Fast and Affordable Fabrication of Microfluidic Mold Templates With Complex Multilayer Geometry

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**Motivation**

Design and fabrication of a microfluidic channel is fundamental to all microfluidic applications. The commonly used Silicon wafer templates are expensive and take a long time to produce. There are demand for microfluidic devices in resource-poor environments such as biological assays of blood and urine as well as potential technologies that could stem from microfiber creation, such as enhanced drug delivery substrates and microbial resistant bandages.

**Preparation of Microfluidic Templates**

A microchannel geometry with core and sheath flow inlets was created as a base-layer in SolidWorks. Common laserjet computer lab printers were used to print the geometry with multiple layers of ink onto Shrinky-Dink thermoplastic sheets by sequentially allowing a single layer of ink to dry and reprinting the geometry with the same settings.

Chevron grooves were designed as a second layer for the template, and were printed onto the base-layer in the same manner. The geometry of the chevrons were confined to the area covered by the base layer such that the ink is deposited onto the dried ink layer of the base geometry. Subsequent layers of features can be produced in this same way, so long as they are confined to the area of previous layers.

**Data Analysis**

After all layers are printed onto the microfluidic device, the geometry was cut out of the Shrinky-Dink sheet and was placed in the over at 135°C for 3-5 minutes until it was flat. The height of the resulting features were measured using a Zygo NewView 7100 profilometer. Below is a longitudinal surface profile of one of the height of a template with four layers of ink.

The spacing of features after the base layer were discovered to be constrained to a minimum spacing of 200 µm. This is because printing the geometry multiple times results in an ‘overlapping’ effect due to slight shifts of the thermoplastic sheet each time it goes through the printer. These findings were assessed qualitatively as shown in the images above. The figure on the top displays chevron grooves that were printed with a spacing of 150 µm between each groove, and the figure on the bottom shows a similar set of chevrons that were spaced 200 µm apart, and the results were consistent among several samples.

**Conclusions**

Microfluidic templates made from thermoplastic sheets with ink printed onto them before shrinking are comparable to high accuracy silicon wafer templates. Complex, multilayer geometry is possible by using the method proposed here, which is capable of microfluidic phenomena such as polymer fiber creation.

**Creating Polymer Microfibers**

To prove the feasibility of this method, polymer microfibers with a controlled cross section were created from the device by pumping a solution of 2% Polycaprolactone (PCL) polymer in 2,2,2-Trifluoroethanol (TFE) through the core flow inlet and 5% Polyethylene glycol (PEG) in a 1:1 water/ethanol solution through the two sheath flow inlets.

Simulation of the fluid flow through the microfluidic device (above) and SEM images of the resulting fibers (below) with core/sheath flow rates set to 30 µL min\textsuperscript{-1} and 5 µL min\textsuperscript{-1}, respectively. The fibers have a thickness of approximately 17 µm.

By adjusting the flow rates to 150 µL min\textsuperscript{-1} and 5 µL min\textsuperscript{-1}, similar fibers with a thickness of 21.5 µm were created (below). Achieving different cross sections with varying flow rates agrees with data from silicon wafer template formed microfibers.

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