Supplementary Information for:

Three-Dimensional Fabrication of Heterogeneous Microstructures using Soft Membrane Deformation and Optofluidic Maskless Lithography

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Fig. S1. Schematic diagram of two-layered microfluidic channel fabrications.
Fig. S2. Confocal microscope images of fluorescent bead-embedded hydrogel structures (Fig. 4B)
S1. Calculation model for the membrane curvature

To determine the width of the channel, $w$, to ensure flat membrane in the fabrication area $d$, we used simple model as given in Fig. S3. Since the aspect ratio ($w/h$) of the underlying channel is very large, we assumed that the cross-section of the deformed membrane forms an arc with a curvature radius $r$. The median vertical position of the membrane, $h_0$, corresponds to the desired thickness of the fabricated layer. We defined $\Delta h_0$ as the maximum height variation within the fabrication area $d$ at $h_0$. Considering the size of the structure, we defined $\mu m$ as the tolerable flatness of the membrane surface at the desired value of $d$ and $h_0$.

From fig. S3, the curvature radius of the membrane can be determined as

$$r = \frac{(\frac{w}{h})^2 + (h-h_0)^2}{2(h-h_0)}$$

Using the obtained radius value, $\Delta h$ can be calculated with the following equation.

$$\Delta h = r \left(1 - \sqrt{1 - \left(\frac{\Delta h}{r}\right)^2}\right)$$

The value of $d$ that is tolerable to certain $\Delta h$ can be obtained as below.

$$d = 2r \sqrt{1 - \left(1 - \frac{\Delta h}{r}\right)^2}$$

Fixing the channel height, $h = 100 \mu m$, $\Delta h$ of the membrane according to $w$, $d$ and $h_0$ can be obtained (Figure S4).

The maximum value of $d$ is determined by the field of view of the optical systems, which was approximately $1 mm$ to ensure uniform UV intensity and no image distortion. Toughest condition in all experiments was to have $\Delta h < 2 \mu m$ at $h_0=10 \mu m$ and $d=800 \mu m$, which required a large channel with $w=5.5 mm$. In normal conditions, we used $w=2 mm$ channel, which provides $2 \mu m$ $\Delta h$ tolerance at $h_0=20 \mu m$ within $d=300 \mu m$ area.

Fig. S4. (a) $\Delta h$ variation within the $800 \mu m$ fabrication area with the channel width $w$ and membrane height $h_0$. (b) $\Delta h$ variation along the fabrication area when the membrane height is $20 \mu m$. (c) Width of flat fabrication area according to the channel width while fixing $\Delta h$ to $2 \mu m$. 