Supplementary Information (SI) for Lab on a Chip.
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Supplemental Information

3D Printing Monolithic, Multifunctional Polymer Acoustofluidic Devices with Tunable Mixing and Particle Focusing

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3D-Printed Acoustofluidics: Acoustic Mixing

Evaluation of MI can occur continuously across the length of the acoustofluidic device. For context, Figure S1 shows the MI at three spatial positions corresponding to spike positions 5, 10, and 15 for two flow rates: 3 µL/min (Fig. S1A) and 6 µL/min (Fig. S1B). Under diffusive mixing (i.e. the absence of acoustic mixing), a fully mixed condition occurs only at an extended distance away the device inlet for the 3 µL/min flow and does not achieve a fully mixed state at 6 µL/min. Under acoustic mixing, a fully mixed state is obtained near the entrance of the device (i.e. spike position 1). Waterfall plots for both flow conditions (3 µL/min – Fig. S1C; 6 µL/min – Fig. S1D) illustrate the dynamic variations in MI values over time and across the channel length.

The region of interest (ROI) used to calculate the MI throughout the device is shown in Fig. S2E.

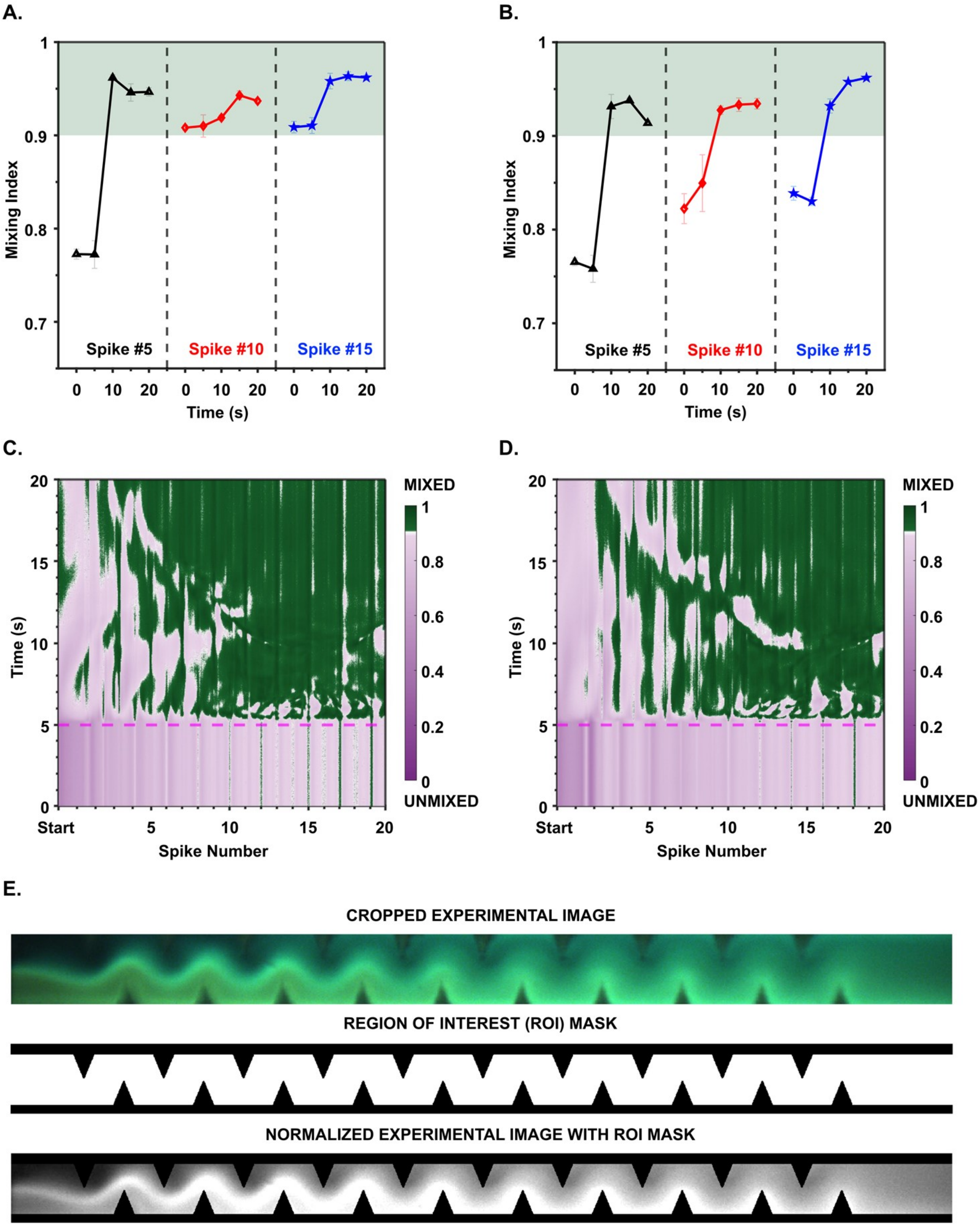

Figure S1. MI at three spatial positions in the device without and with acoustic mixing for two flow rates: (A) 3 μL/min, (B) 6 μL/min. MI at (C) 3 μL/min and (D) 6 μL/min in the region of interest over time. The magenta dashed line indicates the time of acoustic field application. (E) Experimental image masking process used to calculate the MI within the ROI.

3D-Printed Acoustofluidics: Acoustic Focusing

Schematics of the acoustic focusing chip design from various views (e.g., front, side, top) are provided to visualize the adjusted dimensions (Figure S2A-D).

3D microfluidic chips with varying thicknesses (200 μm, 400 μm, 600 μm, and 800 μm) enable investigation of the influence of device total thickness on acoustophoretic force (with voltage as analogue to acoustic energy 0 V, 15 V, 30 V, and 45 V). Black paramagnetic polyethylene microparticles (2 w/w%) suspended in silicone oil entered into a device via a syringe pump at a flow rate of 12 μL/min. As Figure S2E indicates, not all chips supported acoustophoretic focusing. The presence or absence of focusing depended on device thickness. Among the tested designs, chips with a nominal t_{top} and t_{bottom} thickness of 600 μm exhibited the strongest focusing at 45 V (Figure S2E).

As revealed via cross-sectional analysis, a key consideration is the occurrence of compression during the printing process of the bottom of the chip (i.e. chip interface with the build plate). Figure S2F highlights the critical importance of this compression factor in ensuring fabricated devices have the as-designed channel dimensions. From the investigation we discovered an asymmetric t_{top} and t_{bottom} thickness can significantly influence the chip's acoustic performance and is a key design parameter.

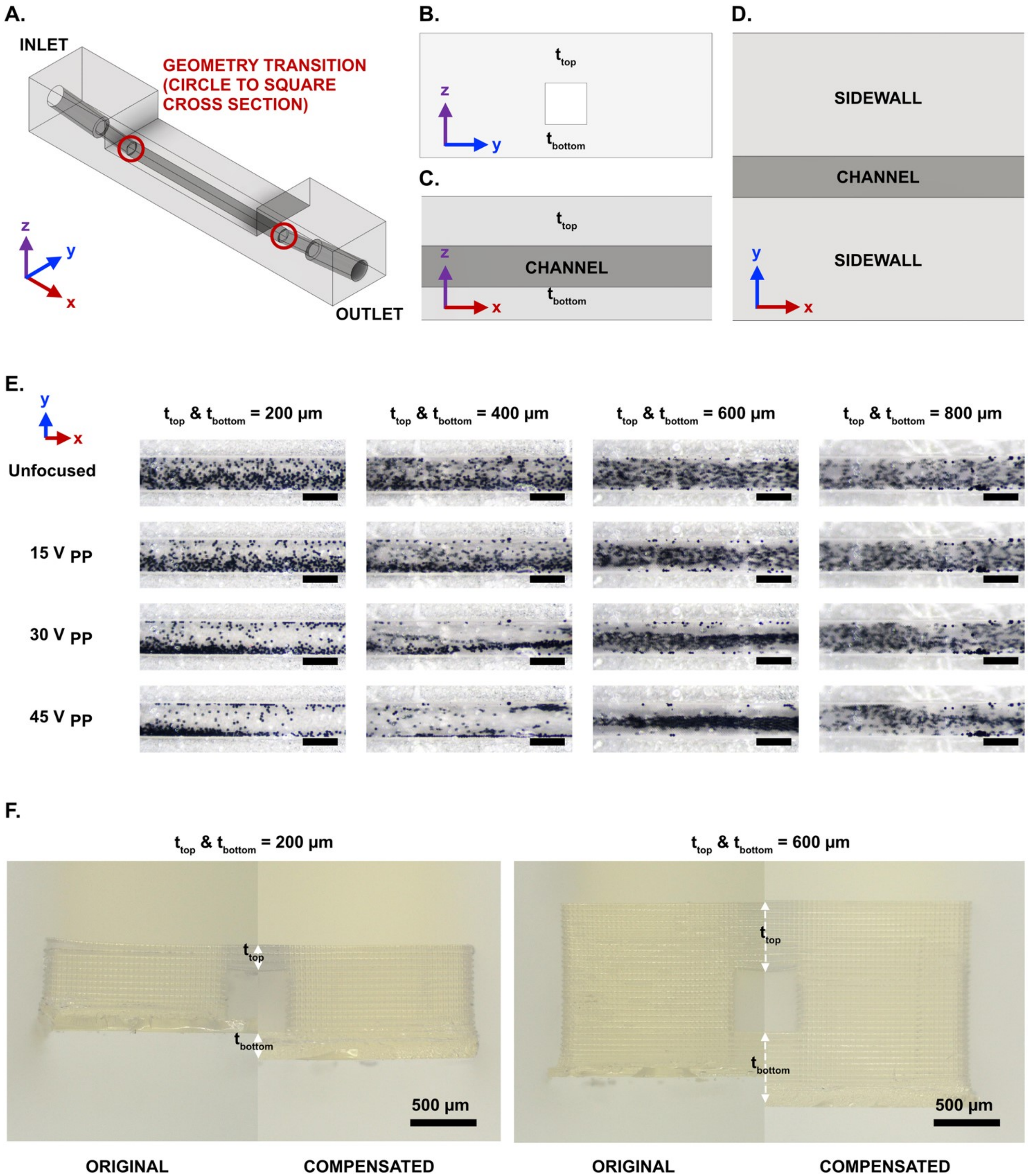

Figure S2 (A) Acoustic focusing chip design with various cross-sectional views: (B) front, (C) side, and (D) top. (E)Various top and bottom thicknesses experiencing different applied voltages during thickness and voltage tunings. (F) Printed chips with the original nominal and compensated thicknesses.