Sensors and Actuators
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Lecture - 13
Wafer Bonding and PDMS moulding

Wafer bonding is the joining of two or more wafers together to make a wafer stack.

Three types of wafer bonding:

- Direct bonding
- Anodic bonding
- Intermediate Layer Bonding

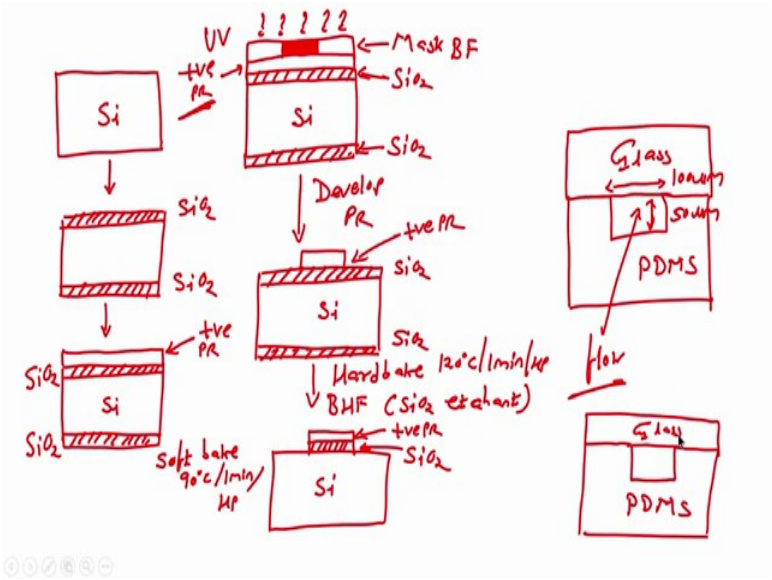
All the three types of wafer bonding require substrates that are flat, smooth and clean. There will be no bond formed if the surface is rough. Hence, for a strong bond, the surface should be flat, smooth and clean.

To etch about 5 microns, we can use Reactive Ion Etching (RIE). We can also use wet etching. If we have a wafer of, let's say, 500 microns and we want to etch 400 microns, we use a process called Deep RIE (DRIE). It enables high aspect ratio etching.

DRIE has fluorine, SF_6, CF_x and SF_x. If we use silicon dioxide, it will act as a mask. SF_6 or any material that we use for etching silicon dioxide will not etch it. The etching rate of silicon dioxide is extremely small compared to etching of your silicon which is why silicon dioxide can be used as a mask.

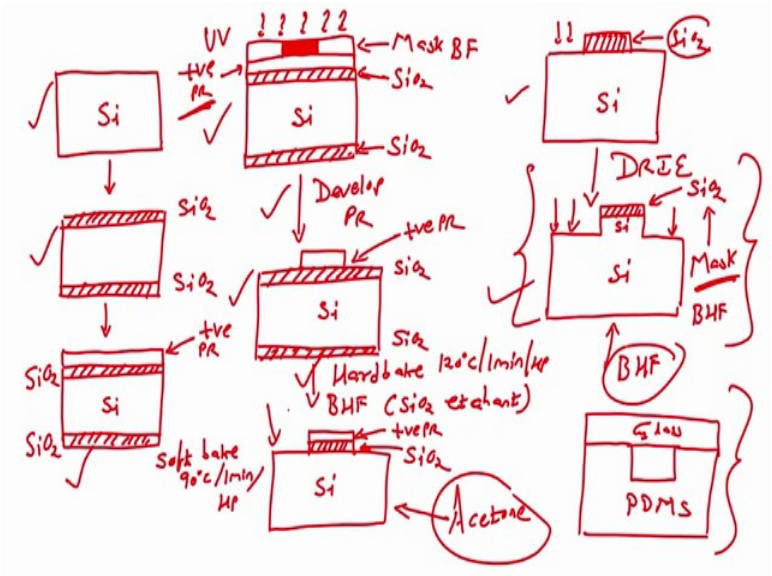
Now, if we use SF_x, it will start etching. We will use another gas for the polymer layer like CF_2. It smoothens the wall. We use the same gas to etch from the bottom, but the side would be comparatively smoother. If we use DRIE, we have a much smoother wall than when we use wet etching. Depth of the etch can be of hundreds or even thousands of microns into the silicon substrate.

For a 4-inch wafer, the silicon thickness is close to 500 micrometers. So, DRIE can be used for etching a few hundreds to a few thousand microns of silicon wafer with much smoother walls compared to your wet oxide wet etching.



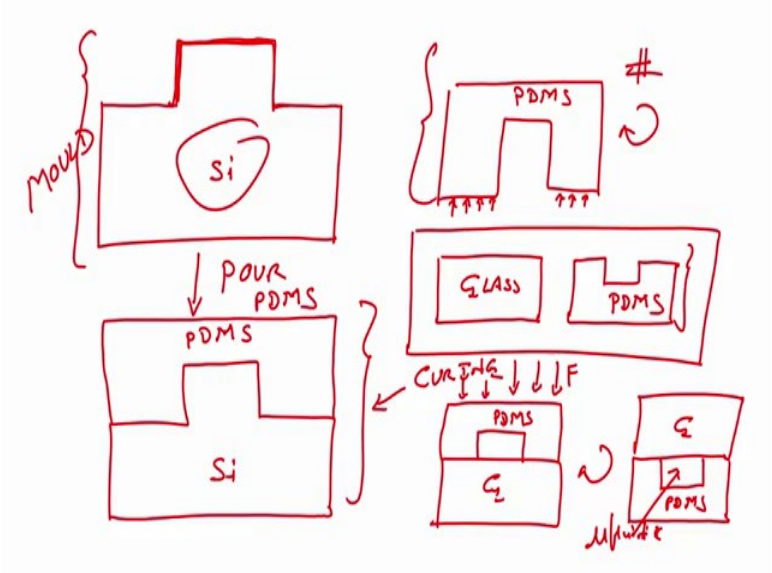
There is a channel and then we are bonding it. Let's say that the width is 100 micrometers and the depth is 50 micrometers. We will flow either a liquid or a gas through this microfluidic channel as this is our device.

First step is we need to create this PDMS which would look like the one in the figure. So, you take a silicon wafer, silicon and you grow silicon dioxide; you can grow silicon dioxide using thermal oxidation. Next step is spin coat photoresist. We are using positive photoresist. Next step is soft bake; 90 degree centigrade for 1 minute on a hot plate. On this, we load a mask. The mask would be a bright field mask. Next, we expose the wafer with UV light. Next is to develop the wafer. We have silicon dioxide and photoresist because we have used positive photoresist; that means that the unexposed area will be stronger. Next step is we must perform hard bake; 120 centigrade for 1 minute on hot plate. After hard bake, we dip this wafer in Buffer Hydrofluoric acid (BHF) which is SiO_2 etchant.



The next step would be that we dip this wafer in acetone to strip off the photoresist. Now, we perform DRIE. We have read the DRIE process flow earlier. The silicon will get etched in the regions as shown in the second row, third column diagram in the drawing above. Silicon dioxide will act as a masking layer. We again dip this wafer in BHF.

Next step is we pour PDMS onto the silicon. The next step is we must cure it. Curing would be done depending on the thickness of PDMS. There is a datasheet that we can use to understand the temperature and the time required for curing. Once we perform curing, then we strip off the PDMS. After curing, we get the PDMS in the opposite shape of that of the silicon as shown below.



Next, we load the PDMS onto glass. We keep both in an oxygen plasma chamber. We must make sure that the surface which we want to bond is on the top side. We have to take PDMS and bond it by pressing it, applying a uniform pressure.

Now, if we want to make more of these microfluidic devices, we just want to use the silicon mould. We keep pouring PDMS, cure it, strip it off and we get the design. Again, we cure another PDMS, cure it, pour PDMS, cure it, we have second design. We can repeat the process till the mould is intact. We are using lithography but not using conventional lithography techniques like UV lithography. This method is called soft photolithography.

If we have PDMS and if we have a mould, if we pour PDMS on that mould, cure it, strip it off and we can do it a hundred times, we can make hundred devices like this. We just require oxygen plasma system.