is a matter of life and death right which drug will be more effective and which not because every patient will respond differently.

So, now, as an engineer is an micro engineer who knows micro engineering and micro technology can you design a device that can be used from patient centric point of view for rapid drug screening you get it?

We will see how you can design this device right; so that when we use this device then based on the result a proper drug can be given to a proper patient. And it may change from patient to patient right, thus making the delivery of drug, thus making the screening of the drug more effective alright.

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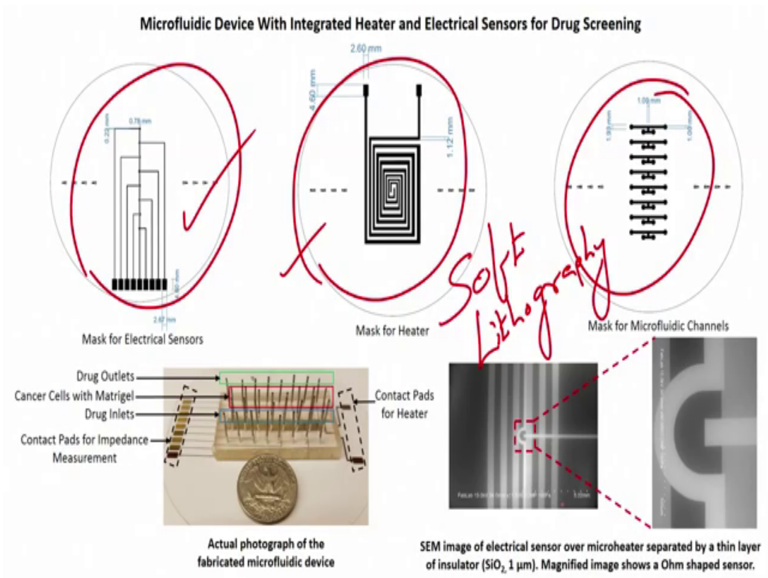

So, if you see the screen what we see? That there is a micro heater right on which there should be an insulator on which there are electrodes and this everything. So, this one and this one should be on one chip.

And for flowing I need a channels, this channels I can fabricate using soft lithography, using soft lithography alright.

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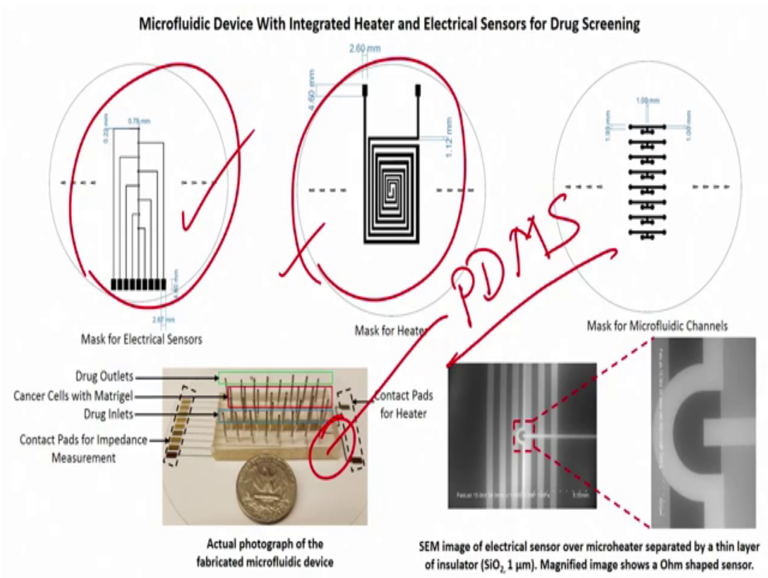

And the material that you can see here this material neither cube is PDMS, the material is PDMS right. So, can we design a tool or can we design a device that can be used for rapid drug screening? So, we will see this device, how we can fabricate this device and how it can be used; and what are the preliminary results that I obtained using this particular device.

Similarly, this are all research problems you can work on this, you can design these devices. By understanding this is what we are understanding we are gaining expertise or we are understanding or we are improving our knowledge for designing several sensors that can be reused from research point of view right.

Can you do some kind of research by gaining this experience from this course right. There is a idea of this particular course. At least you know the process flow, once you know the process flow when you go to clean room for fabrication of the device you will not be like a blank. You will know this devices or this equipment is used for this particular device. We will also see kind of equipment that are used for fabricating device not only process flow and recipe alright.

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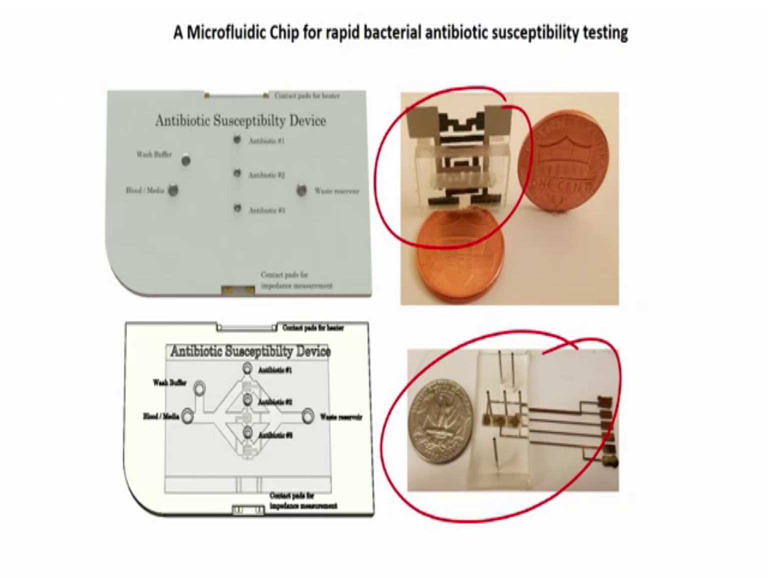

So, if I go to next slide and next slide is for antibiotic susceptibility. We will see how we can design right a microchip that you can see here right over here for understanding antibiotic susceptibility. Now what does that mean? What does that mean right and we can also design a micro fluidic chip for understanding the antibiotic susceptibility.

So, if you ever went to doctor right if you went to doctor and you have some kind of infection right, the doctor will generally prescribe tropical antibiotics that is 3- 4 antibiotics to eat right. And we take this medicine we eat and we pay doctor right. Why to eat 3- 4 medicines? Why not 1? Why not 1? Why do we eat 3- 4 tropical antibiotics? Because, because, first which antibiotic would be useful we do not know, we do not know right.

Even we know that this is a bacterial infection and this infection is due to particular bacteria and there are medicines antibiotics meant for killing those bacteria's still we had to take 3- 4 antibiotics. Because, we do not know which antibiotic would be useful for killing this bacteria or will the bacteria would be having a resistance against antibiotic. We do not know neither do doctor right. So, the one is we are we are given the antibiotic, second is we had our blood is taken or a urine sample is taken for further understanding what bacteria and suppose bacteria is known what antibiotic to give.

And the results from the pathology comes in 24 to 48 hours, 24 to 48 hours in some cases even more. Some cases even more time is taken for giving you the results ok. This antibiotic would be more effective with these particular bacteria since the patient is suffering from this particular disease right.

It is known like if I have a urinary tract infection then I know that the E coli that is bacteria called E coli would be in higher concentration right. But, which antibiotic to use that will a a a doctor can a doctor can generally understand based on the reports from the path lab.

Now, it is ok, it is ok, I do not say that the currents current way of medicine is wrong. It is what it is, this is what we know right. But, the idea is why we cannot reduce this time? Why we have to wait for 24 hours? Why we have to wait for 48 hours to get the report.

Can you can you design a device that can perform the analysis within a shorter period of time by requiring us lesser sample. Why I have to give like 10 ml of blood? Or even 20 ml of blood? Or even 1 ml of blood. How about micro litres; how about similar to glucometer I just puncher and that is it that is enough for me to give right.

So, reducing the sample size rapidly getting the diagnosis and and giving a correct correct antibiotic to the patient not correct this are all are correct antibiotics by the way, the antibiotic that will be effective for this particular bacteria. If we can do this whole thing within a shorter period of time using a device then that will be really awesome is not it.

Now, again you understand from our point of view if I have a bacterial infection if a doctor gives me a antibiotics I can take antibiotic and wait for 2 days. Even this antibiotic one of the antibiotic is useful, another one is not. It my immune system can take it, but, what about neonates? What about babies?

There are lot of bacterial infection in neonates and the immune system of a baby is extremely weak. So, in that case waiting for 24 to 48 hours may cause a death or life threatening issue for a neonate. Thus this kind of device that can do a rapid testing of antibiotic medicines that are antibiotics and can tell that the bacteria is resistance or not it is extremely useful right.

So, for that we will see how we can design a microchip or a micro fluidic device alright. So, that is what we see on this screen a micro fluidic chip for rapid bacterial antibiotic, susceptibility testing. Alright, we will see this device how we can fabricate this device.

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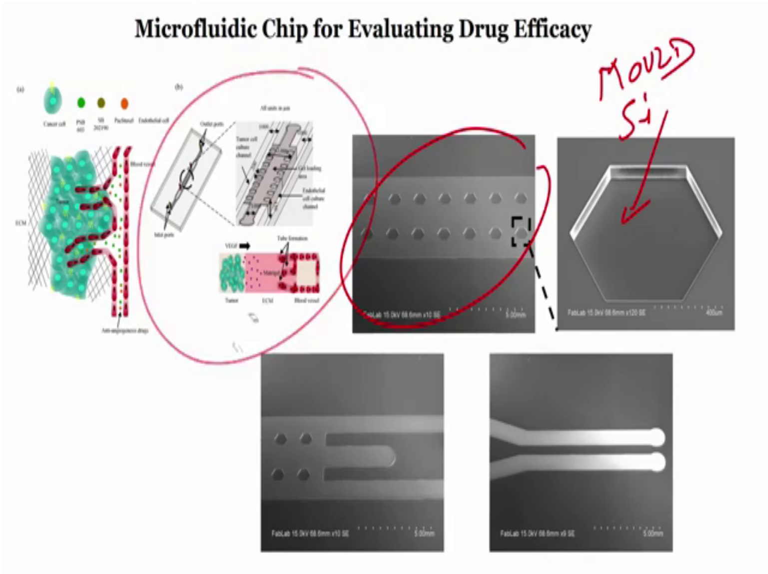

Now, I go to another device I go to another device and this are micro fluidic chip again you can see it is a micro fluidic chip. These are SEO images of micro fluidic chip and this is just a mould image of the mould that is made in silicon. And we will see why we have made this mould in silicon, what is a use of this device we see everything.

So, what is the idea? The idea is that if I want to understand that which drug can be used for killing this cancer.

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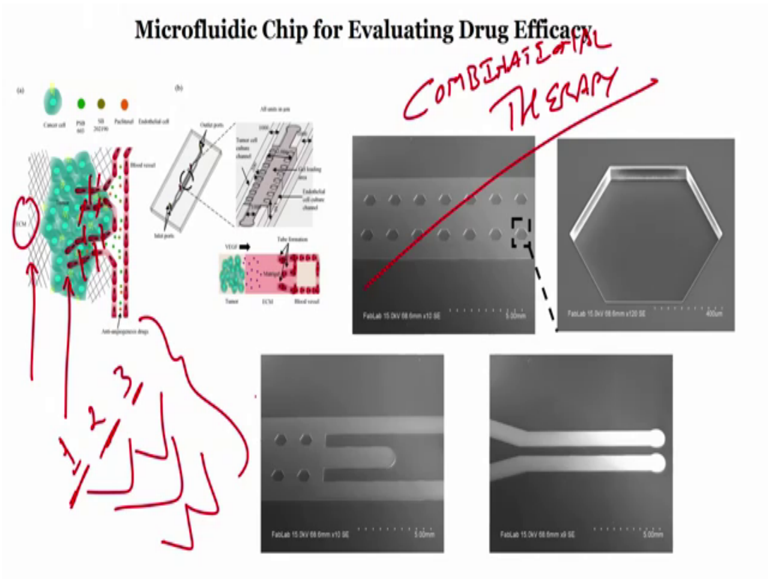

Suppose this is a cancerous tissue and you can see here vessels right, blood vessels supplying oxygen and nutrition to the cancerous tissue. Supplying oxygen and nutrition to the cancerous tissue and then you can see here there is a extra cellular matrix alright.

So, I want to test a drug that will start or stop that will stop growing of these vessels. If the vessels are stopped, if the growth of vessels are stopped or the vessels are destroyed right, the vessels that are providing nutrition and oxygen to the tumour are destroyed right.

Then what kind of drug would be effective? Or what kind of combination of drug would be effective? What kind of suppose there are 3 drugs 1, 2 and 3. One will be effective, second will be effective or third will be effective or combination of 1 and 2 will be effective or combination of 2 and 3 will be effective or combination of 1 and 3 will be effective or combination of all 3 will be effective right.

If I want to study this combination or we call combinational therapy what we call COMBINATIONAL COM BI NA TI O N AL, combinational therapy alright combinational therapy then.

What can I do?

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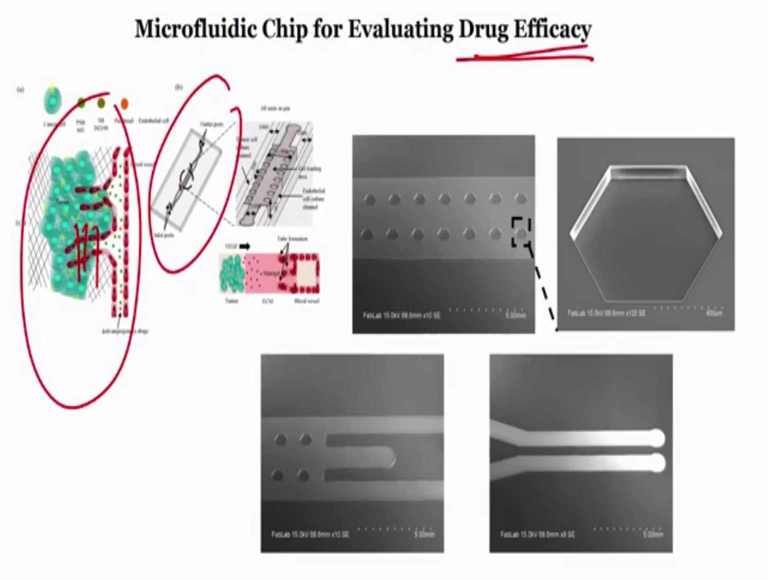

I can design a micro fluidic chip that mimics the same thing and I can test different drugs. I can test different drugs whether drug is effective or not that is drug efficacy, whether drug is effective in killing the tubules or in destroying the vessels that are supplying oxygen and nutrition to the tumour. If the nutrition and oxygen is stopped then the tumour will start dying because tumour is nothing but group of cells growing abnormally right.

So, this is another device that we will be looking at the clinical perspective then we go to the next slide.

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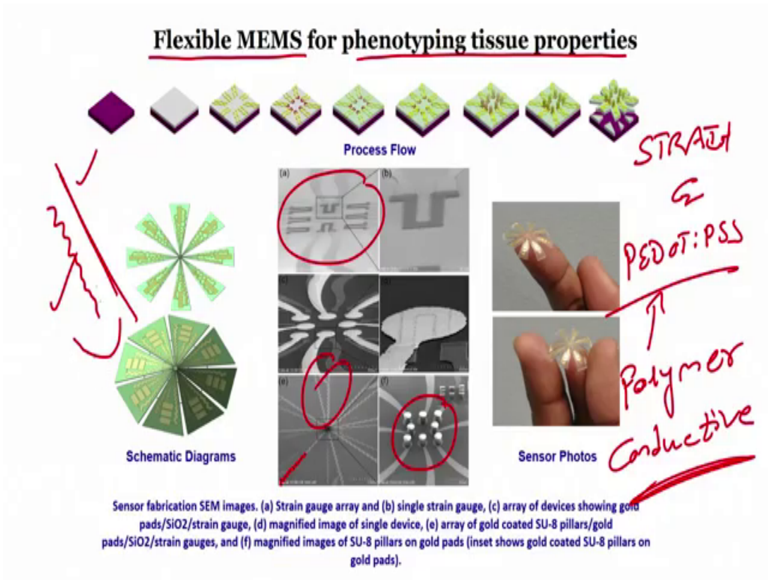

Alright, and this is very interesting application of a flexible MEMS right. Flexible micro electromechanical sensors or MEMS based systems based sensors for phenol typing or understanding tissue properties alright. And we will see how the process flow happens, how this device looks like.

If you see closely this device has this particular pattern right and actually there are array of this patterns, array of this patterns alright. And this arrays are nothing, but strain gauge, what is that strain gauge?

What is the use of strain gauge? Strain gauges are nothing, but when we apply strain it will changes in the resistance it is a kind of piezoresistor. So, I can make this array of sensors using P DoT PSS. P DoT PSS is a conductive polymer, what is it, conductive polymer polymer that is conductive alright one.

Second, if I have a insulator on it insulator on this right and on insulator if I have gold pads, you can see here gold pad patterns. And and and by the way everything that you see here like here in the centre a consists of piezoresistor and gold pad and SU 8 pillar it is right here you see. So, tiny super tiny you see this is 1 millimetre 1 millimetre. So, it is about about 1 millimetre within that area we have the sensors, within that area we have the sensors. So, anyway coming back to here.

If I have piezoresistors on which I have a insulator on which there is a gold pad and on gold pads there are SU 8 pillars, there are SU 8 pillars. Then I have a sensor if the substrate is flexible substrate is flexible then I can use this sensors right. And in SU pillar we can make it conductive, we can make it conductive. I can use this sensor for measuring the electrical and mechanical property of a material. And we will see how, we will see how we can use this device for measuring the electrical and mechanical property of the material.

And you can see here the contact pads the, you see it is like zigzag right, it is like here. It is not straight line why to have this kind of pattern? Why not to have straight line? What is the designing problem in this one or this one? Why we have selected this particular design? We will see that as well we will see that as well.

So, that you understand that how you can design this kind of flexible sensors right for your particular application. Because, you see I am showing some of the application of my work, my research right.

But, what about the the problems that you come up with, if you come up with a unique problem and you want to you want to find a solution for that particular problem, you have to design your own sensors. By better understanding these flexible sensors what we were talking about right can you use a concept and can you create your own sensor that is the idea alright guys. So, what I will do is I will teach you how to fabricate these flexible sensors using the MEMS technology alright so.

There are few more devices, there are few more devices that we have to see and those devices we will see in the second module right. This is a introductory module where you I wanted to you to get familiarized with lot of devices, different kind of sensors and MEMS based technology right; and how this sensors or devices or micro fluidic chips can be used for clinical perspective from clinical perspective actually right.

But please make sure or please understand this thing that this is not only one area where you can use the knowledge of micro engineering. We will see the fabrication and you can use this fabrication for designing sensors for other applications as well right.

So, I will show you devices that are used for clinical perspective, but you can make a devices which can be used for electronics, which can be used for robotics. For example, if I want to have a touch sensor or robot wants to have a touch sensor, can you design this touch sensor using the using the knowledge that you acquire in this subject that is the idea alright.

So, we will be looking at from that point of view as well that if I want to design a flexible 4 sensors or a touch sensors what kind of what kind of changes in the design can be alright.

So, I will see you in the next module we will discuss few more devices and then we will start understanding micro fabrication. We will see the process flow how we can design a device, what are the techniques used for designing this device, such as what are the equipment used, how a clean room looks like, what are the equipment within the clean room.

And then we will see each device in detail and how it can be used for solving a particular problem alright. Till then you again just look at the lecture at the end of this particular course you will be understand you will understand how you can fabricate a device at least using the process flow, at least on paper. And then in the next course I have a plan to go to the lab and perform actual experiments. But, to go to that level first we need to understand how we can fabricate devices or how we can design the process flow and SUV for the device alright.

So, I will see you in the next class, till then you take care. Bye.