Supplementary Information

Digital microfluidics using differentially polarized interface (DPI) to enhance translational force

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Theoretical Equations

Lippmann-Young's Law of electrowetting

$$\frac{1}{2} CV^2 = \gamma_{LF}(\cos\theta - \cos\theta_0) \quad \text{(S1)}$$

Where, $\frac{1}{2} CV^2$ is the applied energy and $\gamma_{LF}(\cos\theta - \cos\theta_0)$ is the surface barrier. Ideally, they both should be equal but due to nonlinearity θ never becomes zero with increased voltage. And this equation explains the original change of droplet contact angle due to voltage. However, when it comes to the application to translating the droplet, there must be a net force causing the droplet to move in the direction of the acting force. By rearranging **Eq. S1**, we can write the dynamic equation for a droplet in motion simply applying Newton's Second Law considering the droplet as a rigid body in its simplest assumed form.

$$m_{droplet}\frac{d^2x}{dt^2} = \frac{1}{2} CV^2 - \gamma_{LF}(\cos\theta - \cos\theta_0) \quad \text{(S2)}$$

Where $m_{droplet}$ is the droplet mass and $\frac{d^2x}{dt^2}$ is the acceleration of the droplet due to the net force. Similar equation can be found in other literature as well [1].

This electrowetting phenomena is described by Young's Law

$$\gamma_{SL}(V) = \gamma_{SL}(0) - \frac{1}{2} CV^2 \quad \text{(S3)}$$

where $\gamma_{SL}(V)$ is the solid-liquid interfacial tension after the voltage is applied, $\gamma_{SL}(0)$ is the solid-liquid interfacial tension at no electric potential, C is the capacitance of the insulating dielectric of the surface, and V is the applied potential.

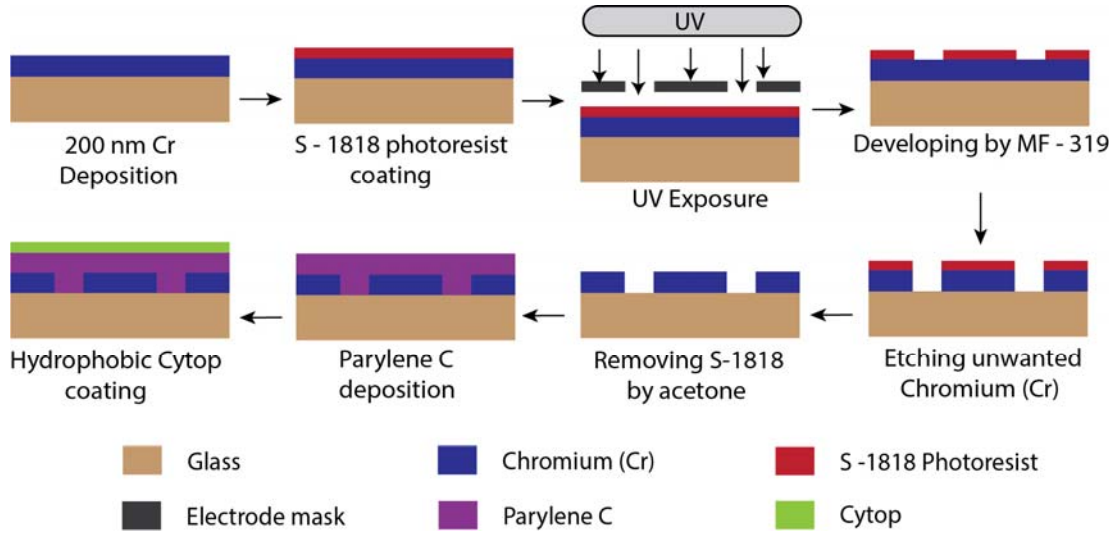

Fig. SI 1. DMF chip fabrication procedure. 1.5 mm x 1.5 mm electrode pattern was fabricated on a 200 nm Chromium (Cr) coated glass slide using standard photolithography. 2.7μm Parylene C and 60 nm Cytop was coated afterwards as dielectric and hydrophobic, respectively[2].

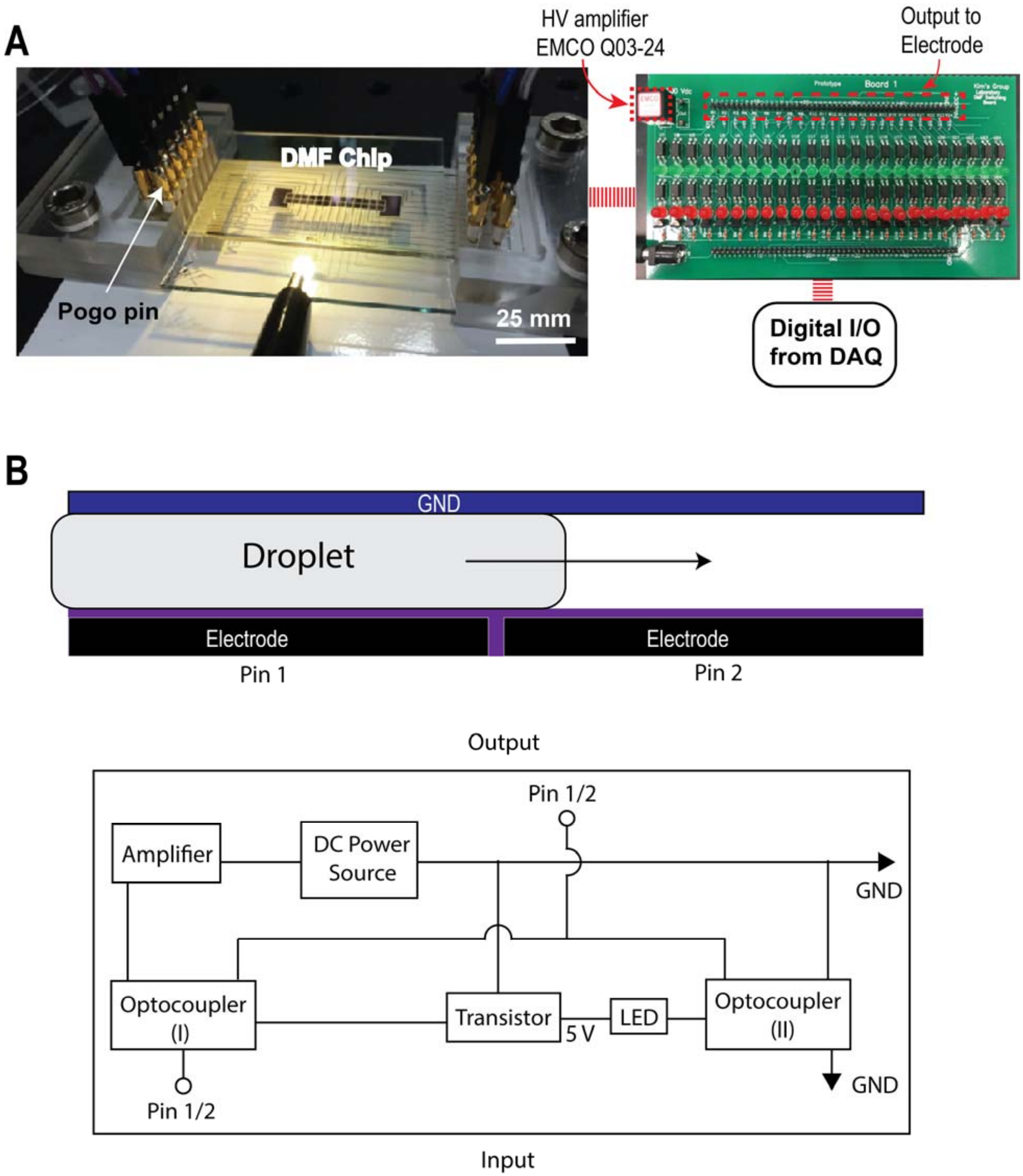

Fig. SI 2. Architecture of DPI control circuit. A) The custom built DMF platform for holding the chip and interfacing with the high voltage circuit, the compact PCB capable of high-voltage amplification and signal switching. B) The DPI circuit design and actuation mechanism.

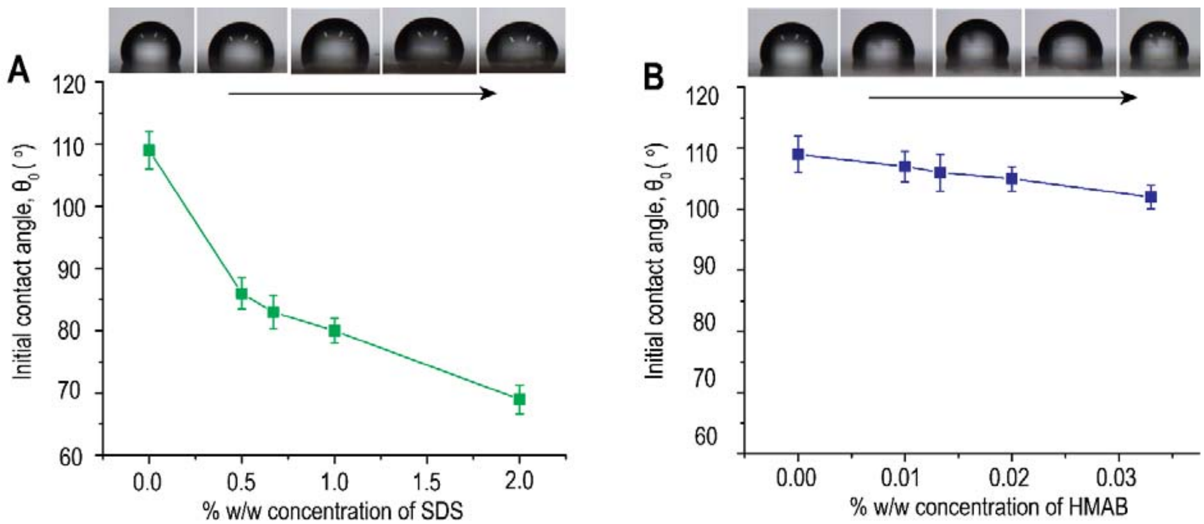

Fig. SI 3. Contact angle change of surfactant with respect to their concentration in DI water A) anionic surfactant (SDS), B) cationic surfactant (HMAB).

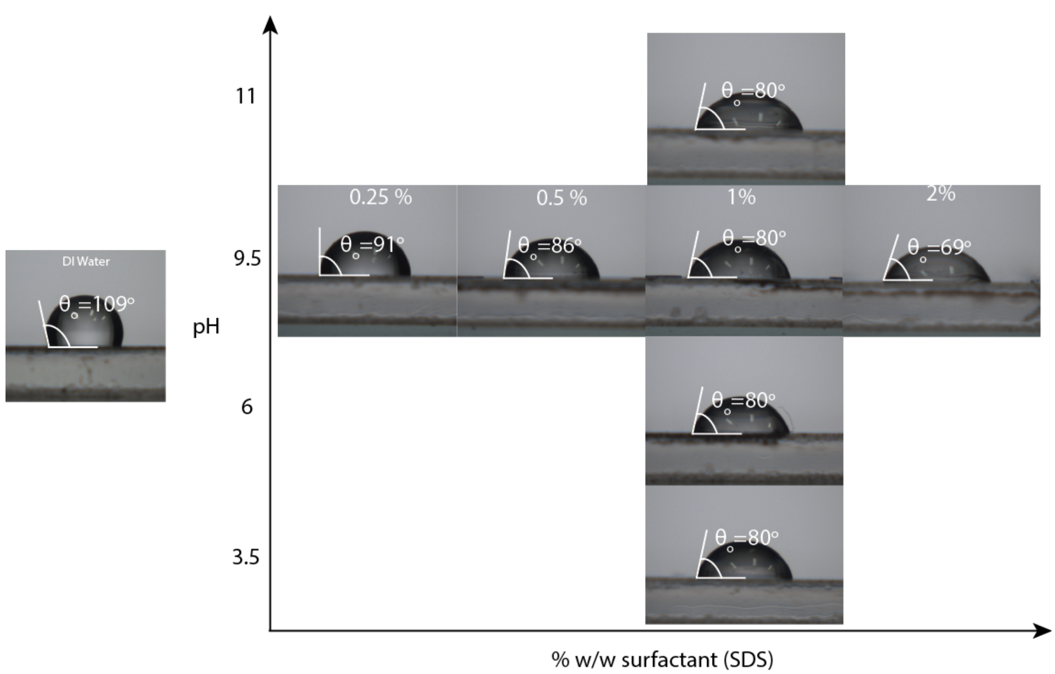

Fig. SI 4. Goniometer images showing initial contact angle of 2.5 μL droplets for various pH and SDS concentration.

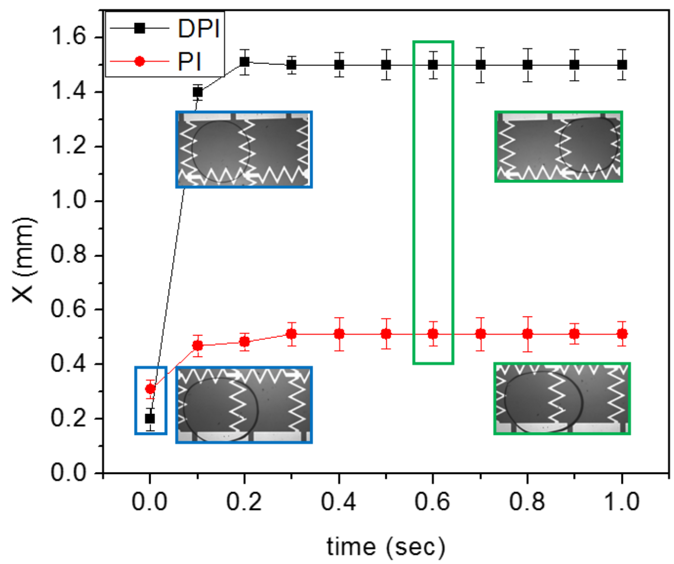

Fig. SI 5. Comparison of the dynamic translation of a DI water droplet at 150 V for DPI and traditional PI. The blue box indicates the initial position of the droplet and the green box indicates the droplet position at 0.6 s with respective frames for DPI and traditional PI.

REFERENCES

1. V. Bahadur and S. V. Garimella, *J. Micromechanics Microengineering*, 2006, **16**, 1494.
2. M. E. Razu and J. Kim, IEEE Int. Conf. Micro Electro Mech. Syst., 2017.