Fabrication Techniques for Mems-based Sensors: Clinical Perspective

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Lecture – 50
Introduction to Equipments: Micromanipulator

Welcome, today we will look at a very interesting equipment that is commonly used in micro fabrication sensor testing laboratories, this is called the micromanipulator system which you can see here.

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The system is kept here first I will go through, what is a micromanipulator, what is the concept of it and why it is required for a micro fabrication course or a field, a lab which works in micro fabrication field. And then we will go into the details of this particular equipment. What are the different components in it? How you can use it and finally, we will end it may be in this module or in another separate module we will end it with the small experiment where we will use this on a sensor to see the response. So, getting started, what is a micromanipulator?

As the name implies this equipment is used for making micro level or micro scale manipulations or movements in your experimental setup. So, this equipment per say will not go into any product that you make, but it forms a very integral and important part of

your testing setup. That is the process by which you characterize your sensors for that process a micromanipulator system is unavoidable and very important.

So, as I have told now what is a micromanipulator? A micromanipulator is used for making micro scale or micro level manipulations or movements with respect to your sensor characterization. So, let us say we have a pressure sensor let us say assume the surface of my hand is a pressure sensor and what does a pressure sensor do, it senses pressure applied on it is sensing area.

Suppose this is a sensor and we have a sensing area here in this in the palm of my hand let us say we have a sensing area. And assume that my fingers are the sensing contacts you might have already seen several sensors that Professor Hardik had shown you in the courses. So, let us say assume that these are the contact points and this is the sensing area.

Now, this sensor what does it do as the name implies it does pressure sensing for that what we have let us say we are measuring the stiffness properties of biological tissues. Then what do we do we take the tissue which will be around 10 mm or 1 centimetre in height and 1 mm in diameter it will be a cylindrical block, let us say we keep that on top of this.

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So, for the time being let me say that this is the tissue I have just put a nut here I think you can see the nut. So, this is the tissue, now you have kept the tissue on top of the sensor and now you want to see what is the stiffness of this tissue for this what you have to do. The stiffness of the tissue is contained in the tissue itself not on the sensor correct.

So, what the sensor does, the sensor picks up the pressure applied on it when you place the tissue by default here there will be a base pressure that is applied. So, that base pressure we can measure from these contact points, this pressure will get translated as electrical signals and we will tap it from here. Now, we want to measure what is the stiffness of the tissue, what do we do?

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Let us say this is something called an indenter. So, we have this is a let this is a 3 D printed indenter, this is a micro scale it is not that micro level this is for understanding purposes this is a 3 D printed indenter, what does an indenter do? It indence or pokes or manipulates on the surface of the sample. So, let us say we have brought this indenter and for the time being for characterizing the sensor we are putting the indenter and pressing the issue with the indenter. So, when we press this indenter will apply one force on the tissue.

The tissue because of it is elasticity and stiffness properties will translate a different pressure at the bottom of the tissue or on the surface of the pressure sensor. So, we press it and then this tissue because it is elasticity translates a different pressure on the surface

of the sensor. This way whatever information gets measured from this contact points as the pressure be measured will inherently have the information of the stiffness of the tissue in the measured value. Now, so this is generally how we are measuring stiffness properties using a pressure sensor.

You can use other sensors also to measure stiffness properties, but for your understanding purposes I am taking this very simple example. So, now, we have seen that we have the pressure, pressure sensing layer the contact points the tissue and we have the indenter. Now, I think the limitation is this becoming slowly, slowly clear to you, when we are doing this with our bare hands there is a limit to the amount of resolution of pressure that you can apply on the tissue.

As you would know you would have done experiments in your school days whenever you do experiments you have a series of inputs and then you see the series of outputs and then you try to understand how the output is related to input correct. Then when you give the input how do you give, you start from 0 or a very low value then you will already have the highest value of input that you want to give then you will slowly slowly increase the input in a finite step size.

Let us say you are measuring an electric circuit and you give voltage as input and you know that the your system can take maximum 5 volt input, how do you start doing the experiment to test it. First you start off with 0 volt, you will apply 0 volt and see is there any output at the output terminals then you will increase by depending on the capability of the input source you will increase your and the amount of resolution required by your circuit you give in steps of very low value.

Let us say you give in steps of 0.05 volt. So, you start with 0 volt then you increase the input voltage by a step of point 0 up to 5 volt up to 5 volt. So, your first reading will be for input of 0 volt and what is the output voltage, your next reading your input of 0.05 volt and what is the output voltage. Then your next input will be 0.1 volt and addition of 0.05 volt what is the output voltage like that you will go to 5 volt.

So, how many input readings would you have? You will have 5 volt by 0.05. So, you will have 100 input lines or experimental attempts and you will see the output voltages. On similar lines when you want to do an experiment to do the input voltage characterization I mean not voltage you to do this stiffness characterization of the tissue. You should be

able to apply force on your tissue from very low value to a very high value like the breaking stress of the tissue till that point you should be able to apply step pressures which is not possible with your bare hands. There is a limit to which you can control the amount of pressure that you can give it is. So, you wish you need some equipment or some system to allow you to give these micro or very small step sizes of pressure to be applied on your sample.

So, that you can characterize your sample very well and have a good fit mathematical model for the stiffness or elasticity of your sample. In this case your sample is a tissue it can be anything. So, it is in this application that a micromanipulator comes into use your physical system like your body is not able to give this finite step sizes just like a voltage source gives voltages in very finite steps this manipulator can give you manipulations of micro level either through distance is movement of distance or through an indenter with the amount of pressure that is applied on your tissues.

So, this background I wanted to give you before we started off with the start off with the micro manufacturer system. So, that will be able to appreciate the importance of this system. So, as I have told this micromanipulator systems are used in multiple multifarious sectors. So, one is this where you are measuring the stiffness properties of different samples, another one is you can attach probes to your micromanipulator to characterize the electrical properties of your designed sensor.

So, there is an equipment called 4 point probe which also uses 4 micromanipulators to attach probes onto sensing parts of your sensor, sense in a voltage and sees the response current to check the a resistance properties of your sensor. I will come to the details of that soon. So, now, let us get started off to see the system at a broad scale and then into the integrities of the system and what all ports, what all features are available.

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So, here we have the micromanipulator system ok. So, this white platform that is there is a main unit and this black platform that is there is a right is a control unit, control unit forms like their brain or the main heart of the manipulation system as far as controlling goes and the manipulators themselves are these 2 black platforms.

So, these 2 are the micromanipulators this is manipulator a and this is manipulator b, these 2 are like hands which you can control and have micro movements. So, these 2 are micro manipulators, they are connected to the control unit through cables. Now, let us see a first I would like to show you the broad aspects of the device before we go into the details of it. So, let us look at the micromanipulator in a slightly more detail. So, I am just pushing the main unit towards you so, that you can see it.

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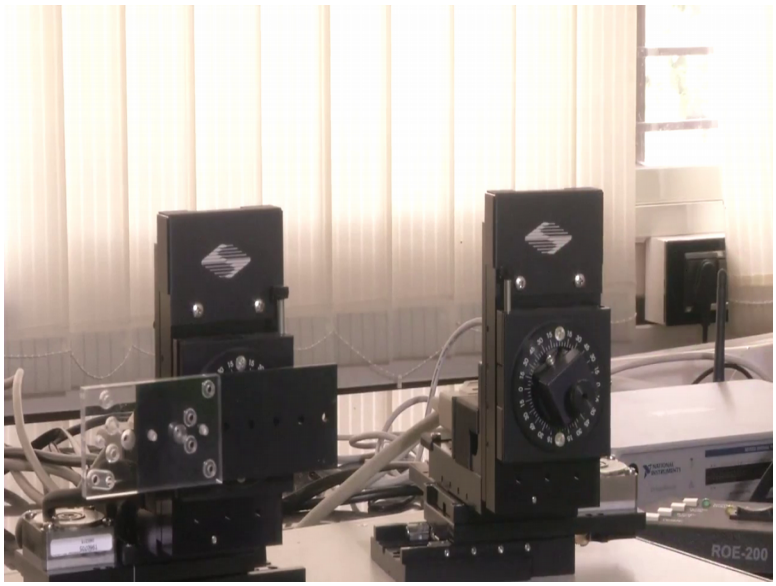

So, this is the manipulator so, I am just tilting it a little bit. So, if you see here in the manipulator micromanipulator will be able to move in x y and z directions.

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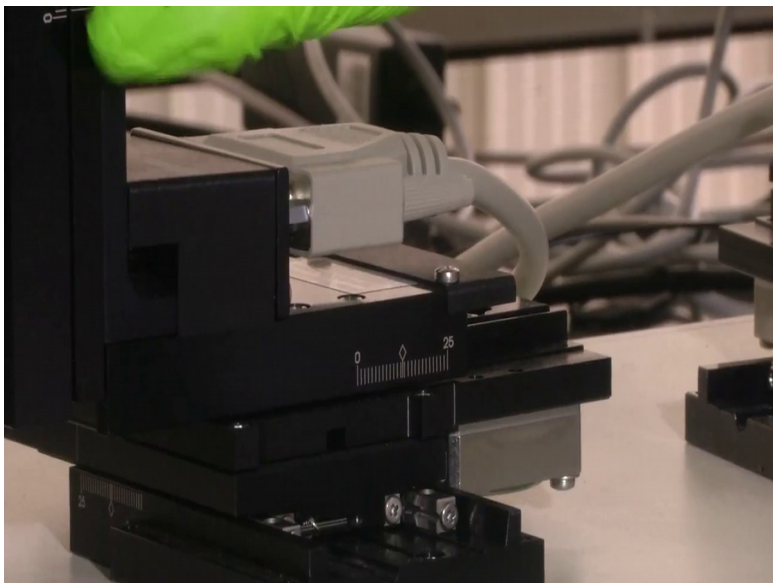

So, if you see here this is the y direction; y direction scale can you see the scale here from marked from 0 to 25. So, that shows that the manipulator can do movement of 0 to 25 mm ok, 0 this total is around 2.5 centimetres or 25 mm. So, it can travel in the y direction through 25 mm that is the scale or range of movement of the y movement of the manipulator understood.

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Likewise, if you see the z direction you see 0 to 25. So, again that is the same thing so, in the z direction the manipulator can move from base position to up to 25 mm of height. And then we have seen that this is micromanipulator so that means, we should be able to manipulate it is movement to the micro level. Shortly when we see the control unit we will see that this 25 mm is shown as 25,000 microns in the control unit; that means, you can control up to a resolution of 1 micron in the controlling. So, you can like 25,000 micron, 24,999 microns, 24998 microns like that you can reduce it.

So, you can adjust the movement of the yyz or x direction from 25000 microns or 25 mm to 0 microns you will see that clearly even we see the control unit. Now, I am introducing you to the basic aspects of the a manipulator so, you have seen the y scale, you have seen the z scale.

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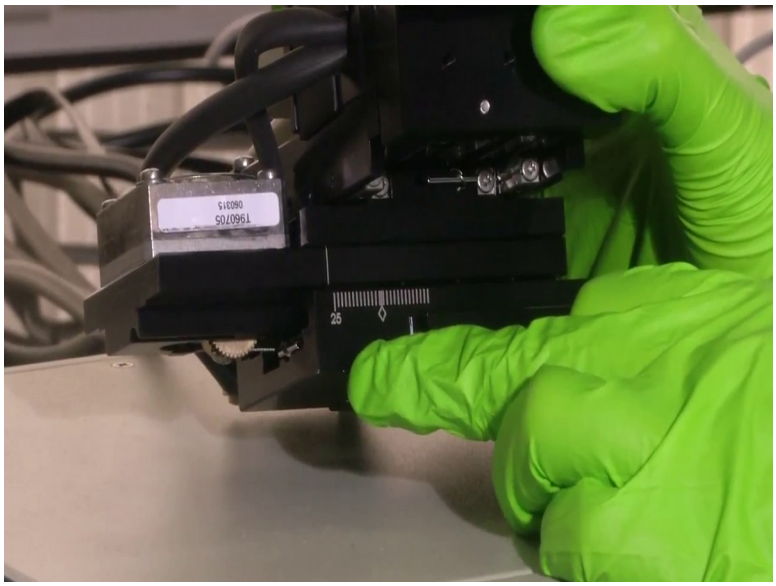

Now, to see the x scale I am just tilting it so, I think you can see the x scale here below there is also 0 to 25. So, we have 25 mm of movement in the x direction, in the y direction and in the z direction clear. Now, that is for the coordinate movements. Now, if you see closely so, in this manipulator we have attached somethings let us just check the manipulator b, this both are same dimensions are there 0 to 25, 0 to 25 and here if you see it closely in the back side it will be there 0 to 25.

So, these also have 0 to 25 now this manipulator is like an arm. So, when you are pushing something you should you need to add some stick or probe in technical terms to the arm right you have to connect some probe to tour arm just like your hands you assume that is manipulators are your hands. When you are probing just be less before we saw we were intending the nut with the 3 D printed indenter right there our hands were the manipulator, but they were not capable to do micro manipulations. These are much more efficient hands they are they can do micromanipulations, but we should be able to attach indenters or probes to those hands. So, this is the point where we attach probes to the manipulator.

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So, if you see here this you can see an angular scale here so, we can actually we can attach an angular scale here.

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Then will be just tilted you see do you see a hole here. So, you can actually attach any probe to this so, let us say I have this tool with me I can attach the probe like this, you can adjust the gap like this you see then I can insert the probe like this and then tighten it. So, I have attached a probe so, it has become like a hand you see now the hand has some

probe to manipulate it is target you can see it attached here clear. So, this angle so, now, it is kept at this angle right.

Now, we can actually make this change is angle like this to any direction we want by adjusting the screw here, if you adjust if you loosen this screw here you can rotate this part and it get tilt whichever we want this plas part is for loosening it and then tightening it to whatever dimensions we want ok. So, these are the main flexibilities or the degrees of freedom in technical terms that the manipulator has. So, which all did we see there is an x direction, there is a y direction, there is a z direction, each with a range of 0 to 25,000 microns.

There is a probe holder for an indenter holder which can actually rotate through at various degrees of angles which are seen there is an knob to adjust and attach your probe onto this holder. Now, if you see look closely instead of this probe holder we have attached another interesting piece to this sample indenter holder or probe holder. This is because now with the there are several options you see this dots here holes there are holes here also you can attach your indenter to this holder itself and then the indenter can probe from here.

So, this is like an extra attachment to the manipulators. So, I hope this is clear to you so, we have 2 manipulators, manipulator a and manipulator b, these they form the main what you call the people who do the work in this instrument and the brain that controls the items that do the work is the control unit which we will go into details soon. Now, let us see how the manipulator is connected to the main unit for that we need to look at the back side of the main unit.

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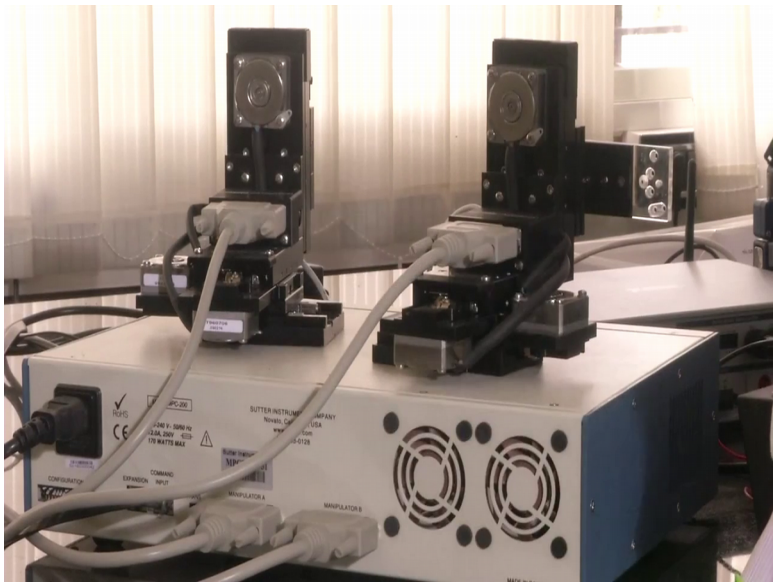

So, let me just rotate it so, that you can see the back side. So, you have to be very delicate by handing this equipment these are very costly equipment, but they serve a lot of purpose. So, now, you see that this is manipulator b and this is manipulator a, you can see motors here which control the micro manipulations of the equipment. Now, how do they communicate with the main unit, they communicate with the main unit through these connectors, I am just taking out the connectors.

So, the system is completely modular by modularity, what do you mean by modularity, what we mean is each important component of the system should be we should be able to remove it and service it or look at it as an individual hold. So, the manipulator a and manipulator b come as separate entities which can be connected to the main unit through these connectors.

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So, I have taken out the connectors if you see. So, this is a 25 pin connector, 24 pin connector so, the entire communication control data, measure data, all communications from the main unit through the control unit goes to the manipulator through this connector, this connector is eventually connected to these ports. So, if you see clearly just look at the back side; back side of the main unit you see the manipulator b and manipulator a, manipulator a, manipulator b. So, manipulator a, manipulator b these 2 are the 2 cables they come from here and they end up in the manipulator.

So, let me connect it back ok. So, these 2 form the main connections form the main unit, then we have the power supply connector as you can see power supply has be connected. So, power goes to this main unit and the main unit distributes power to the manipulators as well as the control unit. To the control unit all data comes and goes from the control unit through this command input port, if you see here the command input port is a RJ 45 connector this RJ 45 connector. So, this RJ 45 connector connects to the command input port of the manipulator.

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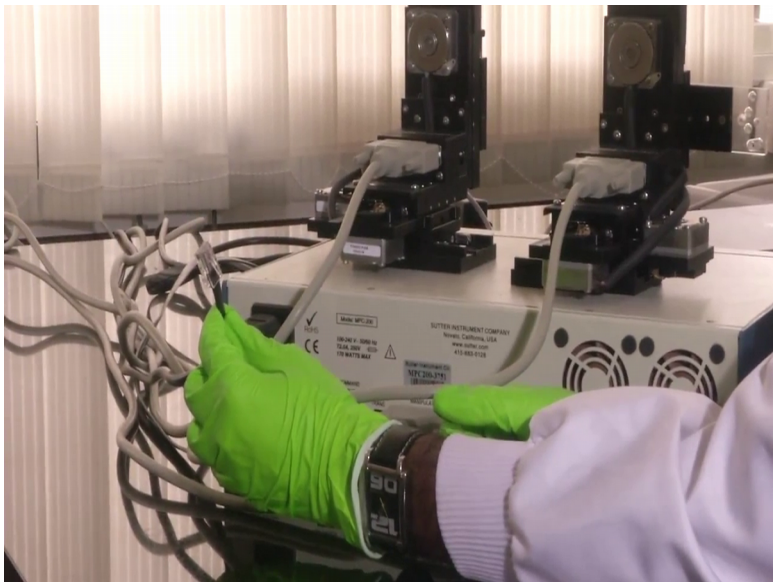

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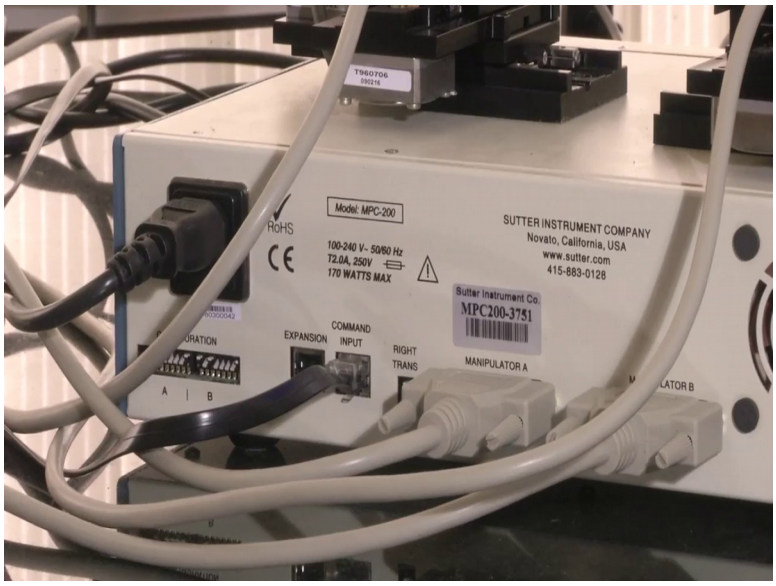

So, I have connected it back this is a command input port. So, let me just show the control unit to you now ok, this is the back side of the control unit ok.

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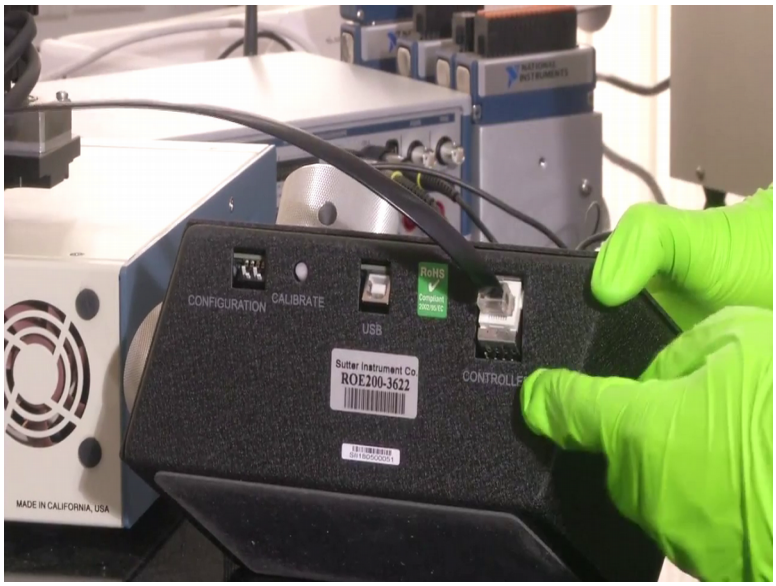

This controller is again an RJ 45 connector so, the controllers control lines go from here and the power for the controller also comes through this RJ 45 lines. So, from this, this wire eventually goes, goes around and then finally, ends up in the main unit ok, what else is a control unit have ? The control unit has a configuration support where there are DIP switches here can you see. So, there are switches here which you can toggle also they are kept it in the way they have kept in the factory default settings. So, these toggle switches can be cannot changed to configure the ROC or the control unit which is called ROC here to work at specific requirements.

Then we have an USB connector, if you want to control the manipulator or the control unit during through a system which also we will be showing in this module or in a future module through this USB connector you can actually control the ROC itself from a software and then make the manipulations to happen through the software.

So, these are the only ports that are there in the manipulator and there is a calibrate button here once power is turned on if you press the calibrate the manipulator will calibrate it is movements. And make sure that when we actually make a movement for one micron in the control unit there is actually a movement of one micron on the manipulator or that is what you call what you called calibration. So, that is how you do the calibration.

So, these are the main ports available back side of the control unit and those are the ports available in the main unit. So, these two are fans for cooling the main unit because it has it is own power system to take in the input voltage then convert it into the different voltages that are required for the manipulators to function as also the different voltages required for the ROC or the control unit to function.

So, we have seen these two connectors are there, these are connected to the manipulator, we have the command input port that goes to the controller, then we have expansion port right now we have not connected anything. So, let us say we want to connect extra manipulators or extra control units to this main unit, then we have a another RJ 45 port here called the expansion port that can be connected through this extra system can be connected to the expansion port.

Then we have just like we saw a configuration port on the control unit this one. You have seen the configuration port right on the control unit, just like this on the main unit at the end you can see a configuration port you can see that. So, this configuration port is there and you can configure each line on it as per the data sheet provided and then configure for multiple types of operation. So, these are the main functional ports or connections that are there between the main unit, the main manipulators and the control unit.

So, what are the 3 main components of this micromanipulator system? So, this micromanipulator system for your information only is called the model number is called MP 385 and is supplied by Saturn instruments. So, where Saturn instruments is a kind of a global leader of supplier of good quality micromanipulators. So, that is why we have purchase that from them. So, this is from Saturn instruments. So, this other why I am telling this is micromanipulators made by other companies might not look the same, but their fundamental philosophy of operation will be similar. If you understand this system you will be able to quickly understand any other different system that is made by a different company.

Now, let us just see the specifications mentioned on the main unit. So, if you can see the main unit needs an input power of 100 to 240 volt 50 or 60 hertz. So, in India our input voltage is 220 volt AC at 50 hertz so, this unit can take in that power. So, it just takes in that power from this power cord and makes all other DC voltages required for every other component to function. That is the reason why one of the reasons why this unit is

the bulkiest because it has lot of power modules to cater to different power requirements of both the control unit and the manipulators. And then it is telling T2 amps 250 volt 170 watts maximum. That means it uses maximum 170 watts when it is used in full 100 percent utilisation.

So, these are the main so, you can see the company name written that is not important here. So, these are the main body called ports as I have told and connections, you should before you start understanding any equipment you should know how the different parts of the equipment talk to each other before actually going into how the equipment works. Because, if it directly try to understand how the equipment works and if somehow things do not work as you expect them to be you should be in a position to debug on your own what when what would have gone wrong or where it would have gone wrong.

For that in this very important for you have to have a holistic view of the connections in your equipment and you should not always depend on the service engineer from the company to do minor changes for you. So, most of the things that might not work we should you should be able to debug at your lab itself for that it is very important that you understand, what are the connections, basic things. So, that you are because if you do that you are in a position to debug or fix minor things you are work with work will also progress faster otherwise, the people who come to service they take time.

We have to raise a ticket you have to ask for help there is a online set procedure, then they will take it and most of this equipments are imported they come from either US a or European countries. So, we have to wait for their response and they have to come and finally, when they come you will realise that they will fix it in 1 minute, under 1 minute which and also you being engineers and researchers in the field which uses these equipment you should be as good as or even better than the people who come to service.

Unless there is something that you need to change and you are scared that it might affect the warranty or that guarantee of the equipment then you should not touch it. Other than that if you are confident that you will be able to make these changes and fix the small problem that has occurred you should go ahead and do it. For you to go ahead and do that you should understand you should be able to know what are the different connections, how are each module, how is each module communicating with another

module and what might go wrong where, these things if you know you should you will be able to debug it properly.

So, now, we have seen basic components now we have to power on and see what are the how these things actually work. So, let me reset it back to the home positions. So, now, we have kept the system the equipment back to it is home position we had shifted it a bit to show you the ports available at the back side of each of the components. Now, we have kept the micromanipulators the main unit is there, the control unit is here. Now, another way where we the another arrangement of how it will be arranged is that there will be a microscope at the bottom ok, the microscopes eyepiece will be here.

So, we will observe this is the work area and manipulators indenters or probes will be connected like this as I had shown you how probes would be connected? Probes would be connected like this and this would be your work area for you to have better visibility. The control unit would be kept here and the microscope would be here and you will see your work area through the microscope and then manipulate it from here. So, because that would be a very complex arrangement for you to understand that is how exactly we would be using it, but then for you to understand this equipment alone we have kept in a simpler arrangement please be sure about that.

So, manipulators are kept on top of the main unit right now. For that it is clearly visible to you when we move this you should be able to see the movement that why it is kept at this level. So, now, we have a power on off switch finally, the moment we are waiting for is come we are going to power it on and see. So, once power comes you see the green light coming here and then as I have told the power to the control unit also comes through the main unit.

So, the control unit also has powered up and you can see the display here, is a display clearly visible to you yes you can see. So, if you see here there are in the display the mainly 3 sections; one is drive, what is the drive that you are using? So, you have manipulator a and manipulator b right. So, it is showing drive a. so, manipulator a is being driven, then you have mode.

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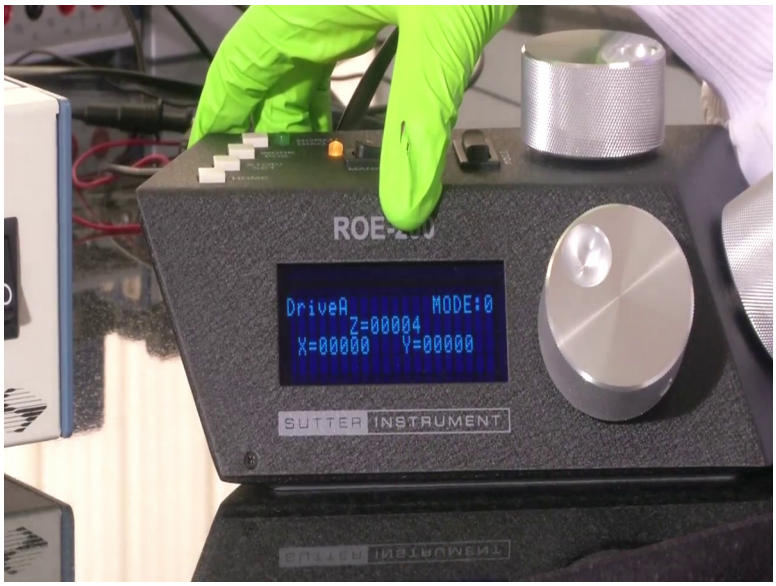

So, you can go up there it is showing that it is mode 0; mode 0 is visible, drive a is visible, then you can see is z, x and y values. So, z, x and y can go from 0 to 25000. So, z, x and y can go from 0 to 25000. So, I am just making it back to 0 now z, x and y are at 0 ok so, one is drive what is the manipulator that you are driving and then one is mode and one is the z, x and y values.

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Now, there are it is very clearly visible to you there are 3 knobs available here, one is for x manipulations, one is for y. So, the top one I am changing it when I change it you can

see the z values changing correct. So, this is the z manipulator ok, now this is the y manipulator when I am changing the y you can see the y values changing, this is the x manipulator when I change x you can see the x values changing clear.

So, then drive so, let us see the knobs or buttons that are available on the control unit ok.

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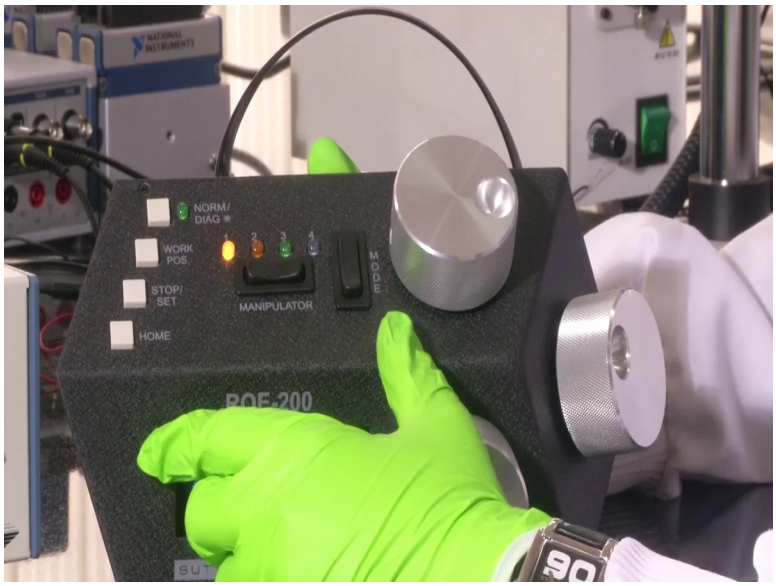

So, we have manipulator selection here. So, there are 1, 2, 3, 4 is written; that means, you can connect up to 4 manipulators to this control unit. You can even have more than 4 manipulators connected to the control unit, but you need to add another controller through the expansion port which we saw earlier. So, that expansion port needs to be connected. So, this manipulator so, if we press it if the control will go to the second manipulator see now it is gone to second manipulator, as we as it is well aware to you we have connected only 2 manipulators to this control unit correct.

So, manipulator 1 and manipulator 2 only makes sense, the other 2 are not available. So, that is why even if you change the mode it will only switch between one manipulator and the second manipulator it does not go to the third and fourth because the system has not detected extra manipulators connected to it so, that much intelligence is there in the control unit.

So, right now let us keep it back to controller 1. So, when you connect the 1 the manipulator will be able to control manipulator a ok, then there is normal or diagnostic

test. So, if you click that it will do a basic calibration test of the manipulator so, that is what is happening.

So, that have fixed it up then there is there are 3 things, there is home you can see home at the bottom, then there is stop and set then there is work position ok. So, let us say we have started manipulating the manipulator by changing the knobs and you arrived at a position. Let us say x is 15000, y is 10000 and z is 20000 in microns, as you must remember the x, y and z directions can navigate from 0 microns up to 25000 microns or 25 mm.

And you have reached at these values x is 15000, y is 10000 and z is 20000, you at this value you are able to indent your sample properly. Then suddenly you got some other work and you have to rush out and then again for you to search and seek out this value this place it is difficult. So, you can always save your work position here this is a work position. So, if you say the position if you get back we just click the work position the manipulator will go back to those x, y and z coordinates and you can start your work immediately instead of again seeking out the sample where it is under the microscope.

To set that work position we use this set stop set button now there is one more knob available here called mode, you can see here next to the manipulator. So, this is mode ok, if you change the mode the mode is basically to give you control of how fast the x, y and z values change when you rotate the manipulator knobs. Understood what does it the mode do, there are 10 modes from mode 0 to mode 9 as you increase your mode it gives you more control of how your x, y and z values change as to change your manipulator knobs.

Let us say we are in mode 0 correct you can see it in the display we are in mode 0. Now, look at my hand; my hand is on z manipulator I am changing it very less see you can hardly feel my hand movement, but then the z values are changing quiet fast 73 78 84 85 correct. Now, I am changing the mode I am increasing it to let us say mode 5 or mode 6 now it is in mode 6 is it clear to you mode 6 is written. Now, let me change it see now I am changing this much still z value has not changed now only it has changed. So, again you are changing and now only it has changed.

Now, you are rotating now only it has changed, let us say we increase it to mode 9 which is the most finest mode, I am in mode 9 now here let us say the value is 156 right z value

I am changing the manipulator see this much movement I am doing on the manipulator still the z value has not changed. I am changing, changing and changing, changing I completed almost 3 quarters of the circular movement then only it has changed. So, this gives you more control about your of your x and y, xyz motions.

So, this mode selection depends on the kind of sample you are testing. So, if your sample is quite destructive and if you put so, much extra pressure on your sample in case if it gets affected then you should be working at very high mode. So, that you are you can you are making very fine changes in your manipulators movement for that you will have to use the mode 9. If it for general applications you can work with mode 1 if you want to quickly characterize your sensor you can do this.

Then see I am I am back to mode 0 and your z value is fast is changing very fast and in one circle itself the z value will cover almost 1000 microns of movement ok. Now, you it is very clear to you now what are the control knobs available in the control unit, you have the x knob, y knob, z knob, you have the manipulator selection points to select between manipulator a and manipulator b, see when I am changing the manipulator selection it is changing to drive b or drive a. So, you can select the manipulator a or manipulator b correct, then you can do the mode selection also.

Now, let us see the fun part; so, let us look at the manipulators now manipulators are in view. So, as I had told this is manipulator a, this is manipulator b, now let us you need not see the control unit. So, I have kept the you just focus on the manipulators you are seeing the manipulators in the control unit as you remember I had kept it in manipulator a control now I am changing the z manipulation ok.

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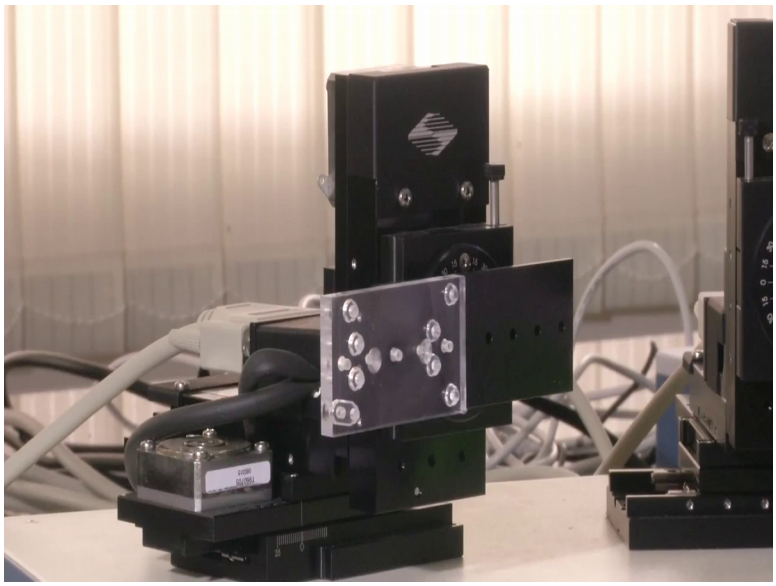

Now, you closely observe the manipulator a I am changing the z manipulator. So, do you see the manipulator going down in the z direction. So, I increase it to 25000. So, it has gone down fully up to 25000 fully gone, down now let me go back to 0. So, you can see the manipulator going up so, this way you are able to manipulate it in the z direction correct, I am moving it up and down. Now, let us try to move it in the x direction see you can see the mark also below, we are moved it full 25 mm or 25000 microns correct. Now, let me go back to 0 position, you can see it moving in the x direction very clearly correct.

So, let me keep it somewhere in the middle because, I wanted to show you the home knob know z also I will keep somewhere in the middle ok. Now, y direction let me just manipulate it y you can see it going back clearly you can see it going back. So, I am manipulating it in the y direction by changing the control unit ok. Now, it is in some x value, some y value and some z value correct you have you might have remember the home button in the control unit right. Now, if I am going to press the home button once I press the home button you will see the manipulator automatically adjusting it is x, z and y to the home or the 0 value ok let be press it.

So, you saw it now x, y and z went back to it is home values, let me just show it you again. So, I am again fixing z to somewhere in middle pushing it down, x I am pushing it to somewhere in middle ok, y also I am pushing to somewhere in middle clear ok. Now, I want to start fresh I will press the home button when I press the home button x will go to

0 position, then z will go to 0 position, then y will go to 0 position clear. So, instead of you going to do that the system provides single button to do this, now as I had told you there is also the work position.

So, I have saved a work position for manipulator a. Now, if I press work position it will go to that work position so, I pressed work position so, is going there. So, the position is z value of 12321, if you see here let us see in the control unit ok. In the control unit the work position is z equal to 12321, x equal to 12484 and y equal to 12479, I slowly adjusted it. So, let me go back to the work position 12315 clear so, this is the work position.

Now, let us try to manipulate manipulator b, I am changing it now look at the control unit I am changing the manipulator to manipulator b clear. Now, let us look at manipulator b this is manipulator b, on now manipulator b is in your view point. Let me just change the z value of manipulator b, you can see it going down clearly yes then let us change x clear, let us change y clear. Now, let us go to home position just like manipulator a you go to home position x, y and z will change clear and you can go to work position so, it is going to work position also it is clear to you.

So, this is how the manipulations are done, the x direction, the y direction, the z direction, what is the what does the home button do, it will go to their home configuration or 0 configuration 0 position and the work position is something that you can save and then go back to every time you reuse the equipment. Now, let us look at one more thing we have seen the micromanipulator. So, it is these are the hands of the equipment, but we have not given any tool to the hand right so, as I had shown you.

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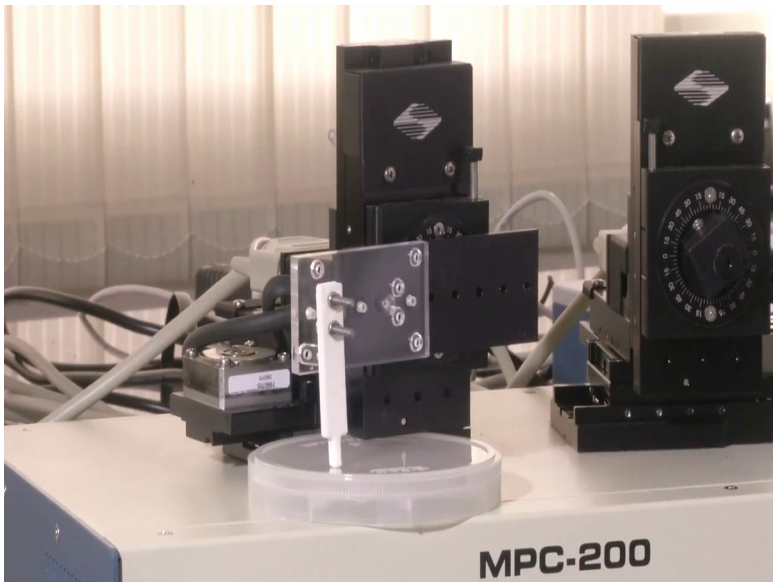

Let us look at manipulator a now so, we had seen manipulator a, we have seen that there is a indenter holder for the manipulator correct and we have attached this indenter holder here which has lot of holes here, which will allow you to attach several indenters to this port ok.

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So, we have 3 D printed using 3 D printing technology, we have 3 D printed quite a big a macro scale indenter so, that is very visible to you. So, this is the attaching part of the

intender and this is the tip of the indenter with this tip you can actually interact with the sample.

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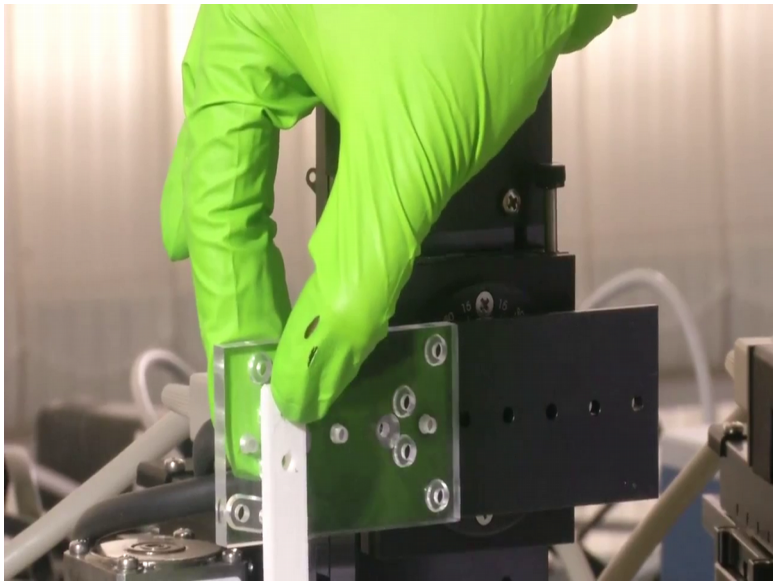

So, we can attach this to this port of the sample holder. So, let us say so, it is there like this we can attach it. So, we have to we can attach it with screws I am attaching it with screws clear. So, I have to put a nut so, let us put a nut. So, one nut is put and then tighten it from behind ok we have to put the other nut also ok. So, it is even if you do not put the nut it is reasonably tight now ideally we should be putting second nut also and tightening it, but this is how it will work, just pause now I will put it so, let us put the second nut also.

So, this way the equipment gives you lot of flexibility. So, the because of this stand is there. So, this connector is connected to that sample holder or the indenter probe holder you can 3 D print or you can fabricate any kind of micro needle or whatever it whatever you want. And then connect it to your micromanipulator and indent it so, there is lot of customisation probabilities possibilities that are there available to you.

It does not mean that you have they have given you this equipment and you have to use these needles or these probes only to interact with a sample it can be anything. So, these are exactly like your fingers you can hold anything you want with your fingers correct so, they are like that ok. So, we have connected our 3 D printed indenter clear, we have

connected 3 D printed indenter to this manipulator so, for fund sake for your own interest, let us just manipulate it is in the z direction ok.

So, now you are in with the indenter your manipulator will go down correct and it go up also let us say we have to interact with some sample, let us just keep some sample at the bottom ok. So, let us say I am having this wafer career this is a wafer carrier and this is your let us say your sample is on top of this. So, if I am manipulating I am bringing it down ok. So, when it comes down it will touch it see. So, when it touches it will apply pressure, you would not be able to see it because it is already interacted with the wafer sample. So, it is gone up, then we are bring it down and then it is interacting clear.

So, this way you can increase the pressure applied like this. So, this is how you usually test with the micromanipulator instead of this we will have a sensor and sample on top, with that experiment also we will be doing soon in another module. So, I think this would have given you a very good introduction to how the micromanipulator system works? What are it is uses? How it is used? Where it is used? What are the different components micromanipulators? What are indenters? What are the probes? How can the probes be connected? How can you have angular arrangement for your probes? What is the main unit? What is the power requirement?

How does the main unit provide supply to the other manipulators and the control unit? How the manipulators are like your hands? And how the probes are like your the tools that you hold in your hands? Hope that is understood to you. Then you saw the control unit which forms the brain or the controlling CPU of your manipulator, what are the different knobs available in the control unit the x manipulator, the y manipulator and z manipulator, the what are the different modes? Why there are different modes? What is the use case of the different modes?

How do you change from one manipulator to the other? What is home position? What is work position? What is diagnostics? What is calibration? And how do you set your work positions? So, I hope this has given you whole some understanding of how manipulators work. In another module we will also see a short experiment where we will force indent a pressure sensor and see how it responds. So, see you then.