3DprintedFluidics—Revolutionary Fluidic Components Enabled by Additive Manufacturing Technologies

S. F. Graf, J. Kaufmann, S. Berchtold, T. Volden, N. Schmid, O. Chandran, S. Lani, J. Schleuniger, F. Lütolf, V. Revol, H. F. Knapp

Additive manufacturing offers new freedom to conventional manufacturing. While some industries have fully adopted additive manufacturing, this potential is currently not fully used for creating innovative designs of fluidic components and systems. We focused on the design of fluidic components which can be used as building blocks for new applications. By combining state of the art printing technologies as Fused Deposition Modeling (FDM), Stereo Lithography Apparatus (SLA), inkjet and screen printing, crucial components such as valves (passive and active) and pumps (mechanically or magnetically actuated) have been developed and integrated with sensors to monitor pressure and measure light scattering. These components can also be combined into compact, integrated systems.

3D printing is getting more and more popular. Even the sharp calculating automotive industry prints an increasing number of parts instead of using conventional manufacturing methods. Emerging multi-material 3D-printers (piezo-ceramics, polymers, metal inks) together with hybrid assembly are opening new opportunities for functional components. In this project, new design approaches for active fluidic components were investigated. The ultimate goal is to be able to realize complex fluidic functions in customized chips including actuators, chambers, manifolds and sensors.

In the first year, innovative designs were explored for individual components: pumps, valves, light barriers, pressure sensor and connectors.

3D printed pumps & valves

On-chip pumps and valves in microfluidic chips are often realized using flexible PDMS structures, which are actuated pneumatically[1]. A drawback is the required pneumatic connection which is cumbersome to connect and prone to leakages. For these reasons, alternatives using mechanical actuation as well as magnetic actuation were selected. One pump design is illustrated in Figure 1. It was printed in a SLA process and works with a pump chamber and co-printed check valves. Another example of a printed Tesla valve is shown in Figure 1.

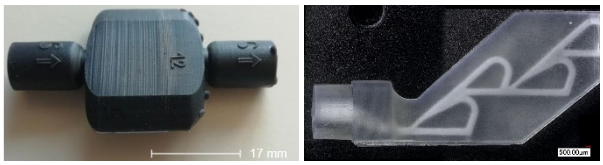

Figure 1: Pump with integrated check valves for mechanical actuation (left); Printed Tesla valve (right).

For the magnetic actuation, a pump chamber was FDM printed, then closed-off with a PDMS-membrane in a dispensing and curing process. Finally a magnet was assembled by hybrid bonding for a completely contact-free actuation. In a next step, the magnet will be replaced by printed magnetic particles to minimize assembly steps.

Integrated pressure sensor

Printed pressure sensors would enable to functionalize fluidic components such as manifolds in order to monitor and control the flow. A capacitive pressure sensor was realized on a SLA printed substrate. Metallic electrodes were inkjet printed together with a water soluble sacrificial layer onto the substrate. A cross-section in Figure 2 shows the fluidic channel with the underlying electrodes. The measured capacity is thus directly related to the pressure. Current effort is put into thinning the pressure sensor membrane as well as increasing sensitivity by bringing the electrodes closer together.

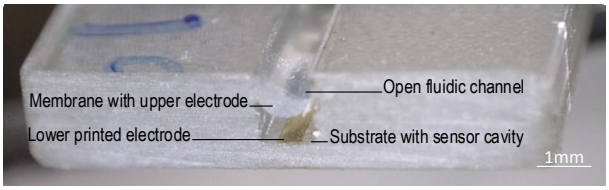

Figure 2: Cross section of a printed pressure sensor flush with the fluidic channel. Covertape to close-off channel not shown.

Light barriers

Light barriers are often used in fluidic chips to detect bubbles or particles in the flow. As shown in Figure 3, a light barrier was realized by inkjet printing a waveguide into a SLA realized substrate. Passing particles or air bubbles result in a change of the measured intensity. This information can be used to trigger an event (e.g., valve opening) in the corresponding operating system.

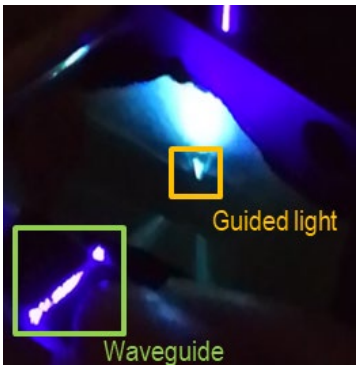

Figure 3: Light barrier printed across a channel to detect air bubbles or particles in the fluid.

In a next step, the developed fluidic components will be characterized in detail and integrated into an organ-on-a-chip platform.

This work was supported by the Swiss Confederation and MCCS (Micro Center Central Switzerland). CSEM thanks them for their support.

[1] M. Unger, H. P Chou, A. Scherer, S. Quake, "Monolightic microfabricated valves and pumpsby multilayer soft lithography, Science, 288 (2000) 113.