

3D Printed Microfluidic Devices for Oxygen Control in Cell Culture

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1 INTRODUCTION

3D printing of microfluidic devices enables rapid, one-step fabrication of complex designs infeasible to make with planar lithography and replica molding techniques. In addition, planar lithography is time consuming, requires specialized equipment and facilities, and has a high failure rate. On the other hand, 3D CAD printing allows for unambiguous specifications and nearly eliminates time and effort spent on fabrication which is outsourced to a 3D printing company for around \$100/device [1, 2]. Recently 3D printing has emerged as a method for directly printing complete microfluidic devices (folch, spence, that other one). Printing is currently limited in choice of materials when compared to MEMS style fabrication. As of yet there is no widely available methods or materials to facilitate direct printing of gas permeable materials. Here we report on the development of 3D printed microfluidic devices for the control of oxygen in cell culture microenvironments.

2 EXPERIMENTAL

The 3" petri dish device contains a 500 μm wide channel following a serpentine path leaving 500 μm of spacing between channels and has integrated hose barbs directly printed onto the device. The 3D part is printed with the channels embedded in the bottom of the petri dish. A 120 μm thick PDMS membrane is adhered across the channels. This device allows cell cluture in a large open well format compatible with assays requireing cell scaping. The membrane is easily peeled away allowing additional fixing/staining assays to be preformed and can also be repaced with a new membrane to reuse the device.

The 24 well plate insert is designed to control gas in 6 wells of a 24 well culture plate from one input, borrowing the working principle of previous work[3] and also incorporates integrated hose barbs. The pillars extend into each well leaving a \sim 500 μm gap for media between the diffusion membrane and the culutre surface at the bottom of the well. Diffusion occurs rapidly across this gap allowing control of the dissolved gas environment around the cells. This

is a prototype intended to be expanded to control all 24 wells. A distribution network stems from the central input that equalizes the flow along each path length by varying the channel width to the proximal, intermediate, and distal wells. The device also features a ‘pipe within a pipe’ design so that gas flow enters and leaves the diffusion area in a uniform, and symmetrical flow pattern, which would not be possible with standard lithography and demonstrates the capabilities of 3D printing (Figure ??). A PDMS membrane is adhered to the microchannels of both designs by spin coating a thin PDMS layer as an adhesive.

Both devices were printed by Fineline Prototyping in Watershed XC using stereolithography. Oxygen was measured in the 3” petri dish device with a commercial fiber-optic probe and the 24 well insert was quantified with a planar oxygen sensor as shown in Figure 2. 3D CAD models are designed and printed with microfluidic delivery channels, and then completed by adhering a gas permeable membrane of PDMS (Polydimethylsiloxane) to enable diffusion of gas to the culture area.

3 RESULTS AND DISCUSSION

Two devices are presented and characterized: one is a large area (3” diameter) open-well format, and the second is an insert for a standard 24 well plate as shown in Figure 2.

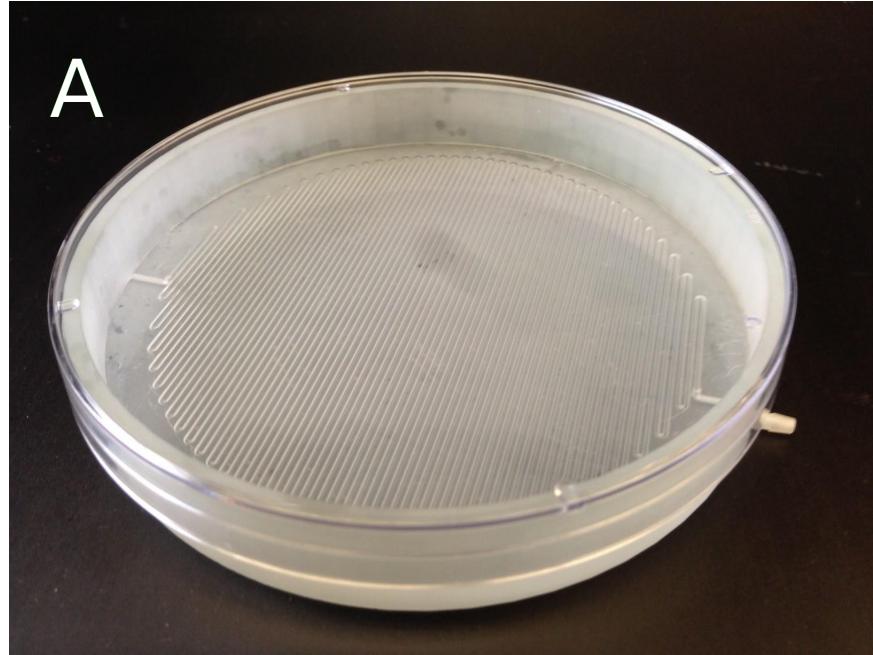


Figure 1: 3” petri dish device



Figure 2: 6 well device oxygen control device

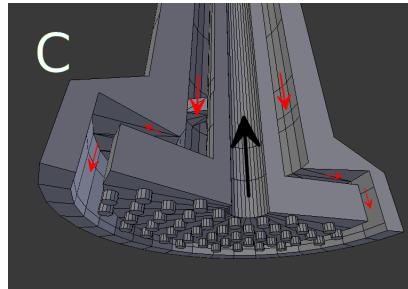


Figure 3: 6 well device oxygen control device

4 CONCLUSION

3D printing allows complex designs, integrated tubing connectors, and is comparable in price to standard PDMS fabrication. This technique represents a bridge to commercialization where robust devices can be more easily shared and disseminated. While injection molding, hot embossing, or other industrial processes are cheaper when making hundreds to thousands of devices, it is not practical to make a injection mold when making tens to hundreds of devices. In addition, PDMS fabrication would be too time consuming, expensive, and the failure rate would be unacceptable. 3D printing is a perfect solution to these device fabrication needs.

References

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