3D printing of round microfluidic channels to mimic the microvasculature

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Microvasculature-on-chip

Mimicking the microvasculature remains one of the challenging aspects in microfabrication of biomedical devices such as “organ-on-chips”. This is mainly due to the round cross sections, small diameters and complex network architectures. Standard fabrication methods fail to represent all these features faithfully, however 3D printing of carbohydrate glass holds great promise to recreate the microvasculature structure in all aspects (Fig. 1). Others have shown it is possible to fabricate networks that are perfusable and can be casted in a variety of materials, however the minimal lumen diameter was still large, i.e. ~200 µm. Our main focus was to reduce the diameter to a size closer to the microvasculature, namely in the 10-500 µm range and be able to engineer hierarchical 3-dimensional branching networks that can change diameter along the vessel.

Setup

A dedicated setup was created based on standard 3D printing technology, with a barrel that can be heated and is connected to a pressure control system (Nordson EFD performus III). The nozzles used in the setup are standard 3D printer nozzles with a diameter of 0,4 mm for the results reported here. By controlling the speed of movement, the diameter can be tuned; this range can be extended further by either stringing from a droplet (Fig. 2 & 3) or adding material by extrusion while stringing. Currently the printable range of fibres is from ~50 µm up to 1400 µm, however, based on existing models on glass-fibre drawing, the lower limit is expected to go further down when using a smaller nozzle diameter. The main advantage of carbohydrate glass is the fact it is self-supporting and therefore can be used for freeform printing as demonstrated in Fig. 1. This allows for a large degree of freedom to print complex structures and networks in 3D, only limited by the inability to print underneath existing structures.

Results

Carbohydrate glass fibre Ø=~100 µm

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Droplets

Frame

Droplets

Frame

Fig. 2: Carbohydrate fibres strung from droplets horizontally across a printed frame with a speed of 600 mm/min. Insert: Microscopic image of 3 fibres, top and bottom strung left to right and middle right to left at 600 mm/min. Fibre diameter ~100 µm.

Fig. 3: Boxplot of diameter for different movement speeds of the stage. Increasing speed reduces variance and average diameter of the fibre. Insert: The high variance of the diameter at 300 mm/min can be explained by the strong tapered shape of the fibres, resulting in a different diameter at the start and end of the fibre. This is probably caused by solidification of the droplet at the nozzle tip leaving less material to string from.

Outlook

The main focus of our work will be on improving the thermal control of the process. This will offer even greater freedom in network design, and it will give the possibility to exactly control reflow of fibres to form a single in-plane junction. In the end, the printed models will be used to investigate the flow of blood and particles inside the blood through a microvascular network, leading to a better understanding of perfusion and particle distribution/interaction in the microvasculature.