Supporting Information

Fabrication of Low-cost Paper-based Microfluidic Devices by Embossing or Cut-and-Stack Methods

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Cutting Paper and Double-sided Adhesive Tape

Double-sided adhesive vinyl tape (3M, Scotch® carpet tape CT1020) was attached to a sheet of chromatography paper (Whatman#1) with one face of tape still protected by a layer of film. The pre-designed pattern was cut through the paper and tape using a laser cutter (Universal Laser VL-300, 50 Watt,Versa Laser), with the stroke setting of 0.05 pt.

Assembling "Cut-and-Stack" Microfluidic Devices.

The patterned layers were manually-aligned on top of each other to make the final device. The device was gently pressed against a flat surface to improve the adhesion of the double-sided adhesive layer against the layers of paper.

Surface Modification.

The assembled devices were introduced into a desiccator for silanization (~ 0.01 m^3) as previously reported.[1-3] We transferred ~ 500 µL of organosilane into a glass vial under inert gas atmosphere and place the vial inside the desiccator together with the samples. Upon application of vacuum, the reagent vaporized and saturated within the desiccator. Diffusion inside the reaction chamber is sufficient for an even distribution of the organosilane within the chamber. The reaction of hydroxyl groups on the surface of paper with vapor of silane readily occurs at room temperature and as such the device is rendered omniphobic after leaving it under silane vapors overnight (*ca.* 15 h).

Sealing and Attachment of the Inlets.

We covered the top of the silanized microfluidic devices with transparent adhesive tape (Fellowes adhesive sheet, PET/EVA/LDPE), and then attached two fluid inlets and two gas inlets to the back of the device, supported by PDMS slabs using a double-sided adhesive layer (3M Command Medium Picture Hanging Strips, http://www.command.com/wps/portal/3M/en_US/NACommand/Command/Products/Catalog/?N=3294736519&=rud).

Scanning electron imaging

Scanning electron microscope (SEM) images (Fig. 2) of the open channel made on paper by embossing were acquired with a Zeiss Supra55 VP FESEM at 10 kV at a working distance of 6 mm. Before SEM imaging, the sample was placed on a silicon wafer and sputter coated with Pt/Pd at 60 mA for 20 s (~8 nm thick coating).

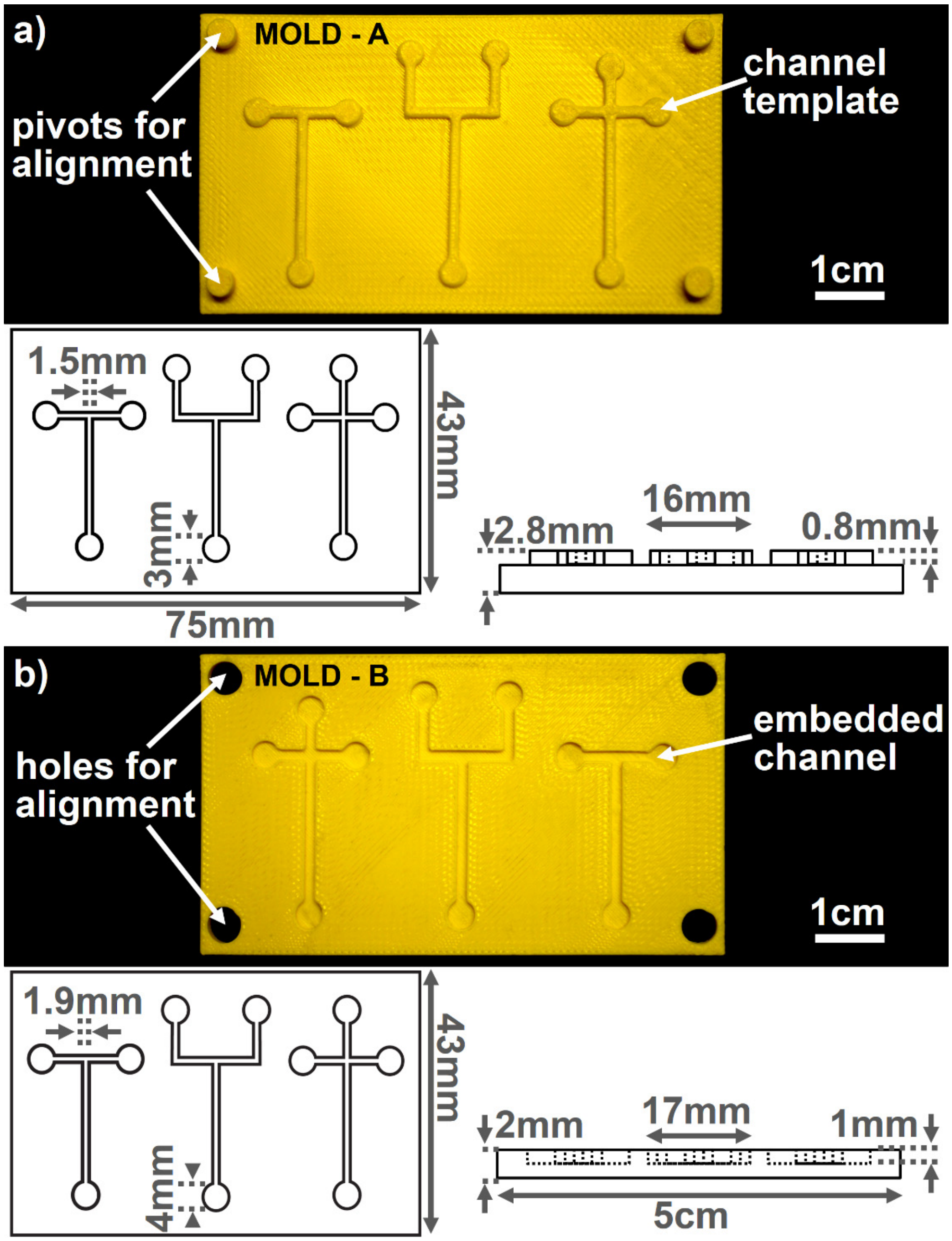

Figure S1. Dimensions and designs of molds used to make the 2D microfludic devices by embossing paper. All molds were fabricated in ABS using a 3D printer.

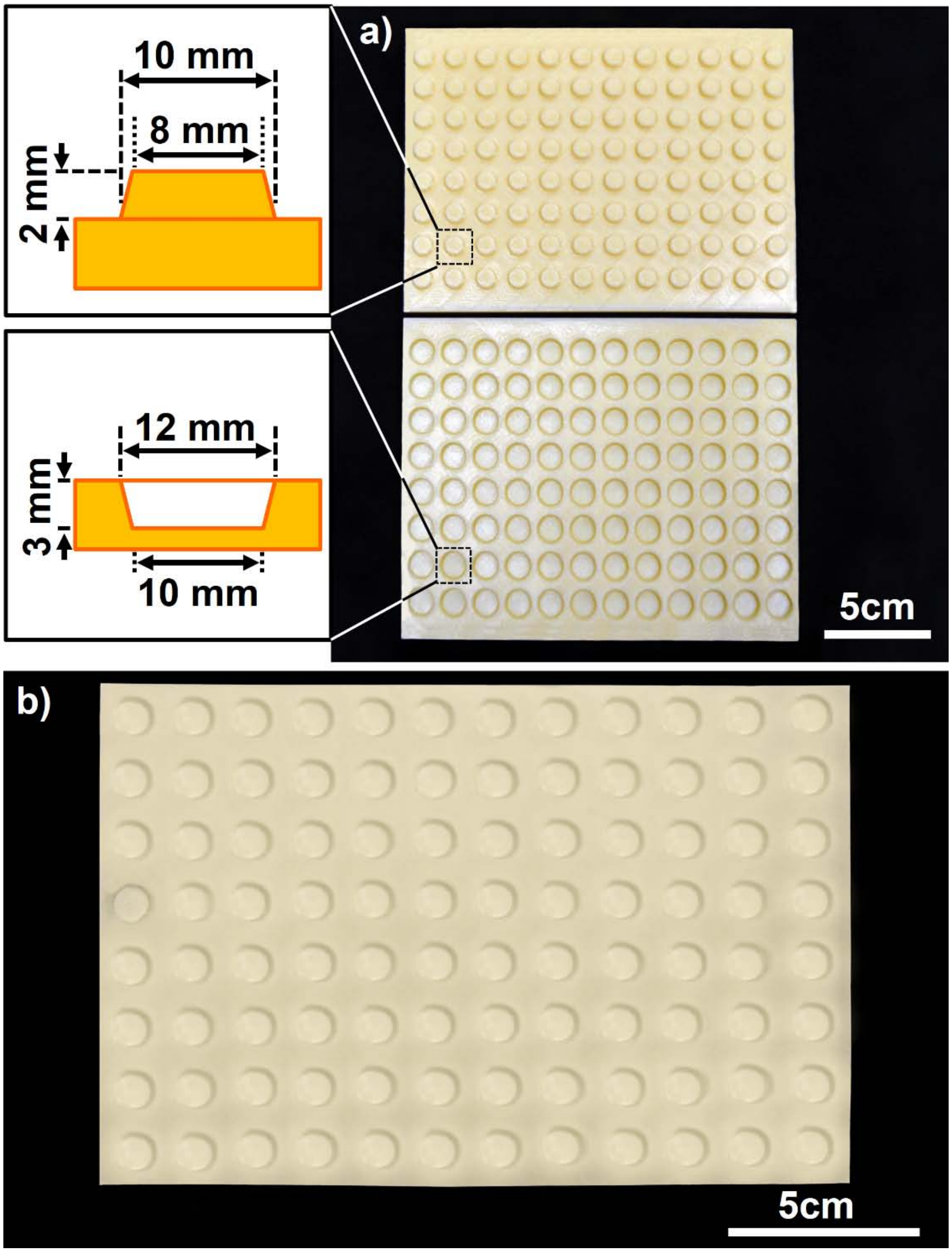

Figure S2. a) Schematic descriptions of the dimensions of the dies used to fabricate a 96 well plate. Pictures of the ABS dies are shown on the right**.** b) Whatman #5 paper embossed with the dies shown on a).

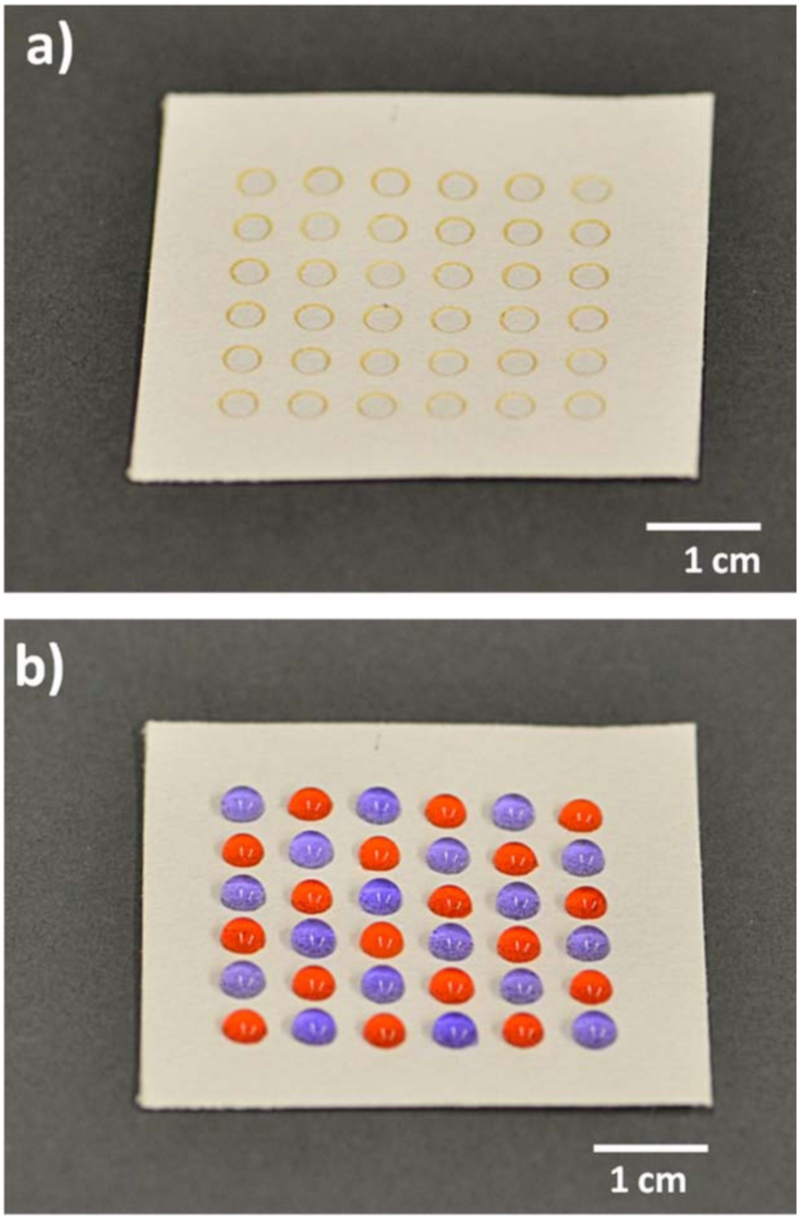

Figure S3. Photographic images of a 36-well plate fabricated from Whatman #5 filter paper using the cut-and-stack approach using a laser cutter to fabricate holes in the top layer. After its assembly, this 36-well plate was rendered omniphobic by silanization with R^FSiCl_3.

a) A completed 36-well plate with a 3-mm diameter wells. b) Wells were filled with alternating drops (20 μL) of methyl orange (orange) and R250 Brilliant Blue (purple).

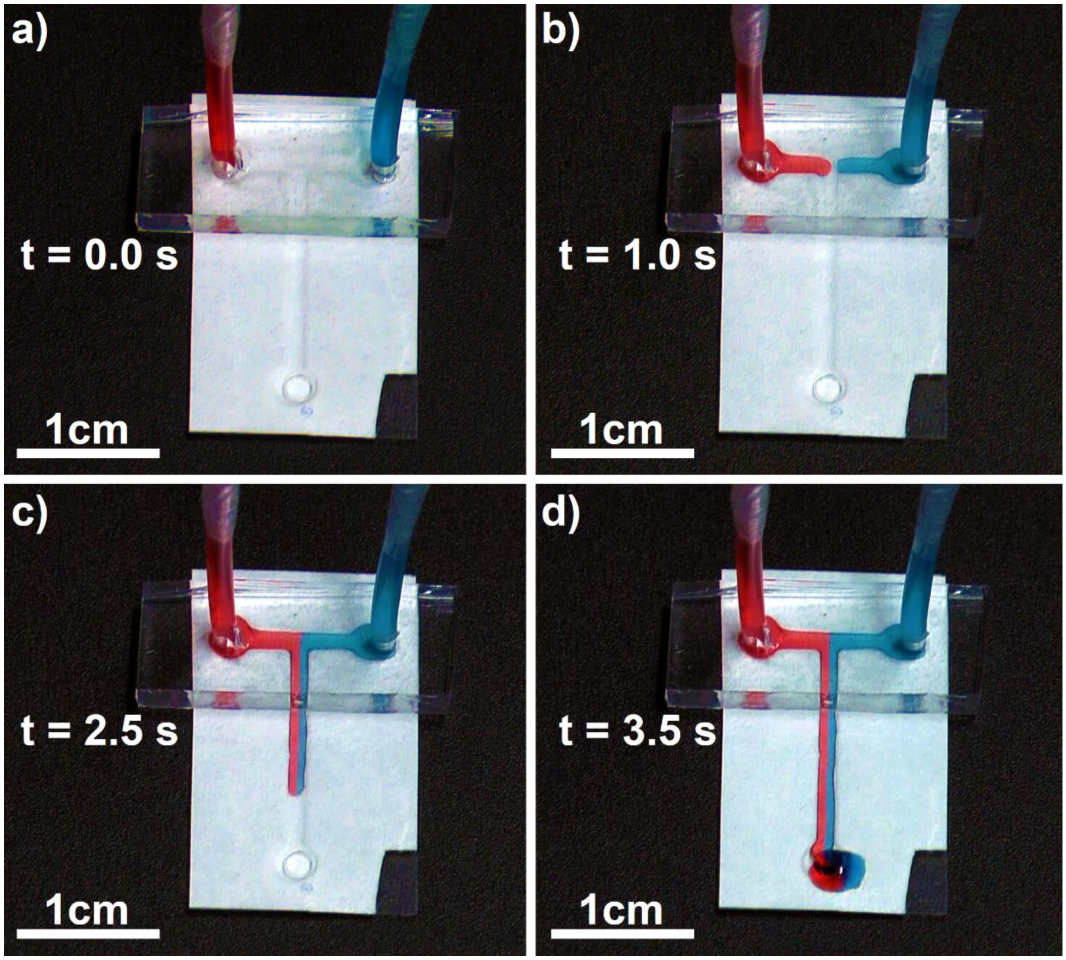

Figure S4. Microfluidic T-junction fabricated by embossing Whatman #1 filter paper. We silanized the embossed paper structure with R^FSiCl_3, sealed the channel with a transparent adhesive tape with holes for the inlets and the outlets. Fluid inlet tubes were supported with 2-mm thick PDMS slab, which was connected to the device using a double-sided adhesive layer. The device shows the laminar flow of two fluids (dyed water). See Movie_M1.

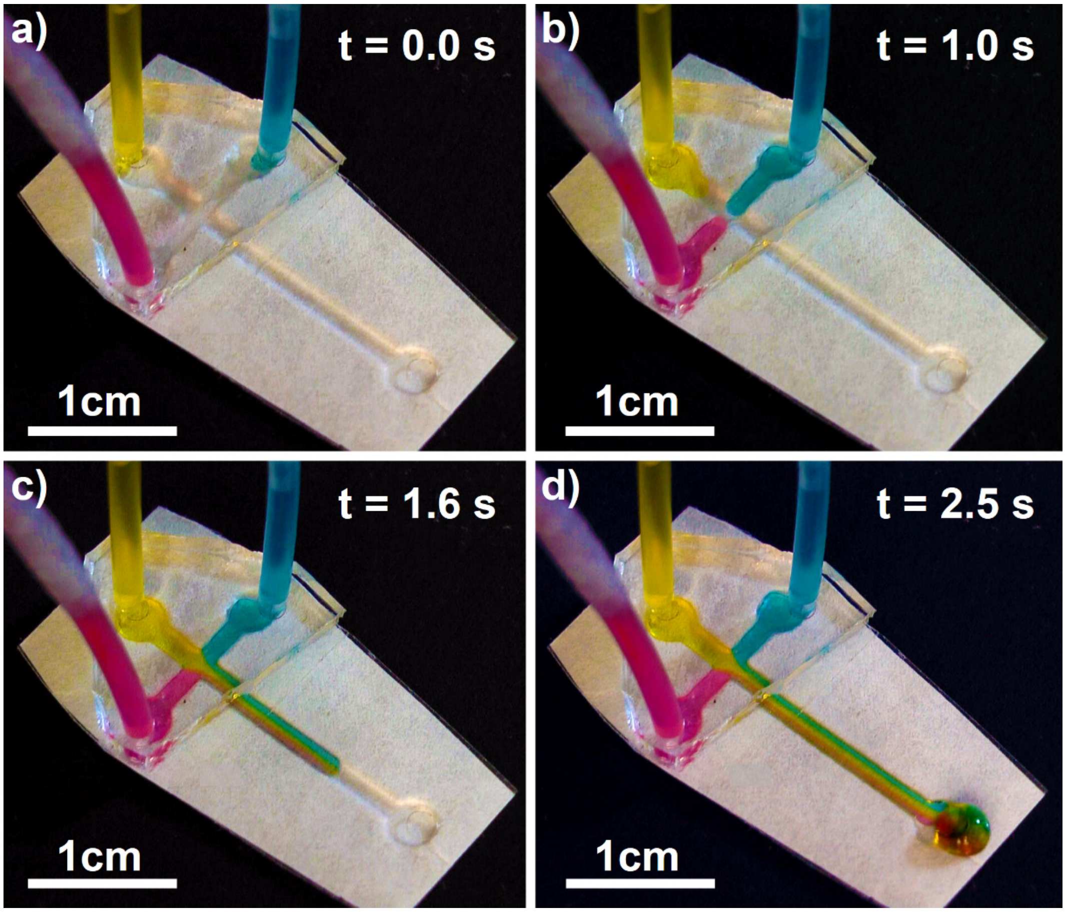

Figure S5. Microfluidic device showing the laminar flow of three fluids (dyed water). The device was fabricated by embossing Whatman #1 filter paper and silanizing with R^FSiCl_3. See Movie_M2.

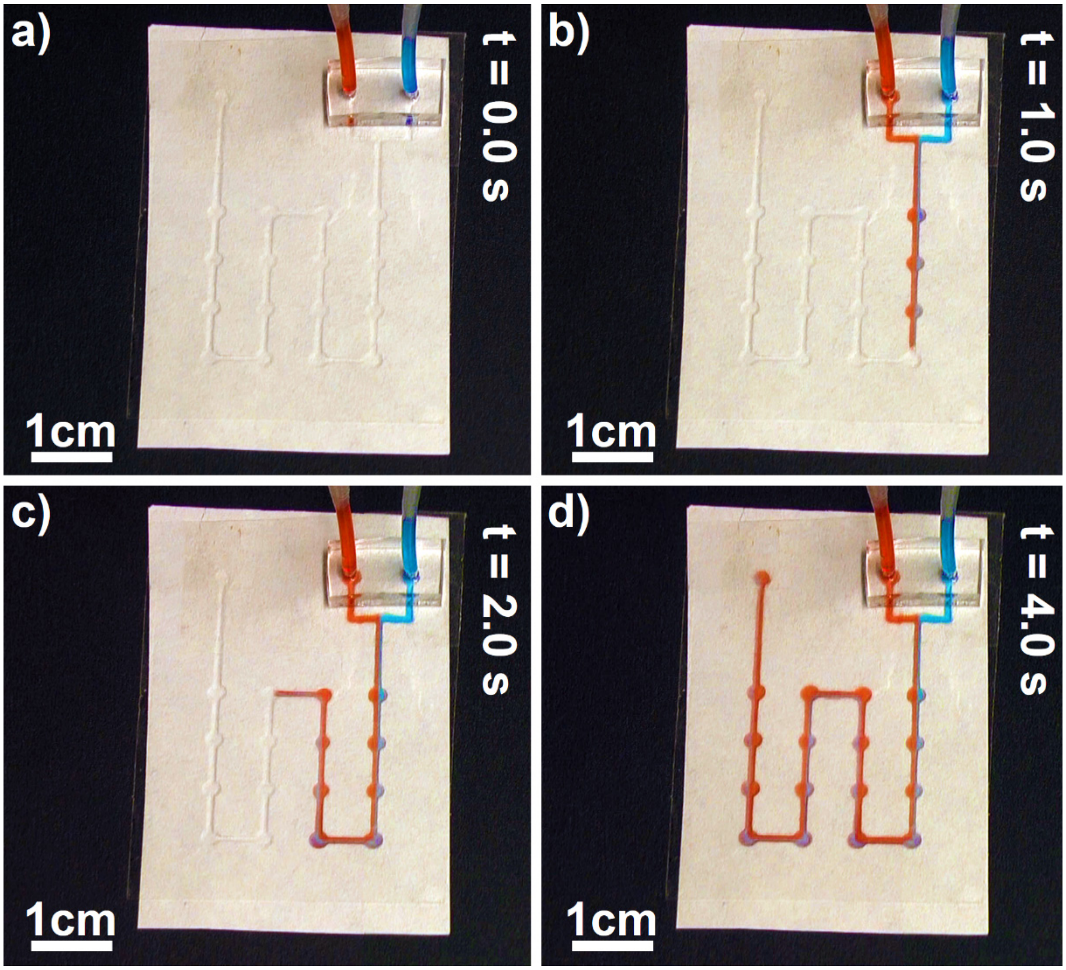

Figure S6. Microfluidic device showing the mixing between two fluids (dyed water) in laminar flow after going around sharp corners (high pressure points). This device was fabricated by embossing Whatman #1 filter paper and silanizing with R^FSiCl_3. See Movie_M3.

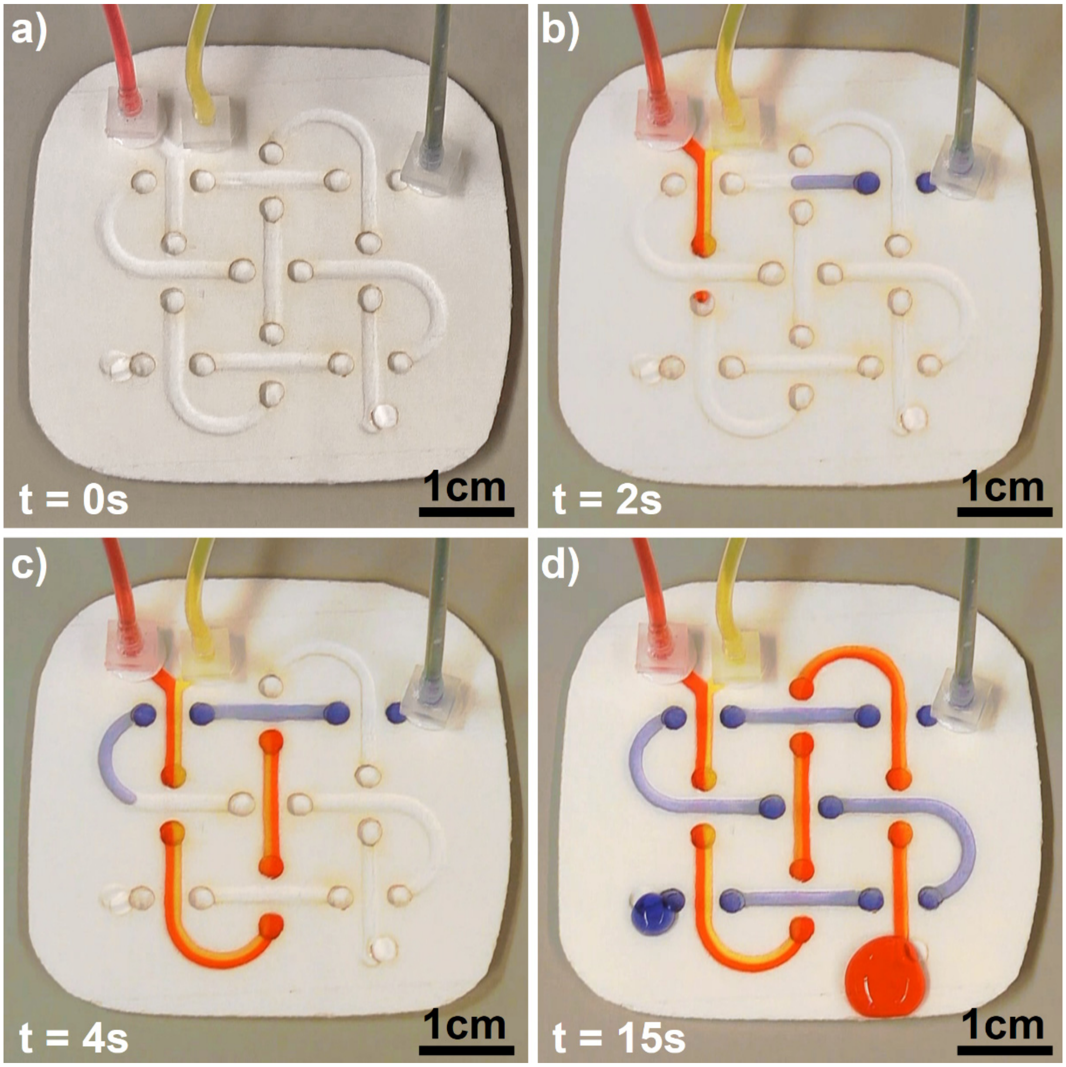

Figure S7. Demonstration of laminar flow and mixing in 3D microfluidic devices fabricated by embossing Whatman #1 filter paper and silanizing with R^FSiCl_3. a) Inlets were attached to the device using rings of double-sided adhesive layer. b) Demonstration of laminar flow. c) Mixing of the fluids originally in laminar flow due to the turbulent flow induced by the changes in direction of the channel. The laminar flow is maintained even when the fluids flow across different layers of the device. d) The device after passing fluids through the channels. Droplets accumulate on the outlet. See Movie_M5.

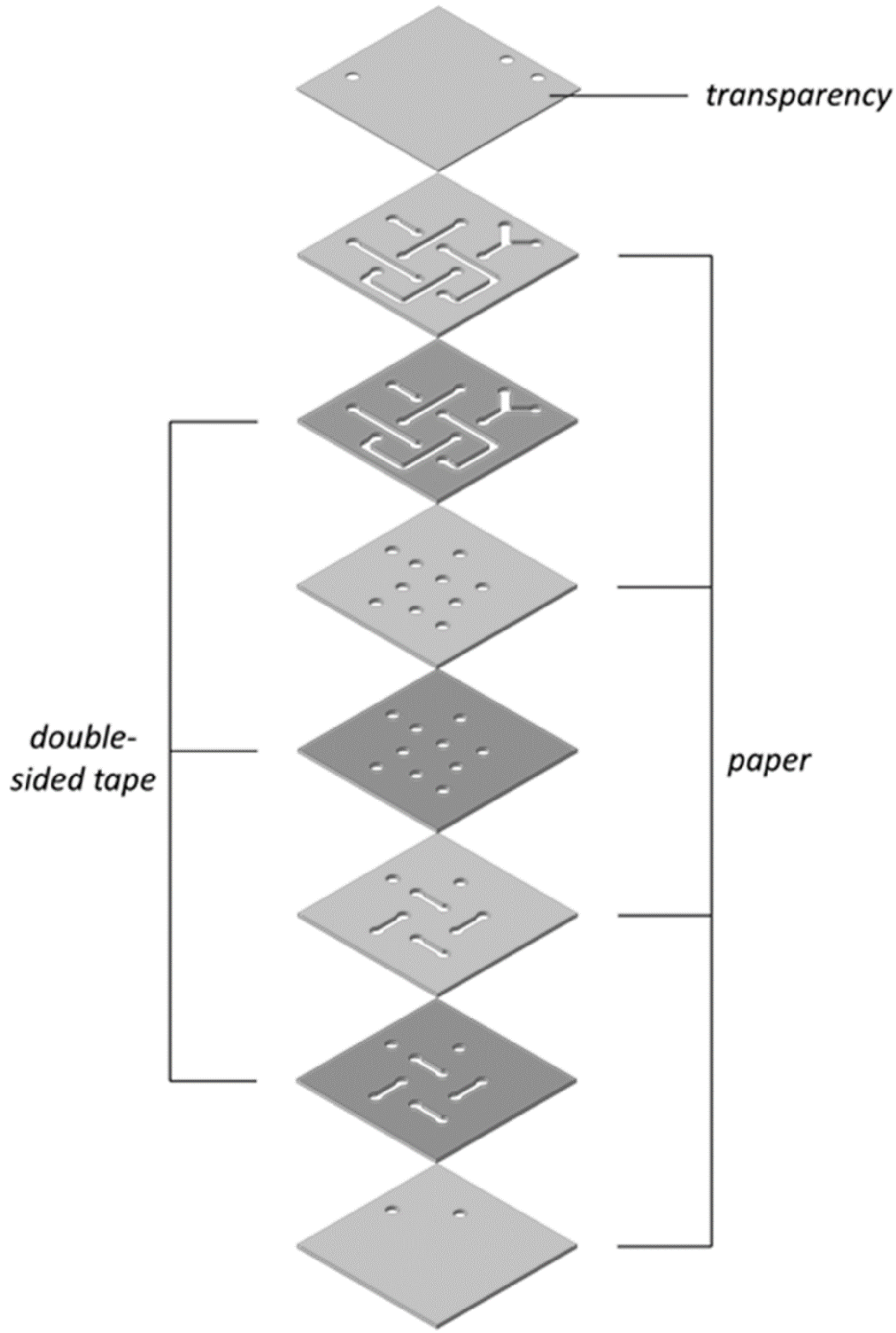

Figure S8. Schematic representations of the layers used in the fabrication of 3D microfluidic devices by cut-and-stack. The layers were lined up and pressed together to make the device. The device was then silanized to render omniphobic the surface of the paper.

Videos. The following videos are part of this supporting information section:

1. Movie_M1. Microfluidic device with two inlets demonstrating laminar flow between two fluids (dye water).

2. Movie_M2. Microfluidic device with three inlets demonstrating laminar flow. All the inlets flow dye water.

3. Movie_M3. Induced mixing in a laminar flow induced by the geometry of an embossed microchannel.

4. Movie_M4. 3D Microfluidic device with two inlets fabricated by embossing.

5. Movie_M5. 3D Microfluidic device with three inlets demonstrating laminar flow and induced mixing due to the geometry of the channel.

6. Movie_M6. Droplet generator fabricated by embossing running an aqueous solution (red) and hexadecane (blue).

References

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2. Glavan, A. C.; Martinez, R. V.; Subramaniam, A. B.; Yoon, H. J.; Nunes, R.; Lange, H.; Thuo, M. M.; Whitesides, G. M. *Adv. Funct. Mater.* **2014,** 24, 60-70.
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