Microfluidics

Microfluidics is defined as the technology and science concerning precisely controlled fluids, usually in the range of microliters (10^{-6} m^3) to picoliters (10^{-12} m^3). Generally, a fluidic system with at least one dimension with length in the range of 10 to1000 μm is considered microfluidic. Miniaturization allows a portable experimental set up, using less sample volume with the potential for parallelization and precisely-timed sequential operations. Micro-scale microbial fuel cells can provide enough energy to power small electronic components and sensors, as well as can contribute to fundamental research and discovery.

Fluid behaviour

The main purpose of a lab-on-a-chip system is to handle fluids. Large surface-to-volume ratios, low thermal gradients, laminar fluid flow, and fast and complete reactions are some of the important advantages of microfluidics systems. Studies in microfluidic channels benefit from the other advantage calling scaling law in which by decreasing the size of system and that leads to extreme decrease in liquid demand and low reagent consumption and reduce the operation time and provide a high degree of control over variables.

Microfluidic fabrication

Techniques for fabrication of microchannels can be placed into two major categories, sequential methods and the template-based. In template-based methods all parts are created simultaneously in one step. In contrast, in sequential fabrication all features are created progressively. Examples of template approaches include casting, injection molding and hot embossing. We focus on the template-based fabrication due to their fast and accuracy fabrication. Generally, casting the viscous elastomer poly-dimethyl siloxane (PDMS) solution with a cross-linking agent against a photlithographic mould is the most prominent approach for microfluidics. The approach, by George Whitesides group used PDMS as the casting agent because it is non toxic, inert, cheap and commercially available and it is easy to separate from the mould due to its non-adhesion property.

Photolithographic processes have been commonly used in microfluidic device fabrication, whereby a photoresist material is patterned based on localized photochemical reactions. Positive photoresists are insoluble before irradiation, and become soluble after photo-degradation of pre-existing crosslinks, whereas negative photoresists are soluble before irradiation and become insoluble after photocrosslinking. The pattern is usually transferred to the photoresist using a binary mask (shadow mask), but more expensive direct (laser) writing systems are now available on the market. Masks are designed using a computer aided design (CAD) and printed on to a thin polymer transparency film (Figure 1).

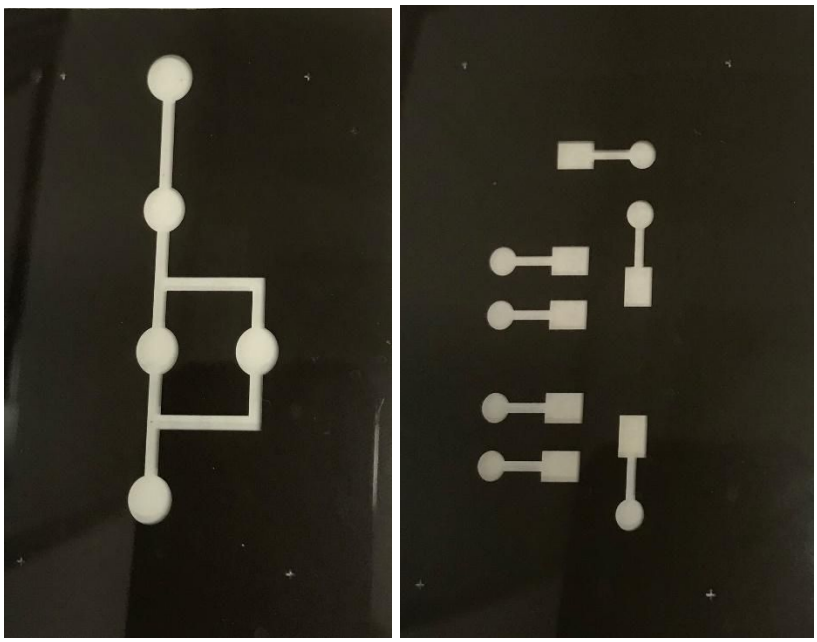

Figure1 Printed binary masks.

The typical photolithography process is shown in Figure 2.

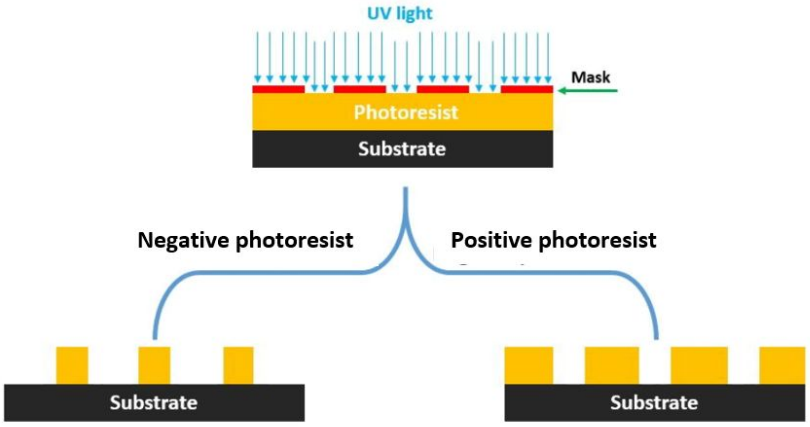

Figure 2 A schematic of positive and negative photoresist patterning. Based on which photochemical reactions occur during light exposure time, positive or negative features can be made on the substrate. Final mould will be ready after washing with the developer solution and cleaning removable portions.

Casting and bonding

The PDMS used in the work described here is supplied in two components, a viscous polymer base and a cross-linking agent. After combining the polymer and cross-linking agent and degassing any trapped bubbles the viscous solution conforms to the shape of the mould and solidifies, usually at a slightly elevated temperature of 70°C. The low surface free energy and elasticity of PDMS allow it to release from the mould without damage to itself or the mould.

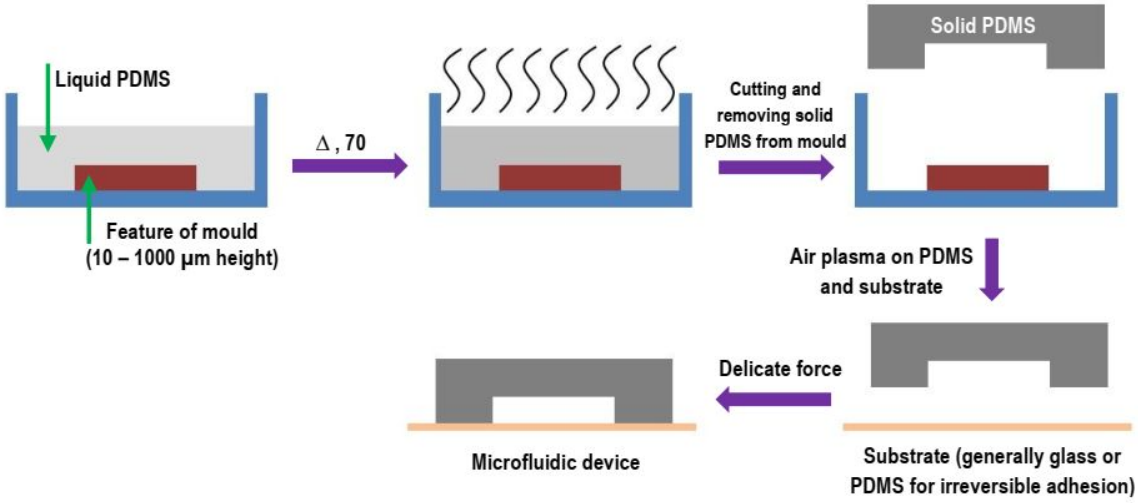

Figure 3 A schematic of PDMS baking and casting for microfluidic device fabrication.

PDMS is easily demoulded from the smooth surfaces generated by photolithographic templates discussed above due to its elastomeric mechanical properties and low surface energy. Another advantage of PDMS is that it can irreversibly seal to itself, or to certain planar surfaces, without distortion of the channels. This is accomplished with exposure to a plasma gas of air or oxygen due to radical oxygen groups that transform Si-CH_3 to Si-OH at the expose PDMS air interface. When the PDMS block is contacted by a glass slide or another plasma treated PDMS surface, Si-OH form a covalent connection (or bond) Si-O-Si. Exposure to O_2-containing plasma gas also has the effect of temporarily decreasing the hydrophobicity, until mobile polymer chains reorganize to hide the Si-OH groups within the PDMS bulk. Adhesive silicone tapes or cellophanes can also seal the PDMS channels reversibly. In Figure 3, a flowchart of PDMS device fabrication is shown.