Electronic Supplementary Information for

Manually Operatable On-Chip Bistable Pneumatic Microstructures for Microfluidic Manipulations

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Structural dimensions of BMP

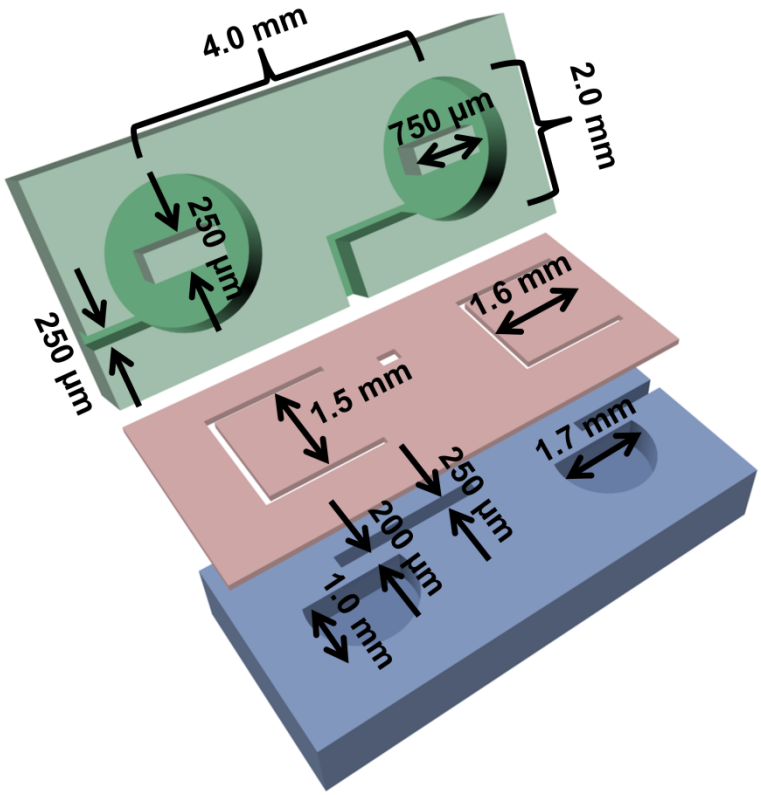

Figure S1. Assembly of PDMS layers and structural dimensions of BMP structures. Figure shows how structures in three PDMS layers are aligned on top of another. The top layer of BMP has circular recess that is 2.0 mm in diameter and 900 µm deep. In the center, there remains an island pillar of 750 µm long and 250 µm wide. A channel of 250 µm in width exits this chamber. Center-to-center distance between two circular chambers is 4.0 mm apart. In the middle layer, membrane cantilever is 1.5 mm wide and 1.6 mm long. In the bottom layer, a semicircle is of 1.7 mm in diameter, centered to the top layer circle chamber, and only 1.0 mm in width is etched. 200 µm above the semicircle edge is a channel of 250 µm in width that ends at the mid axis of the semicircle.

Dimensions in BMP-controlled devices

In the multiplexor and the blood-typing device, microfluidic channels are 500 µm in width. Four parallel multiplexing channels are 20 - 22 mm long and outlet channel is 5.0 mm in length. Blood-typing device has microfluidic channels 10-20mm long. Vacuum networking channels are 200-400 µm in width and 5.0-30.0 mm in length.

Durability of BMP

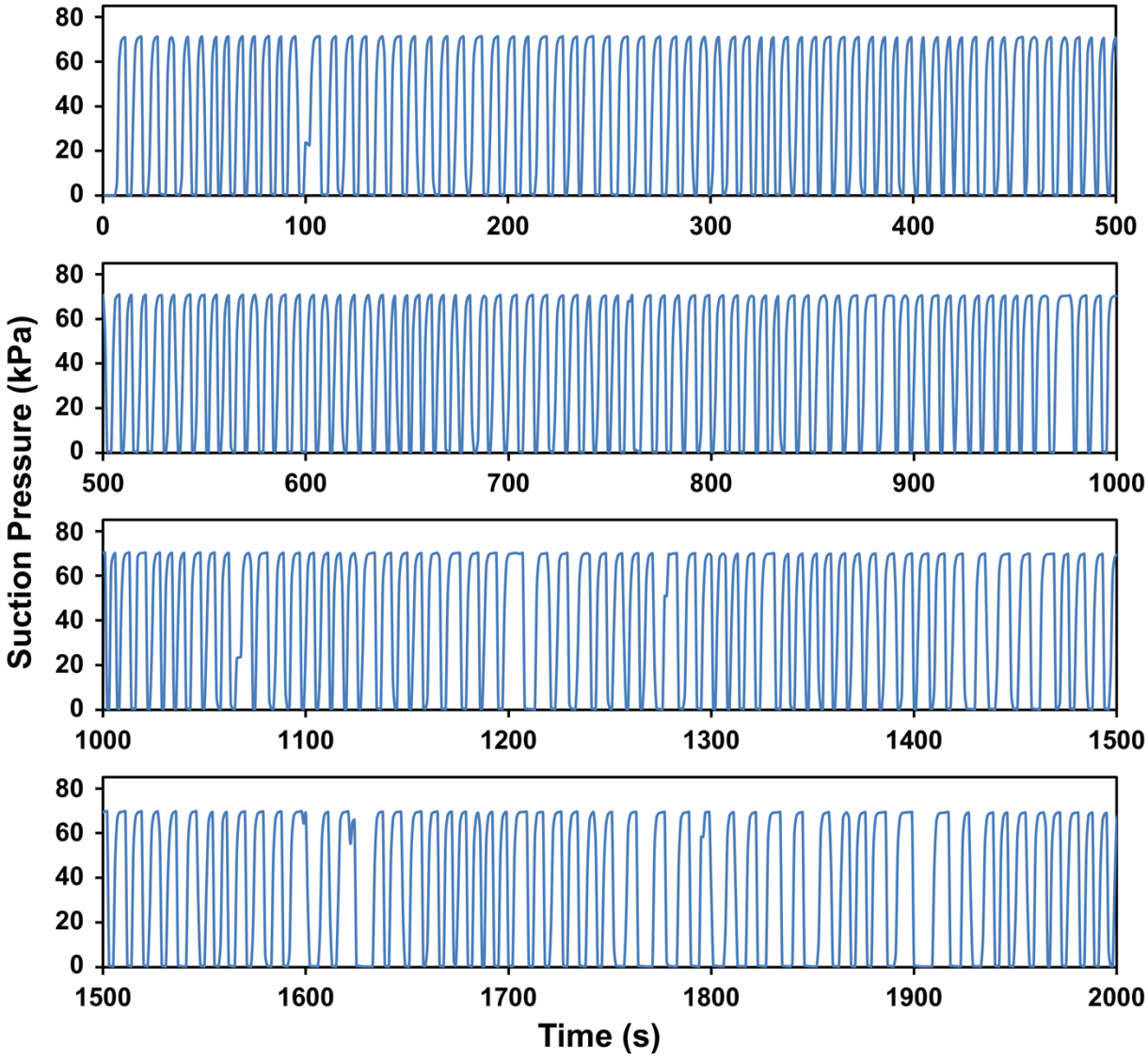

Figure S2. Durability of BPM. The test is performed by manually pressing the VAC chamber to deliver vacuum to a pneumatic chamber of a normally-closed valve then pressing the PRC chamber to release the vacuum back to atmospheric pressure. Vacuum source is from a vacuum line in the building facility. Durability of BPM endured at least 200 rigorous cycles over 30 min with potential for more as no sign of degradation is observed.

Characterization Setup

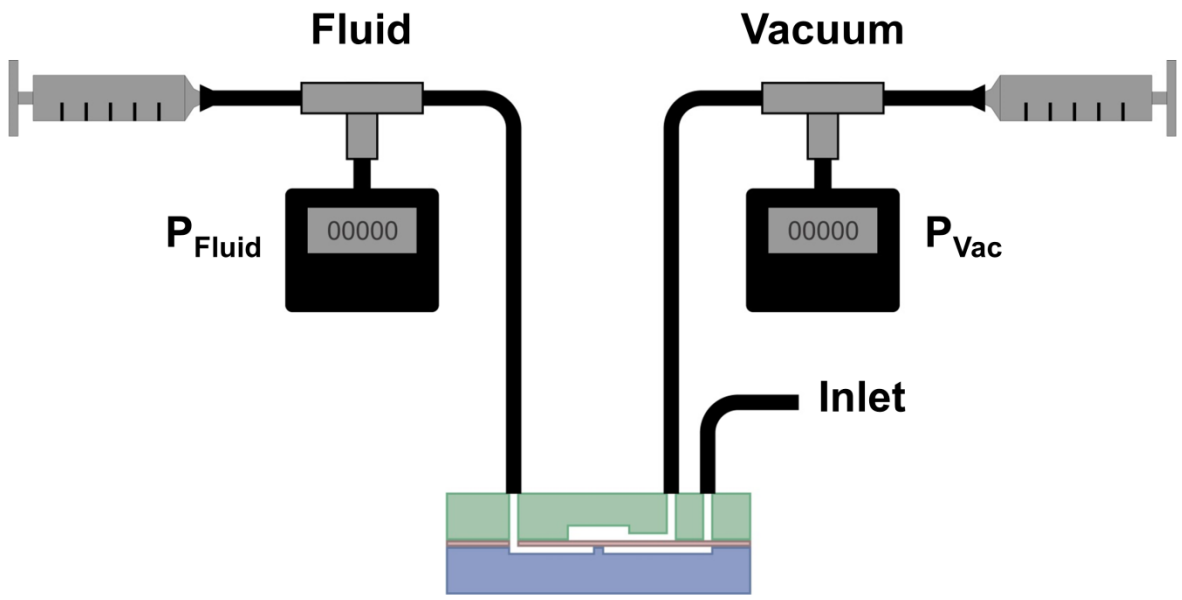

Figure S3. Pressure characterization setup. A vacuum supply (vacuum syringe) is connected to the BPM device and the vacuum pressure is constantly monitored by a digital pressure sensor. The BPM device controls a normally-closed valve in a fluidic channel that is connected to another pressure sensor for assessing the fluidic pressure. The fluidic network is always operated under negative pressures and a normally-closed valve cannot be open by the flow itself. A fluidic pressure (P_{Fluid}) is first generated and maintained near 2.5, 5.0, 7.5, 10.0 kPa using a syringe pump, then vacuum is gradually increased in the vacuum syringe on a pump to determine the minimum vacuum pressure (P_{Vac}) required to open the microvalve.

Vacuum pressure characterization of BMP

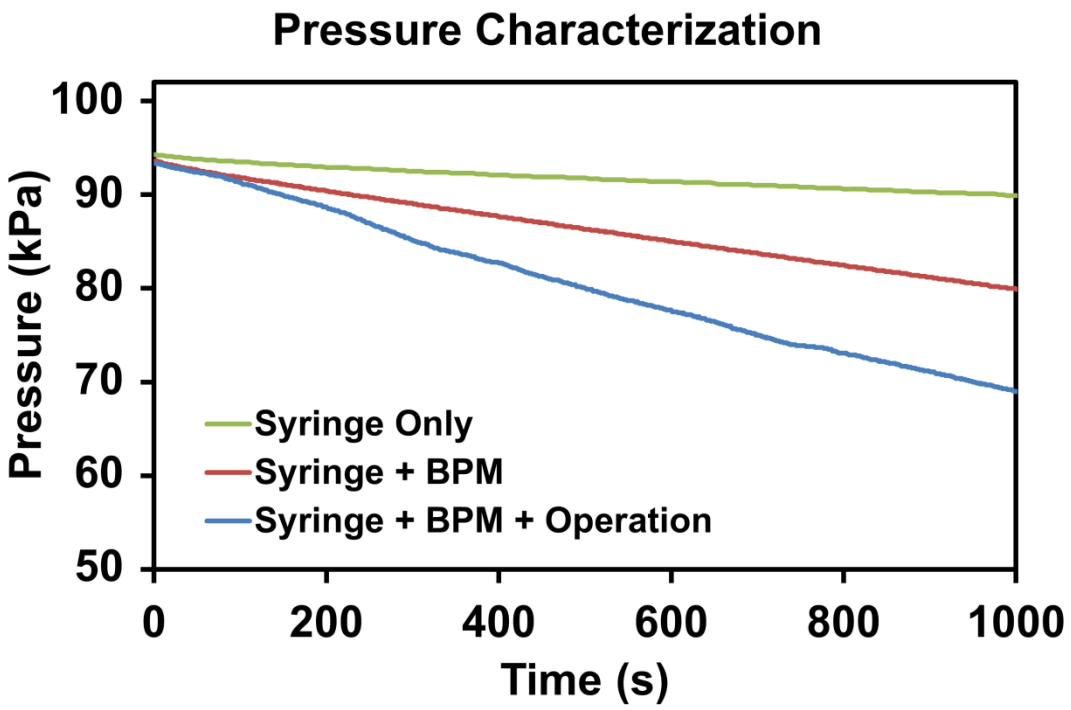

Figure S4. Characterization of BPM using vacuum syringe. Figure shows performance of using an off-the-shelf vacuum-generating syringe as vacuum source. Green line shows pressure within the vacuum syringe alone over time resulting in a loss of pressure at 0.004 kPa/s. Red line shows pressure within the vacuum syringe when a BPM is connected resulting in a loss of pressure at 0.0133 kPa/s. Blue line shows pressure within vacuum syringe when a BPM is connected and is being manually operated. Each BPM on/off toggle results in an average loss of 0.198 ± 0.078 kPa (n=109) and decreased in a step-like fashion.

Vacuum indicator

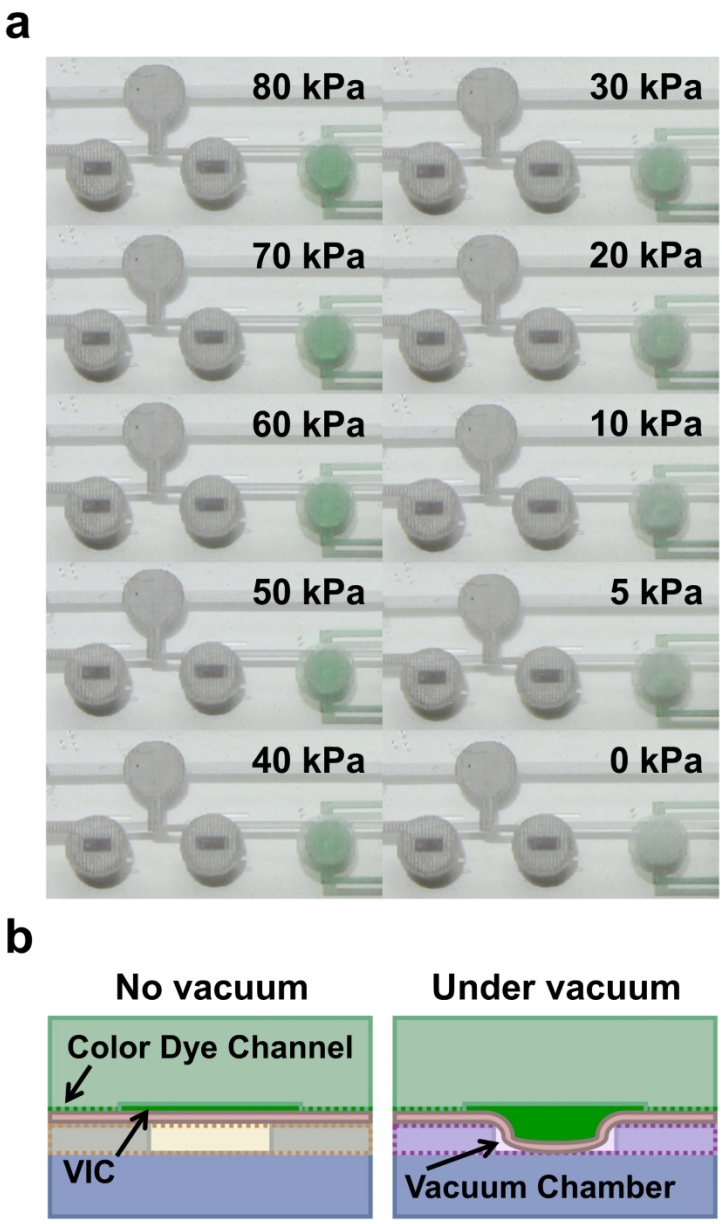

Figure S5. Visual color indicator for presence of vacuum. (a) A vacuum indicating chamber (VIC) is added between the vacuum source and BPMs. VIC displays darker green in presence of higher vacuum strength and lighter color dye in absence of vacuum. (b) Cross-sectional view of VIC, a circular chamber of 2.0 mm in diameter and 30 μm in height filled with color dye indicator. Below VIC is a vacuum chamber connected to vacuum source and BPM. In the absence of vacuum, thin liquid layer in VIC is not distinguishable. Under higher vacuum (≥20 kPa), membrane deformation draws liquid into VIC creating a thicker liquid layer (600 μm) to indicate the presence of vacuum.

BPM-controlled immunoassay device

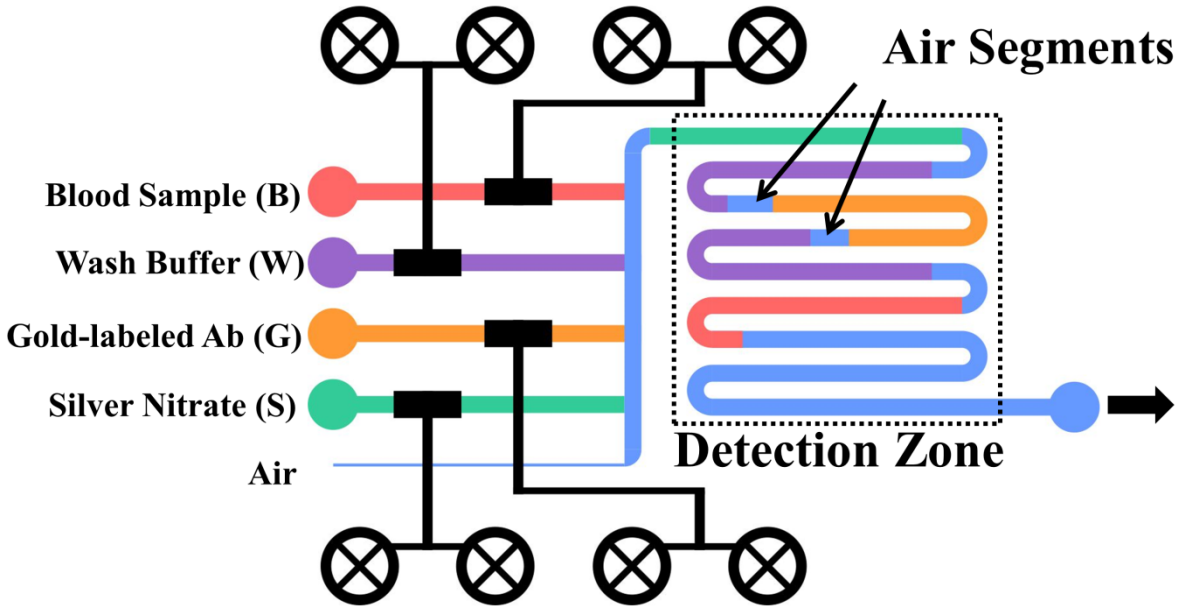

Figure S6. Potential application of BPM in immunoassay microfluidic device. A microfluidic device design is shown utilizing 4 BPMs to generate segments of reagents for running an immunoassay. The order at which these reagents pass through the detection zone is critical for the assay to function properly. First, sample analytes containing HIV-specific antibodies are captured at the detection zone with wash buffer following to remove excess materials. Then, gold-labeled goat antibodies are used to label captured analytes. Finally, silver nitrate with reducing solution permits visual indication. Air segments between solutions prevent mixing during flow operation. The assay will not function correctly if reagent delivery sequence is changed. Therefore, it is imperative to implement on-chip BPM controls to introduce samples and reagents in a controlled and sequential fashion.