Novel approach allows 3-D printing of finer, more complex microfluidic networks

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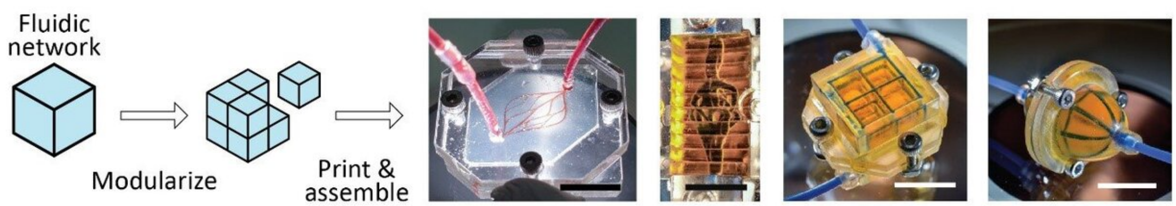

2D and 3D fluidic networks by modularized stereolithography. Credit: SUTD

First introduced in the 1980s, stereolithography (SL) is an additive manufacturing process that prints 3-D objects by the selective curing of liquid polymer resin using an ultra-violet (UV) light source in a layer-by-layer fashion. The polymer employed undergoes a photochemical reaction which turns it from liquid to solid when exposed to UV illumination. Today, SL is touted as one of the most accurate forms of 3-D printing that is accessible to consumers, with desktop models (e.g., liquid crystal display variants) costing as little as USD $300.

SL is an attractive option for researchers in the field of microfluidics. Not only does it have the ability to fabricate microfluidic devices in a single step from a computer-generated model, but it also allows the fabrication of truly 3-D structures that would otherwise have been challenging, if not impossible, with the existing fabrication approaches.

However, when employing SL printers in printing microfluidic channels, two representative problems occur. Firstly, inadvertent polymerization of uncured resin in channel void can occur. During the print, the liquid resin is trapped within the channel void. Illumination from subsequent layers may inadvertently cure the trapped liquid resin, which will result in a channel clog.

Secondly, in the event where inadvertent polymerization of resin does not occur, the evacuation of the trapped resin within the channel void can still be a challenge. This is because existing liquid resin is viscous (i.e., consistency like honey), making the evacuation of narrow channels or networks with multiple branches challenging. These two challenges limit the attainability of channel dimensions and complexity in fluidic networks printed by SL.

To tackle these limitations, researchers from the Singapore Unversity of Technology and Design (SUTD) in collaboration with Assistant Professor Toh Yi-Chin's research group from the National University of Singapore, developed a design approach that can improve the attainable channel dimensions and complexity of networks with existing SL (refer to image).

"The conventional way of printing microfluidic devices with SL printers is to print the entire device as a monolithic entity. However, issues like inadvertent polymerization of channel void and difficulty in evacuating channel void arises from printing as a monolithic entity," explained principal investigator Assistant Professor Michinao Hashimoto from Engineering Product Development, SUTD.

Instead, the researchers took a modularization approach—where they spatially deconstructed a microfluidic channel into simpler subunits, printed them separately, and subsequently assembled them to form microfluidic networks. By applying this approach, they were able to print microfluidic networks with greater intricacy (such as hierarchical branching) and smaller channel dimensions.

"By design, each subunit is spatially deconstructed to have simple geometries that would not result in inadvertent polymerization. The simple geometries also facilitated the evacuation of uncured resin," said lead author Terry Ching, a graduate student from SUTD.

The team was able to fabricate a range of fluidic networks that were challenging to print using conventional methods. Their demonstration includes hierarchical branching networks, rectilinear lattice networks, helical networks, etc. They were also able to demonstrate the efficacy of their approach by showing a substantial improvement channel dimensions (i.e., channel w = 75 µm and h = 90 µm) when compared to using the conventional 'monolithic' printing approach.

One obvious use case is the application of this approach to fabricate fluidic networks using hydrogel to mimic native vasculature. To date, the variety of SL printable hydrogels is limited, and they often lack mechanical properties necessary for an accurate print or biocompatibility required for the incorporation of living cells. By simplifying the geometries of each subunit, the team used hydrogel to fabricate intricate fluidic networks, mimicking native vasculature.

"Simplifying the geometries of the subunits also reduces the use of additives that may be harmful to biological cells," added Ching.

All in all, this is a general design approach that can circumvent some of the biggest challenges in SL printed microfluidics—by applying this approach, existing SL printers can now fabricate microfluidics with finer channel dimensions, and more branching intricacies. This research paper has been published in *Advanced Engineering Materials*.

More information: Terry Ching et al, Fabrication of Complex 3D Fluidic Networks via Modularized Stereolithography, *Advanced Engineering Materials* (2019). DOI: 10.1002/adem.201901109

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