Fabrication Techniques for Mems-based Sensors: Clinical Perspective

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

Lecture – 47
Introduction to Equipments: Peristaltic Pump

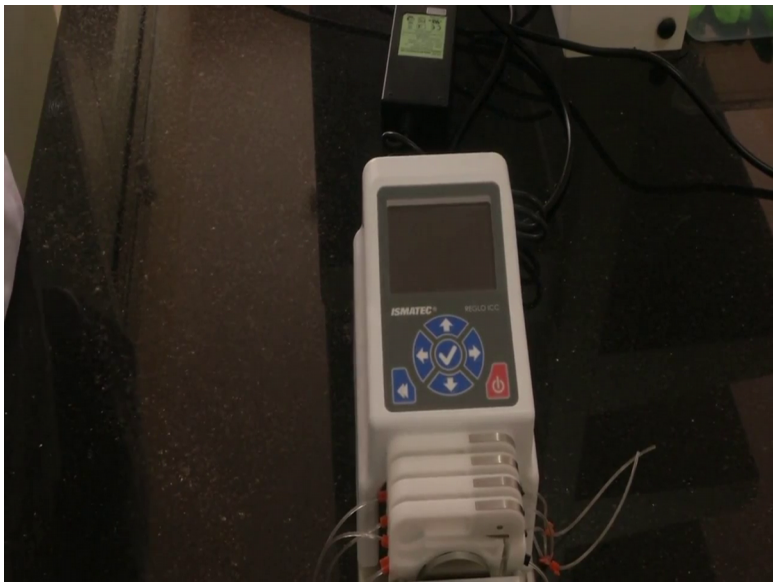
Welcome. Today, we will see a very interesting equipment, that is performs core part of any lab that deals with especially microfabricated microfluidic devices. You might have come across different types of devices that are made using microfabrication technology. Some of them are MEMs devices, what is MEMs? Micro Electro Mechanical systems, they can be MEMs devices, MEMs sensors or a different type of MEMs structure.

Another classification when that is commonly fabricated using micro fabrication technology are microfluidic devices. What are microfluidic devices? They will be small devices, there you will have channels, small channels, very fine features like micron level features. And you will be pushing very small quantities, microlitres of sample volumes through these channels and see the response.

The flow rates in such equipment will be in microlitre spend per minute, like 10 microlitre per minute, 2 microlitre per minute, 20 microlitre per minute. And the flow rate is a point of very high significance and you have to adjust your flow rate properly, else for these devices issues like leakage at the inlet outlet ports and leakage from the microfluidic device, etcetera may happen.

How we fabricate these microfluidic devices is a subject of discussion at a later date; which the if time permits we will be covering that. Today what we will do is, given that we have a microfluidic chip, what is the equipment we use to flow at this very small rates and at high precision fluid flow rates. So, that is what we will be seen today. The equipment that is used for that is called a peristaltic pump. There which we will be seeing now.

(Refer Slide Time: 02:28)



So, this is a peristaltic pump. So, microfluidic for microfluidic devices, you can flow the fluids like it may be blood samples, it may be a solution that contains certain salts or maybe a drug dissolved in a medium. So, such liquids can be flown in a microfluidic device using either peristaltic pump which you see here or syringe pump. So, syringe pump is just like a syringe only, but it is needles will be very small, and you will push that through the inlet and outlet ports of the sensor.

Peristaltic pump is much more advanced pump, where you can actually circulate your liquid with high grade precision. We will see what are the features of this pump and how it is actually used to pump the liquids through a microfluidic device. So, this is the peristaltic pump that we talked about. So, as I told there can be 2 types of pumps that can be used for microfluidic applications. One is peristaltic pump and another one is syringe pump. A peristaltic pump is a technically a more advanced equipment.

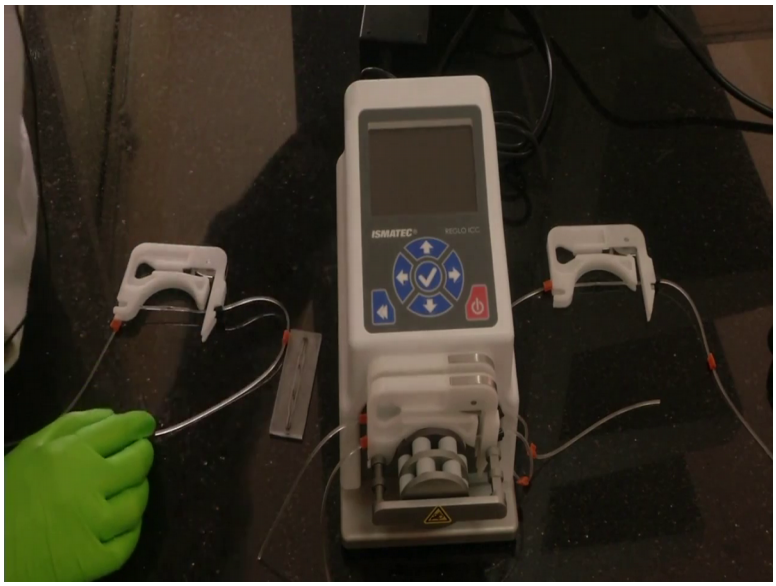
Now, let us see one we have one microfluidic device which we have already tested in the lab. So, I will just show it to you, hope you can see it clearly this microfluidic device. So, here you see there are channels, like this, and inlet and outlet ports are there. So, the fluid in microlitres per minute will be flown through these channels. This is what you call a microfluidic device. These are inlet ports, these are outlet ports and this is where you load something like a static sample, you will load and keep here. So, let us say we load cells or cancer tissue in this middle chamber, this called a chamber.

So, we will load it in the chamber. And then what we will do? We will flow blood or drug or whatever you want to flow around your sample from here to here you will flow it like this. So, the liquid will flow like this or like this parallely across both sides of the tissue and then when it flows it will diffuse, because there are hexagonal barriers you might not be able to see clearly, cause these are very small features. There are hexagonal barriers through which these fluids will diffuse into the sample and then cause changes which we can observe under a microscope.

There are also microfluidic devices; where under this chambers you have another layer where you keep sensors. Like, impedance sensor, pressure sensor, chemical pH sensors, etcetera. This microfluidic device does not have it; it is just a one layer of acrylic sheet where we have engraved the microfluidic channels. So, you see we will see how peristaltic pump can be used to test such a device, and you will understand and appreciate the equipment much more now.

So, you see this is the peristaltic pump. The core part of the pump is the insert cassettes where you have the microfluidic tubes. So, this is a microfluidic tube. It has an outer diameter and an inner diameter. You will not be able to see the inner hole here, but here in this tube the outer diameter is 1 mm, but the inner diameter which is the actual path or the hollow region of the tube is 0.12 mm, that is the diameter of the tube. So, fluid will flow through the 0.12 mm diameter tube inside and the outer casing is just for physical strength and support of that inner tube. Now, this is a cassette. So, I will remove this cassette, let us I have removed one cassette.

(Refer Slide Time: 06:13)



I have removed another cassette. So, here you see these structures right, what are these structures for? So, as we have discussed this equipment is not for pushing in high volumes of fluid. It is for pushing in microlitres of fluid. So, how this equipment does that is, you see this cassette right, these circular patterns will go and push like this, push I think you are I hope you are able to see this clearly.

So, it will go and push every time, this one and then there will be fluid here, right. So, it will push the fluid like this, it will push the fluid at every rotation it will push the fluid like this so that microlitre precision of fluid flow can be obtained like this. See, I think it is clear to you. This is how this circular structure pushes fluid in this cassette. Now, let us see how this structure of circular structures are moving. For that we need to switch on the equipment first.

(Refer Slide Time: 07:20)

So, I have switched on the equipment, this is the interface for the equipment. Let us go to the home screen. So, this is the home screen. So, we have set so, in this RPM measured is the actual RPM at which these motors are rotating. And 4 microlitre per minute is the flow rate that we have kept for the channels. Then so, here this is how we set the flow rates, see the cassette symbol here and that rotating structure here, you can see that no. So, that is rotating circular pattern is a same, whatever circle patterns, I we showed you before it is shown here, here if you zoom in you but let us say you can see it here actually.

It is difficult to zoom to this very small screen. So, here you can see actually the cassettes. So, here this is the volume, what is the volume that you want to push in that defined amount of time. So, volume is given as 4 microlitre, and time is 60.5 seconds or 1 minute. So, what is what will be the flow rate roughly roughly it will be? 4 microlitre per minute, like that you can set your flow rate, and accordingly the device will work.

Let us see the next setting. So, you have to select what is the tube id, what is ID? ID is inner diameter, what is the inner diameter of your tube? So, it is 0.13 mm, it is around 0.12 to 0.13 mm. You can set it according to the hardware actual hardware that you are having on board. Then this is for calibration, these are general things and then what is a language that you want to use. So, let us try to start it and see.

So now I have started the motors. So, see here because we have removed the cassettes you are able to see how these motors are running. See one in one it is going in one direction, in the other it is moving in the other direction. This also we can set here, which direction you want to push your fluid. As you push the fluid with the cassette inserted, it will actually push against the tube and then push the liquid inside. This is how this pump works. See, the according to the amount of flow rate that you set the speed of this flow will change.

So, I have stopped it. So, when we stop it, it will actually show. So, let us say in the port 2, what is the exact amount of liquid it has pushed till now? Right now we have not connected the cassette, but as per the rotation per minute and the values you have set it will show that it has tried to push 2.06 microlitre. Let us say I start again. So, you see it is increasing, it is calculated that if the cassette was there, it will it would have pushed this much microlitres. If you have taken noted time exactly at end of 1 minute, because we have set 4 microlitre per minute, exactly and at the end of 1 minute or 60 seconds, it would have pushed 4 microlitre. So, it is getting ampletor.

And see because it has pushed 4 microlitre, it stops and shows you what it has done. Now we have asked to push only in the second channel. This 1, 2, 3, 4 are for 1, 2, 3, 4; 4 separate channels. So, you can flow 4 different liquids or flow it in 4 different inlet outlet pairs using this equipment. Now let us stop it and see how we can adjust the direction. See here, this arrow right this arrow shows in which direction the circle will rotate.

So, it is showing clockwise. So, it will rotate clockwise, you can change it and then it will become anticlockwise. So, this is volume per time how do you want to change it, then do you want to measure in volume per time or something else only volume or only time or volume plus stop and push, stop and push, volume plus pause what does it mean? I will push for sometime then stop again push for sometime. If you have a similar application, you can use that. Time plus pause like push for 30 seconds, stop for 20 seconds, push for next 30 seconds, stop for 20 seconds those kind of things you can do, and you can even give a direct rate, like microlitre per minute.

And then volume what is the volume that you want to push? Let us say if we suppose we increases volume to 10 microlitre accordingly. And then I will start the equipment, then

you will see that the motor that you saw will move faster. Let us just increase it now. So, I am increasing it to 20 microlitre per second in 60 seconds.

So, here you can adjust the direction, see you are seeing the direction where you can see this white box that is there, this showing the direction now it is clockwise direction, let us say I change it. I click it then I change this see it has become anticlockwise. So, this way you can change the direction in which it is rotating like this. So, once it is done we do it and we come back, ok.

Now, let us start and see if the speed has changed. See now the it is rotating at a faster speed, it is rotating at very high speed now, compared to the previous one. For you to for so, that it is very clear to you, let me again go back and reduce it to a very small value, then you will see this change in speed of rotation of this motor. I am stopping it now, now let us go in. So, I am seeing the updated data of how much it has pushed. So, rate is 100 RPM, the RPM rotations per minute it has become 100 RPM. And now you yeah, we have gone in let us change the volume to very small value to, let us say 0.5 microlitre per minute in; so, 0.5 microlitre per minute I have put that.

So, I am closing that now, see now it is moving slowly. No, but it has not got updated, see here it has not got updated that is why it has gone back to it is starting speed. Let us stop it calibration. So, this is channel 1. So, I want to make it for channel 4. So, here this number shows which channel; are you trying to change. So, I want to make it for channel 4, channel 2, channel 3, channel 4 ok. So, let us remove this channel 2's cassette and see what is the rate now.

So, channel let us make it channel 2, channel 1, channel 2, channel 3, channel 4, channel 2. Channel 2 has pushed 2.81 microlitre till now after we restarted it. Now we have changed as we discussed, I have changed we have changed the channel 2's volume to 0.51 microlitre per 60 seconds. For better clarity for you, all of you I have removed all the cassettes and only show in the motors. So, this is channel 1, this is channel 2, this is channel 3 and this is channel 4.

So, if you look at the settings for channel 2 we have kept volume per time as a setting. And the rate is 0.5 microlitre per minute basically, 0.51 microlitre per 60 seconds. This is channel 2, please see my hand, when I start doing it you should just focus on my hand

which is channel 2, and see how it is differing from the way other channels are rotating. Before that let us see what is the rate set for other channels.

So, for third channel only the RPM is set, depending on RPM it will move. So, third channel it is 100 RPM, 4th channel also it is 100 RPM. First channel also it is 100 RPM, but for second channel we have set volume rate. So, 0.5 microlitre per minute. So, what happens this channel will rotate at a very slow speed compared to other 3. Let us see what happens now.

So now I have started it see all the other 3 channels are moving very fast and second channel is moving very slowly. Because it is push rate is 0.5 microlitre per minute. Or you can see that it is still moving this if you observe it is slowly changing position. See this come till here, come till here, come till here, for better clarity let us try to see we change the setting for one more channel. So, I am stopping it now, always stop and change your settings, because this actually dealing with many mechanical actuator components.

So, let us see I change for third channel. I do not want rate; I want again volume per litre. So, I will put volume per time. So, then what is the volume? Let us give now this we gave in the seconds we gave 0.5 microlitre per minute right. Now let us give 5 microlitre per minute, 5 microlitre for 6 minute 1 minute will be 60 seconds. So, 0, 60 seconds, I am saving it. Before we start let us just check these channel settings of all the channels.

So, channel 3 is now what? 5 microlitre per 60 seconds. Channel 4 is again 100 RPM, channel 1 is 100 rpm, channel 2 is 0.5 microlitre per minute and channel 3 is 5 microlitre per minute. Now when I start it we will clearly be able to see how 100 RPM differs 100 first first channel and 4th channel is 100 RPM. This is 0.5 microlitre per minute, this is 5 microlitre per minute, how each one differs you will be very clearly able to see when I start it.

Now, let me start it, see these 2 are rotating at 100 RPM. This is rotating at 0.5 microlitre per minute. This is rotating at 5 microlitre per minute. So, you can clearly see the difference in the way they are rotating. This is the core concept of a peristaltic pump. Once then once we insert the cassette, it will push the tubes and accordingly circulate the fluid. Now how would how is that does? Let us have discussion or demo on that also.

So, I think it is very clear to you now, how this equipment works, and how after setting the different rates flow rate or RPM, or volume just the volume or time plus pause, we can do so many things like that. Let us also try one more thing, let us change it to run and pause and run. So, let us change the setting for this let us say channel 2 we are changing it to volume plus pause. So, what does that mean? So, I my rate is 100 microlitre, my volume let us let us say we increase it to 4 microlitre RPM with the 2 second pause. So, there is a pause of 2 seconds, let us say we keep the pause to 5 seconds, 3 second so that you can see clearly what happens.

And do this for let us say let us do this for 5 cycles, or let us say we do this for let us keep it high so that we will be able to see it, do this for 50 cycles ok. It is set done so now, channel 3 is again 5 microlitre per minute, channel 4 is 100 RPM, channel 1 is 100 RPM, but channel 2 is set for 100 RPM 4 microlitre with a 3 second pause for 50 cycles. Let us just start and see.

So, check channel 2 it is pausing see. It will pause for 3 seconds and then it will again rotate. So, let us say when it pauses I will count 3 seconds then you will know that it is working exactly 1, 2, 3 it will start again. Stop; 1, 2, 3 it will again start. So, we have set it like that. So, it will rotate like that see how interesting this equipment is. So, this way we can actually do lot of programming on how we want to flow things and have multifarious applications.

Now, let me stop this and let us see how this insert the cassettes back you have to be very, very delicate with this equipment, it is a very costly equipment. First insert this, then push this inside and hear the click sound that is inserted. Now how do we flow actually? So, what we have to do is, first we have to so this tube will hold certain fixed volume of sample content. So, what we have to do is, first we have to connect it like this, like this we will connect. Then what we will do is, this sample has to come from somewhere right. So, we will take a beaker. So, we will have a dish with the beaker.

(Refer Slide Time: 23:16)

Let us say we have the sample put in this Petri dish, you can see the Petri dish right. So, we will have sample put in this Petri dish, we will keep the tube like this, then we will start it we will fix the time in such a way that in this tube will push start pushing out the liquid from the other end. So, we will keep the liquid like this and then push it. So, what we will do is, let us see let us try pushing it with water. So, I will fill water in this, and then we will see where the time it takes in and pushes out from the other end.

So, I have filled this Petri dish with distilled water. Now, we have kept one tube here, the other end of the tube is here it is clear to you know. So, we have set 100 RPM for this channel right let us reduce the RPM. So, that you will be able to see it in real time. So, we will go to channel one and rate we will change it to let us say 10 RPM, roughly 10 RPM done.

So, this is channel 1 now, what will happen? This tube is currently empty, there is nothing inside. We will have what we have put water on this Petri dish. Now it will take water from here inlet as that pump will rotate, it will start filling water here, here, here, here. Finally, water will get filled through the entire tube and it will start coming out from this end, once it starts coming out we have to stop.

Once we stop what will happen? Both ends will have water filled right, fixed amount of volume will be filled with a both ends. Then these 2 with the sample inserted we can

insert into our microfluidic chip and then keep flowing it. So, this is how we load samples into the cassette of this peristaltic pump. So, let us see how it works.

So, we now our objective of this experiment, we have to perform this short loop experiments small small experiments was to understand how things work. So, we will start it and see the when this water comes out from here. Because the diameter is very small, it will take some time, let us just see, ok. It is not happening because you know why? We have made a mistake, I will tell you what is a mistake it is, then you will understand it better. I am pausing it, I am removing the cassette and I will show you what is the mistake.

So, we know that the source is here and the outlet is there, right? Now I am removing the cassette I am starting it again. So, what is happening? It is rotating this side. So that means, it is trying to take liquid from there and push it back here which is not what we want. So, we need to change the direction of rotation to clockwise. Now it is rotating anticlockwise, let us do that change first. So, I have changed it now. So, done saved, let us start it again and see if it is rotating in other direction see. Now it has started rotating in the other direction.

Now, let us see what happens. So, we will insert the cassette again. First this side, clip it, then push it, put it at the inlet port, and then vola; you have steady to ready to start. See now actually if you see, you can see the liquid going up here. Finally, it will come out from here. Just have look at here, at one point it will come out. I let me put it back to the Petri dish itself. It will start dropping from there ok. Now liquid has reached the tip. As we push more the droplet will develop, and finally, the drop will drop ok. Let us wait for the droplet to form, for it to become sufficiently heavy to drop, because gravity has also to play a role here.

So, I hope you can see it see one drop has dropped. Let us wait for another drop to drop. Yes, you can see the droplet being formed clearly? And as soon as the droplet becomes heavy it will fall. See, droplet has become big, yes, the droplet is there it has fallen down; so, this way you can actually. So now what happens? Once now your because 2 drops have already fallen, now you are sure that your pump your tube is filled with water. Now these 2 we can insert in the microfluidic chip, right now we do not have the connectors for it. So, we can insert it like this, in the chip and then flow wherever you want. This is

how you connect the this is how you load samples in into your cassette, how you will load it, how to make sure that it is fully loaded, the from the other end the droplet has to come out, then once it is fully loaded you connect it, set your flow rates and then you are ready to flow your liquid for as long as you want.

Hope you have understood the working of the peristaltic pump what are the different features in it, how the pumps work, what are the different speed settings, directional settings, what are the different tubes. So, say let us say I will show you another tube. So, this is a small, this looks like a smaller tube, but then it is inner diameter is much higher than this tube, but it is outer diameter is bigger. This gives more protection this is does not give much protection. This inner diameter is 0.38 millimetre and outer diameter is 0.5 millimetre.

So, this tube we purchased so that we can use it with this microfluidic device. So, you can insert it into this inlet like this. Like this you can insert it, clear, we will insert it then we will have a coupler mechanism that will connect these 2 tubes, and then again you can flow like this. So, you can your device can actually have this microfluidic tube connected already, and then you can connect it to a peristaltic pump like this though a connector and then again you can flow it, wherever you want. So, you can ship your microfluidic device with the tubes also that is another utility. So, like this tubes are available for multiple different different diameters.

Hope this gave you a good idea about micro fluidics also, how to load sample, how to flow, and everything and hope it was a very informative session for you. It is a very fascinating field microfluidics. So, if you are interested you can read further. So, microfluidic chips are also made using microfabrication technology. And they have to be flown at very high precision flow rates as you have (Refer Time: 31:25) and you understood how why peristaltic pump is very much required to flow at this very critical exact flow rates.

Thank you we will see again.