Fabricating the microvasculature using 3D sugar printing

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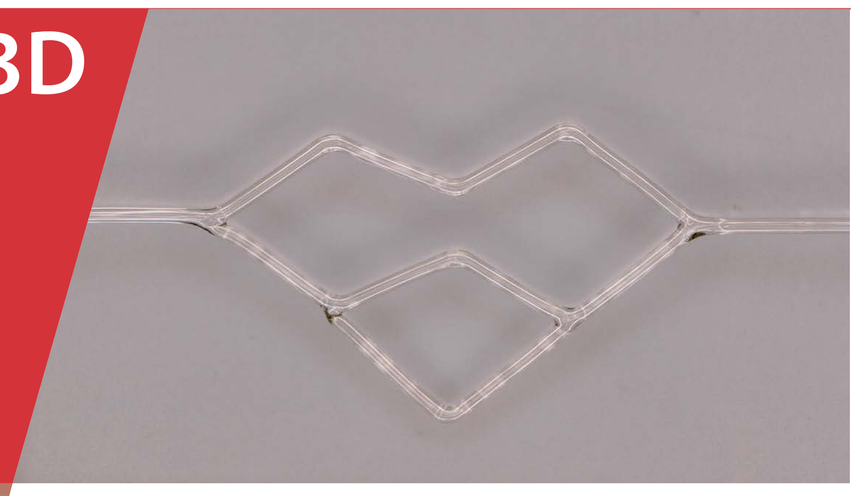

Microvasculature-on-chip

Mimicking the microvasculature remains one of the challenging aspects in microfabrication of biomedical devices such as "organ-on-chip"[1]. This is mainly due to the round cross sections, small diameters and complex network architectures[1]. 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[2] (Fig. 1). Others have shown it is possible to fabricate networks that are perfusable and can be casted in a variety of materials[2,3]. Our main focus was to be able to engineer hierarchical 3-dimensional branching networks that can change diameter along the vessel. These systems will lead to a better understanding of flow and distribution behaviour inside the microvasculature.

Fig. 1: Free-standing structure of sugar glass inside a printed casting frame mimicking the vascular architecture. Insert: Perfused network with dye solution after dissolving sugar glass cast in PDMS. Scale bar 500 µm.

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 0,15 mm and 0,4mm for the results reported here. By controlling the speed of movement with a fixed material flow, the diameter can be tuned. Currently the printable range of fibres is from ~50 µm up to 1400 µm. The main advantage of carbohydrate glass is the fact it is self-supporting and can reflow with existing fibres to form in-plane junctions. 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. Examples of printed and casted structures are given in Figure 1 & 2. Perfusion and subsequent analysis with particle image velocimetry shows the flow profile throughout the system.

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Results

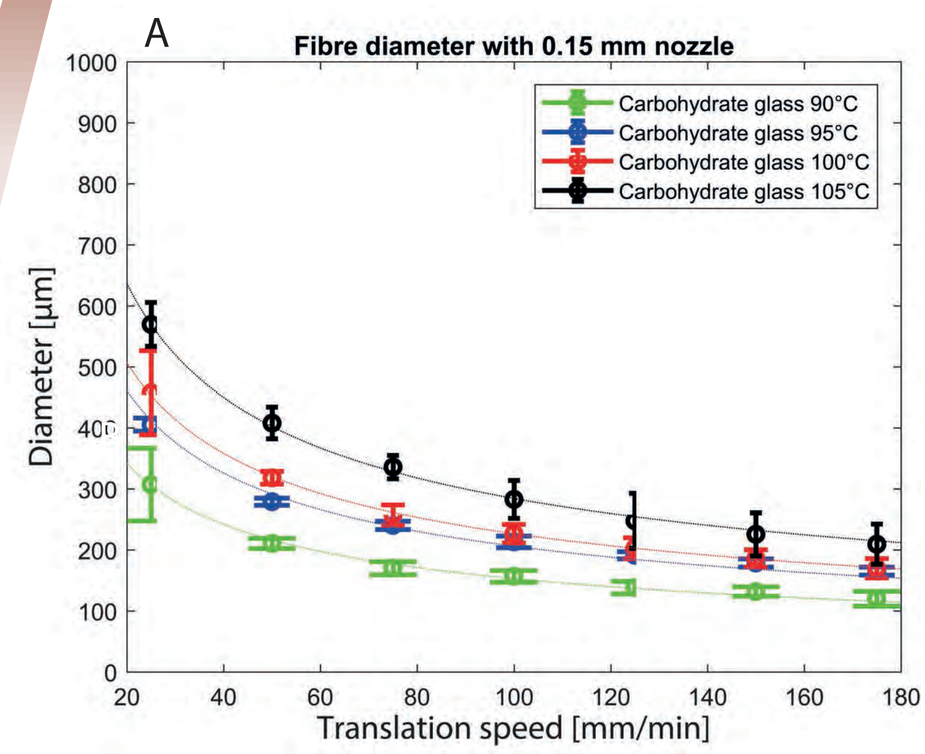

Fig. 2: Fibre diameter of printed Carbohydrate glass and Sugar glass network prints with the resulting PDMS casts. Figure A shows the influence of translation speed and temperature on the printed fibre diameter and deviation. Figure B is the printed sugar glass networks with in-plane bifurcations. Figure C is the PDMS casts after dissolving the sugar glass of similar prints, showing the reproducibility of the printing process. Scale bar 1000 µm for all images

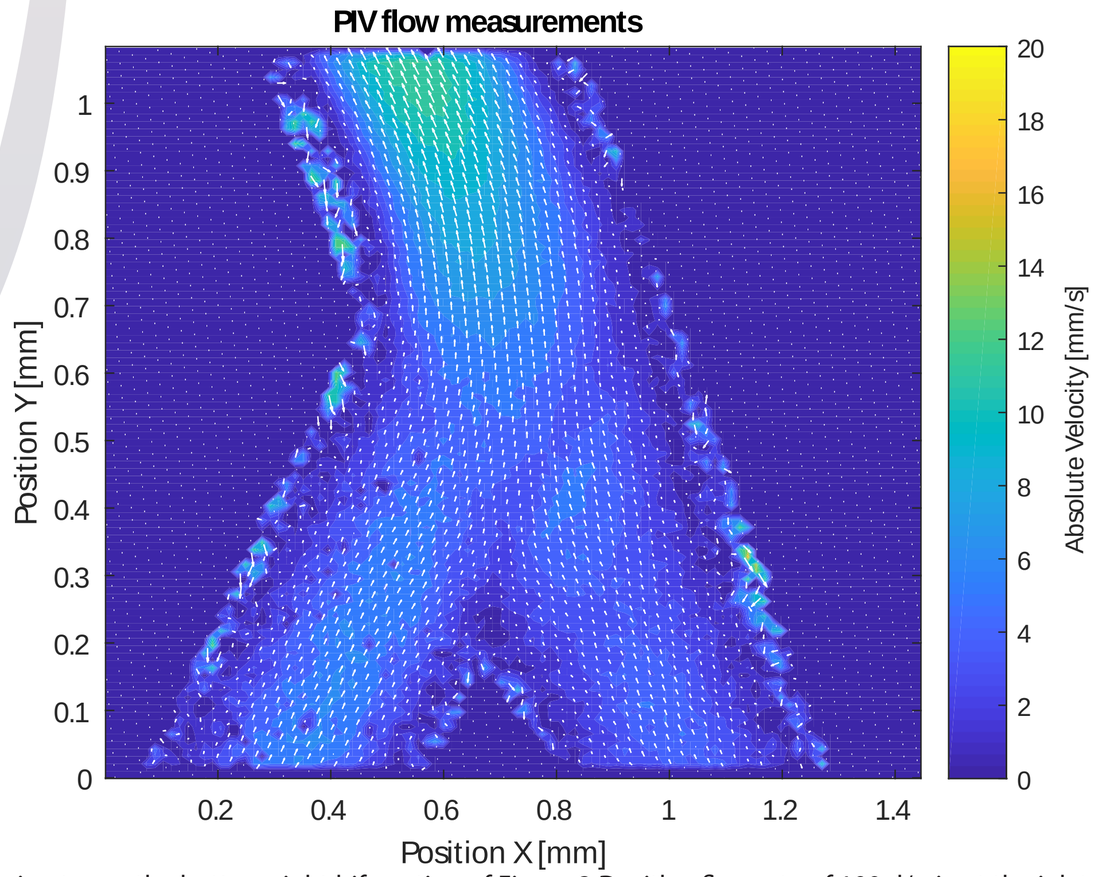

Fig. 3: Particle image velocimetry on the bottom right bifurcation of Figure 2 D with a flow rate of 100µl/min at the inlet. Results show a velocity profile corresponding to the expected Posieulle flow with a maximum velocity of 12 mm/s.

Outlook

In the end, the printed models will be used to investigate the flow of blood and particles through a microvascular network, leading to a better understanding of perfusion and particle distribution/interaction in the microvasculature[4]. To this extent scaling laws that are present in the microvasculature will be applied to the printed structures to increase their relevancy[5].

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