Sensors and Actuators
Dr. Hardik J. Pandya
Department of Electronic Systems Engineering
Indian Institute of Science, Bengaluru

Lecture - 23

Hi, this is your lab class number 10 and in this lab class, we will be looking at PDMS molding. Now, what exactly is PDMS moulding? If you remember in our theory class we had shown you a microfluidic chip. In the microfluidic chip, you should have a silicone mould on which you will pour the PDMS and when you cure it, you can peel off the PDMS.

This entire process will be shown to you in this particular lab class. Alekhya will be taking this class which I have designed for the course and you will be looking at a very important experiment. And if you know this process, your life will become very easy when you are working on a microfluidic platform because in a way it is very easy to replicate the same kind of channels if you have a silicon mould with you.

It is the only one time when you have to prepare a mould and you can use it for "n" number of times if you are careful. We will be showing it to you how to use PDMS to create channels if you have a silicon mould. Focus on this particular lab class and I will see you in the next lab class. Till then you take care, bye.

Hello everyone, welcome to the course on Sensors and Actuators. In this module, we will study what is PDMS molding and how does it become important when you are trying to understand how to fabricate biosensors. We have already seen how sensors can be fabricated using silicon wafers, the fabrication process, how lithography is done, the choice of wafer and the different process steps to achieve a memspace device.

Another part of the sensors is at a micro scale level as PDMS based microfluidic devices. Again when we talk in terms of making biosensors, it could be as small as as a micro or nanoscale level. How do we replicate this? Unlike the standard optical lithography process where we have the photo resists and we follow the standard procedures there is another alternative in order to fabricate a bio-chip very quickly. An important part of bio-chip fabrication is PDMS.

A lot of chips have been fabricated using this polymer. PDMS stands for polydimethylsiloxane and it is a polymer of carbon and silicone. Let us see how we can fabricate a bio-MEMS device using this polymer. Why do we fabricate using this elastomer? In most applications of making microfluidic devices or bio-MEMS devices, the most commonly opted choice of polymer is PDMS based.

If you see from the fabrication point of view, it is very easy and rapid. It can be prototyped and when we talk in terms of cost, it is comparatively lower than the standard fabrication procedures of MEMS based devices.

Another major advantage of using this polymer is that once we mould it into a device, the chip would mimic the physiological, chemical and biological environment of any organism, even human.

For example, the entire mechanism of the blood flow through the veins can be scaled down and replicated in the form of a lab on a chip. All this is based on this means of fabrication. We can even fabricate the entire organ, where we can do several experiments and this is called called organ on a chip. Reason why they are called bio-chip.

Another application widely studied is the antigen, antibody susceptibility, and antimicrobial test, protein-protein interaction, impedance test, impedance analysis on the microorganisms, etc. by fabricating a bio-chip. The applications are vast.

Let’s understand the steps involved in making these biodevices starting with the Requirements:-

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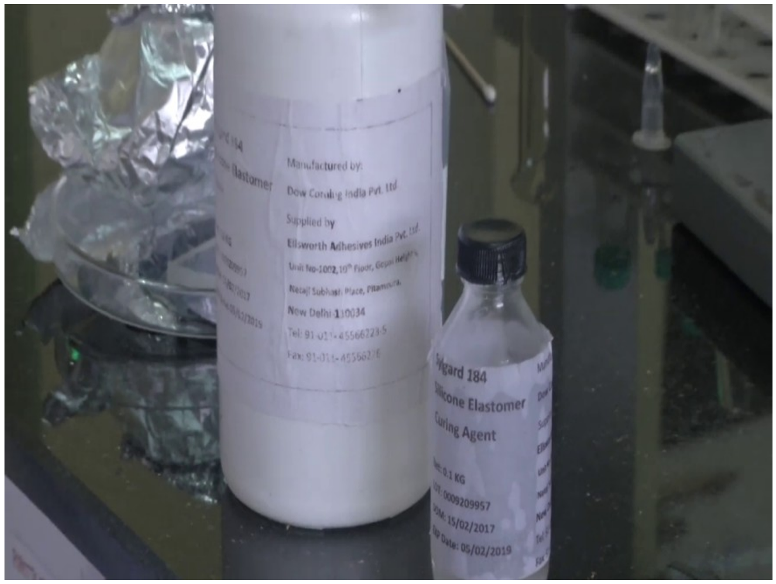

Here what I have is a silicone elastomer Sylgard 184. I am going to make the PDMS molding using this silicone elastomer, along with a curing agent. If you want to make a mould using PDMS then you might consider buying this elastomer and a curing agent. Elastomer and curing agent are mixed usually in the ratio of 10:1. When these two are combined in this ratio, a polymer is formed which can be cured and that easily. You can replicate micro to nano level features in just a few hours.

The curing agent is more transparent and this elastomer is more viscous. Once I pour it into a container, you will see how the two are immiscible initially and then after a lot of stirring it becomes a uniform mixture. Now, let me take the two in a 10 : 1 ratio. you could use a container in order to quantify the amount of elastomer that you are taking. Here I have it handy. I would take 5 ml of silicone elastomer into a container.

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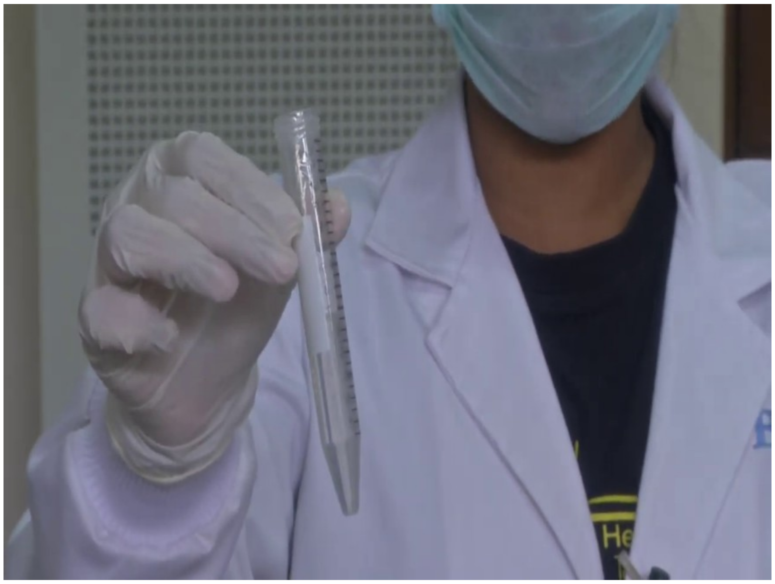

Now that I have taken some amount of elastomer, I take the curing agent. I need to take 0.5 ml of curing agent. The curing agent would be floating on top and then at the bottom I have the PDMS, the silicone elastomer. Now, we have to stir this well. You could take a stirrer and then stir them thoroughly and a lot of bubbles get formed. This process would go on in order to make the two immiscible polymers combine into a single liquid.

You need to stir it for about 5 to 10 minutes so that the curing agent and the silicone elastomer are well mixed. If you do not stir them well and you just use it onto your mould and then cure it, you would later see cracks that become more brittle. It is not a flexible elastomer when you cure it, when you remove it from your mould you will see that they are more brittle and they tend to break even before you dice them in order to get your device.

as you can see I have stirred it for around 10 minutes and there are a lot of bubbles due to the stirring action. Again, a precautionary and important thing is that while stirring, make sure you do not inhale the fumes and do not keep them very close to your face. While you stir there are a lot of chemicals that come out and they can be harmful.

So, you should keep the container at a lower level while stirring and ensure wearing a mask. Once we have the curing agent and the elastomer mixed thoroughly, let us see what to do with this mixture.

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Here what I have is a desiccator. If you have not heard of a desiccator, this is a chamber that will provide vacuum. As you can see this is the top lid that is transparent and there is a bottom casing and an elastic rubber so that the lid sits tightly. You can say that this is a small vacuum chamber.

There are many applications of a desiccator. This provides a clear, neat vacuum environment inside the chamber. How do we generate this vacuum? Here you can see the chamber is connected to a pipe that goes to a pump having a dial gauge. All the air that is inside will be pulled by the pump and a vacuum will be created inside this chamber.

Another important application of using desiccators is while characterizing the fabricated device in a facility that is farther from where you are staying. It is used to protect devices from contamination or to prevent hydrophilic silicon to absorb the moisture in the environment.

Handling the wafers with bare hands can cause contamination. They should not be exposed to moisture or air because they absorb the air and the moisture which is there in the environment and there is a formation of an oxide layer.

The silicon formed is a few nanometres. However, it can hamper the device functionality. Assume you want to deposit A metal layer of 1 micrometer. Then you get your wafer and there is already some 2 or 3 nanometer of oxide formed on your wafer due to not taking precautionary measures, the metal deposition won't amount precisely to 1 micrometer.

In order to avoid all such scenarios, you have to use the desiccator. In our case when we are talking about the bio-MEMS or the MEMS based sensors, it becomes important that the wafers are not exposed to any sort of contamination. Now, that we have the desiccator here and the vacuum pump, what I am going to do with this PDMS mixture is to degas it. Degassing is done using the desiccator to remove all the air bubbles.

We cannot use the mixture containing bubbles for curing because we are talking about making a bio-MEMS device that has channels of a few micron lengths and the dimensions are so small that even a droplet or even a bubble here can block your channel and that is not desired. Even the tiniest bubble has to be removed from this mixture.

We follow this procedure called degassing where the mixture will be put into the desiccator for around 5 to 10 minutes so that all the air bubbles will be pulled out and it would ensure that there is no more air left inside the vacuum chamber. It would turn to be a clear mixture, a transparent clear fluid. Now, I am going to put this into the desiccators. I have my lid properly closed and then I turn on the vacuum, the pump. You can observe the dial gauge, if there is any leakage, the pressure would not increase.

Now I have the tube, the container where I have the elastomer is placed inside the chamber and then the vacuum process is going on. You can see there is some amount of pressure that is the vacuum is being created inside this desiccator.

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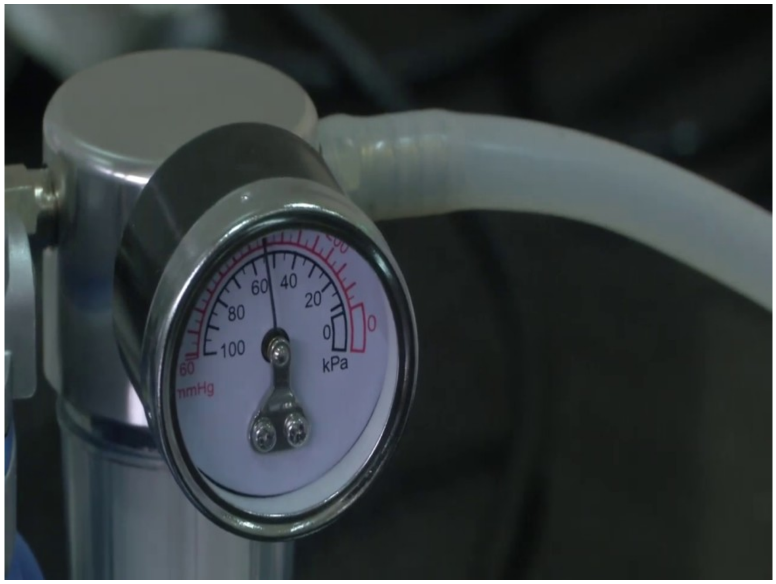

There I am not sure if you can see inside how the bubbles are coming towards the top of the surface. there are a lot of bubbles in the beginning. after you have properly whisked the elastomer and the curing agent there were a lot of bubbles that got formed and then that removal can happen using the process of desiccation. And now, it would this process would take around 10 minutes and then you will see all the bubbles gone out and then you have a clear polymer mixture.

Having given around 15 minutes of time for desiccation, now there are no more air bubbles left. I will switch off the pump and then you have to slowly release this valve here because if you do this very fast there is a lot of air which gushes inside the chamber and that can again form air bubbles into the mixture. That is not what we want.

What we will do is slowly degas. There is a slight noise and that is the air that will be going inside the chamber. Now, after degassing you can remove the lid and we have a clear liquid. Now, that we have a clear mixture I'll just repeat the process. We take in 10 : 1 ratio, the elastomer, and the curing agent. Mix it thoroughly and then once we have the mixture ready, we put them into the desiccator and wait, desiccate it, degas for 10 to 15 minutes until you see a clear mixture like this. Now, what do we do with this mixture?

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Here I have a silicon wafer. You may be able to see the fine lines here. This is embossed on the surface. This wafer has a pyramid like a rhombus structure as an embossing. You could have many different forms of this structure.

If you want micro channels in your MEMS base device or bio-MEMS device then you could just have the micro channels engraved on this. And, what would happen is, once I have this PDMS layer I would pour it on to this mixture. I am having it very close to the surface because even if it is poured at a distance, it would tend to create bubbles on top of it.

There is a very small amount of polymer mixture that I have taken depending on the dimensions, of your device. You could choose the quantity which would be more appropriate to get the device. There are absolutely no air bubbles as you can see and if by chance there are any air bubbles, then what you could do is to remove the air bubbles using a small needle.

I have poured the polymer mixture onto the embossed surface on the silicon substrate. Another thing that you have to take care of while you do this process is to make sure the substrate you have is thoroughly cleaned. You can follow this procedure by first cleaning it with acetone followed by IPA and then some DI water. Be it the silicon substrate or any other substrate on which you want to fabricate the device, follow the cleaning procedure and then have the PDMS liquid poured onto the device.

Now, we will see how to cure this. The setting that we have to follow is to put it in an oven at 70^0 Celsius for 2 hours. What will happen if you set it at a higher temperature? The curing at a higher temperature makes the mixture brittle and it tends to break. Hence, it is important to do the process at optimum temperature and time.

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Take some time to increase the temperature. Now that we have the oven at 70^0, you can place your mould for 2 hours.

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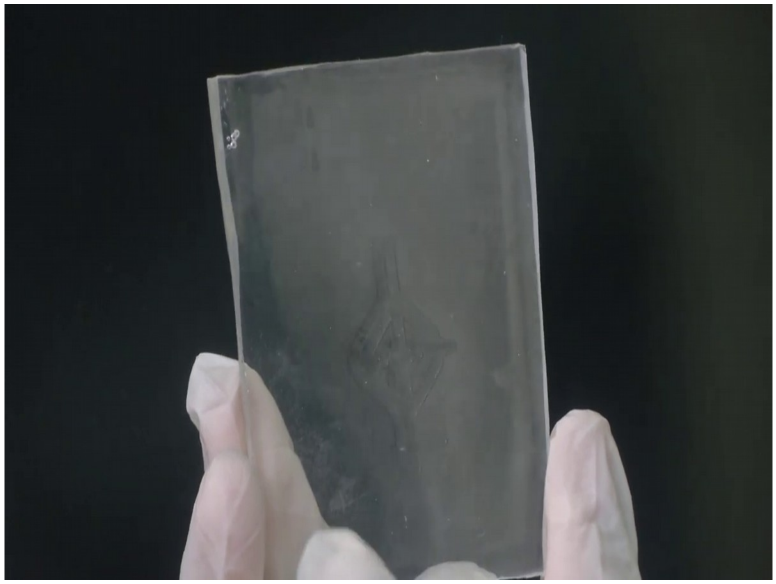

After curing the mixture at 70^0 Celsius for 2 hours, you get back your mould and then you could cut it using a surgical blade and this is what you get. This is the flexible PDMS substrate on which this structure was embossed.

Now, if you see this you can observe how you can easily replicate the structure on your mould on to PDMS devices and you could even mould channels of a few micrometers and nanometres in dimensions using this polymer. Another thing that you can see here is a device structure that we desired, but with tiny bubbles at the end.

Always make sure you remove those bubbles. What happens here is, when you do this sort of molding and then curing, bubbles tend to retain inside the mould. If they stay somewhere between your device structure, it could block your channels.

Ideally, we are trying to make devices with micro channels and then flow fluid at some rate so that we are able to get droplet formation or we are able to send bacteria and then see its susceptibility. All of these tests are mostly liquid based and when they flow through these channels, they could create some sort of blockage. And so, you always need to make sure that you do not have any sort of bubbles while you do the entire process from mixing to being cured and so degassing becomes an important process.

Now that we have seen how you can replicate your structures or features very easily in just a few hours using PDMS, this can be a base with which you can take help and then start making bio-MEMS devices. Once you have your chip you can do the desired study. This was an introduction to PDMS molding and how this can be integrated into making a MEMS based bio-chip.

Thank you.