Supporting Information For

Constant flow driven microfluidic oscillator for different duty cycles

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Fabrication process

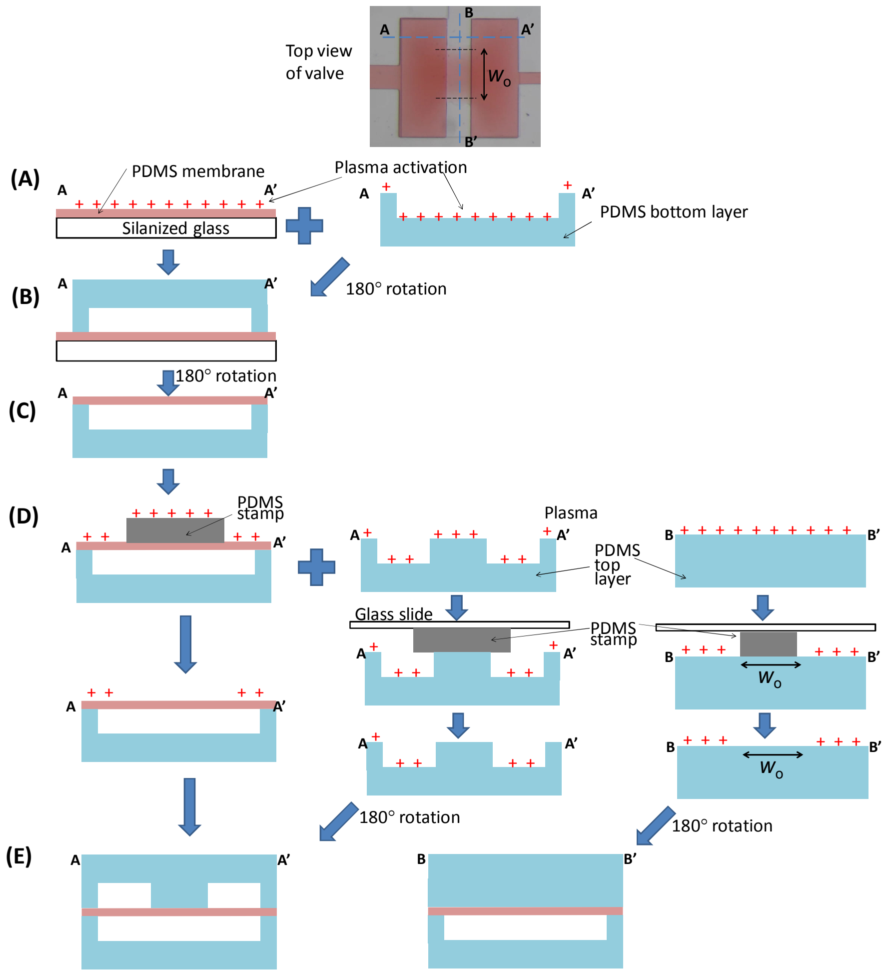

Figure S1. Fabrication process of valve. Cross-sectional views are shown along lines of section A-A' or B-B'. (A) Plasma treatment of middle (membrane) and bottom PDMS layer. (B) Bonding. (C) Detachment of middle and bottom layer from glass slide, and punching connection holes in middle layer. (D) Selective plasma treatment of middle and top layer. PDMS stamps are temporarily placed for the selective hydrophobic treatment and the opening width (W_o) is controlled by stamp width. PDMS stamp for bottom layer was bonded on the glass slide for easy handling. (E) Alignment and bonding.

Theoretical model of the constant flow-driven oscillator

For the theoretical model of the oscillator, we used commercial software (PLECS, Plexim GmbH, Switzerland). The circuit diagram is shown in Figure S2.

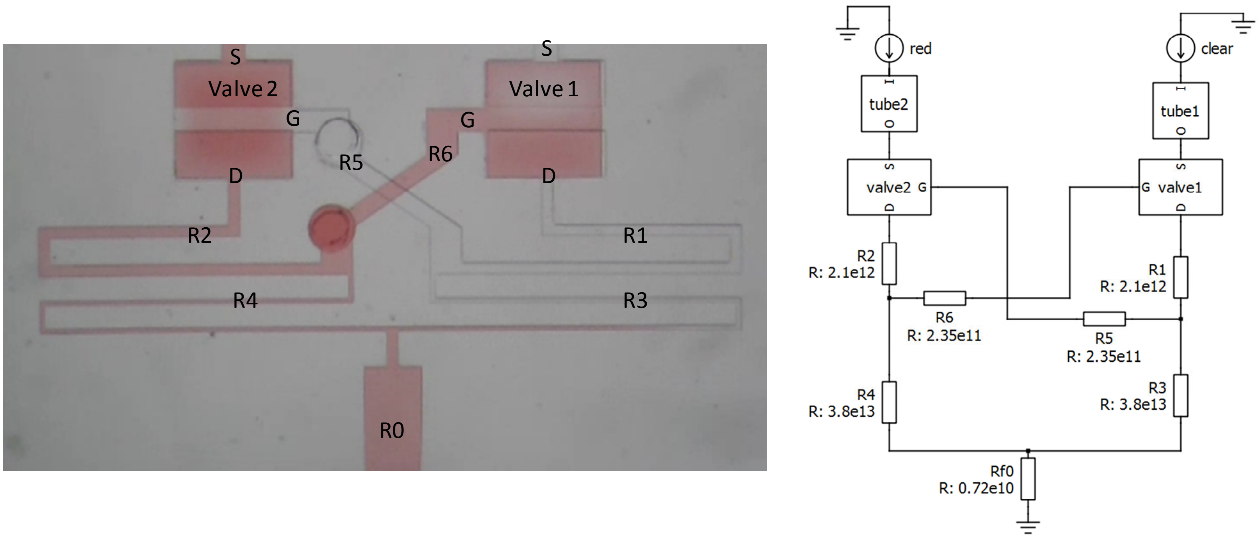

Figure S2. Micrograph of the constant flow-driven oscillator and its corresponding circuit diagram for the theoretical model. The downstream channels are R3 and R4, and the connection channels are R1 and R2.

Difference between P_{S1} and P_{G2} or between P_{S2} and P_{G1}

As shown in Figure S3, the difference between P_{S1} and P_{G2} or between P_{S2} and P_{G1} is ~5% in the valve-on state. Thus, we can approximate P_{G2} as P_{S1} and P_{G1} as P_{S2} to measure threshold pressure.

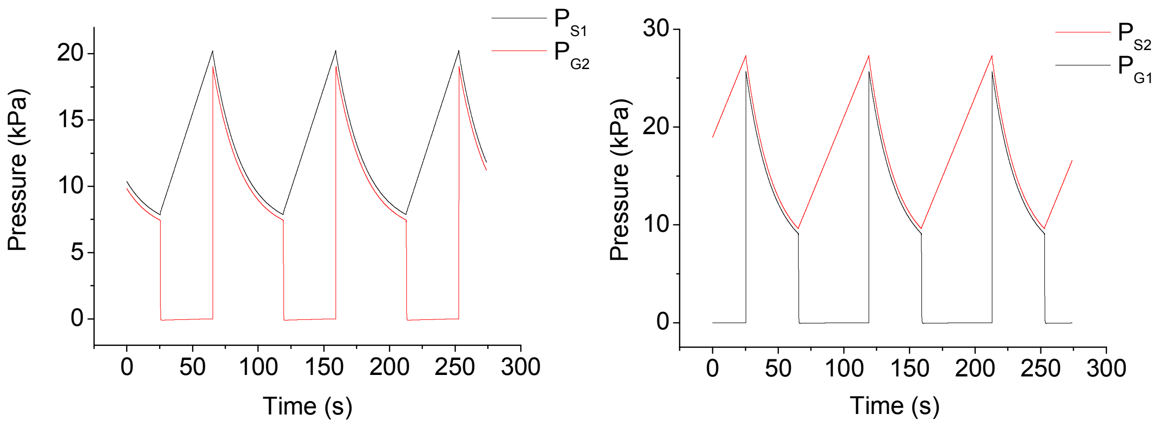

Figure S3. Source and gate pressures. The values were obtained from a theoretical model for the flow rate of 10 µL/min in device 2.

Duty cycle

In the off-valve, the valve and the upstream system work as a capacitor. Thus, off-time of the valve (t_{off}) can be approximated as $t_{off\text{-}i} = (C/\ Q_{in})\ P_{th\text{-}i}$ from $Q_{in} = C\ dP/dt$, where Q_{in}, C, and $P_{th\text{-}i}$ are inflow rate, fluidic capacitance, and threshold pressure, respectively. Subscript i is 1,2 or 3, which represents the valve type number. Duty cycle can be defined as $t_{off\text{-}i}\ /\ (t_{off\text{-}j} + t_{off\text{-}i})$, where subscript j is 1, 2 or 3, but i and j should be different except $i = j = 1$. As a result, $t_{off\text{-}i}\ /\ (t_{off\text{-}j} + t_{off\text{-}i})$ is $P_{th\text{-}i}\ /(\ P_{th\text{-}j} + P_{th\text{-}i})$, because Q_{in} and C are used both in the numerator and denominator of the equation. The equation gives us the duty cycle of 0.5, 0.4, and 0.2 for device 1, 2, and 3, respectively. The values are in good agreement with the experimental and theoretical results (See Figure 3B).

Comparison between static and periodic staining

Figure S4(A) shows that, in static stain, once the intensity decays it does not recover whereas intensity oscillates in periodic stain. It can be explained as follows: photobleaching is relatively fast and the illuminated region is relatively wide (> 500 ×500 μm^2) as shown in Fig. S4(B). In the case of the static stain, effective fluorescent dyes are quickly depleted by photobleaching and diffusion of the effective dye into the illuminated region is slow. As a result, intensity profile of the static stain decays quickly and does not recover. In contrast for periodic stain, fresh dye is periodically provided by convective flow of the dye. Thus intensity recovers when dye solution is provided.

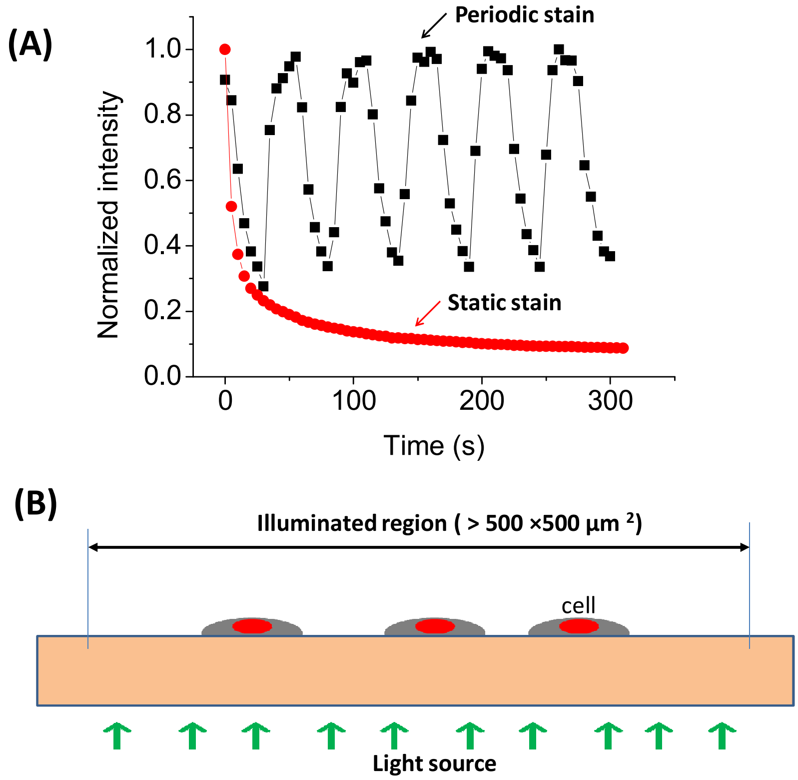

Fig. S4. (A) Intensity profile for periodic and static staining of C2C12 cell nucleus, and (B) illustration for the illuminated region.

Movies

Movie 1and 2 are for device 1 and 3 at the inflow rate of 10 μL/min, respectively.