High-throughput Microfluidic Droplet Dispenser for Lab-on-a-Chip Application

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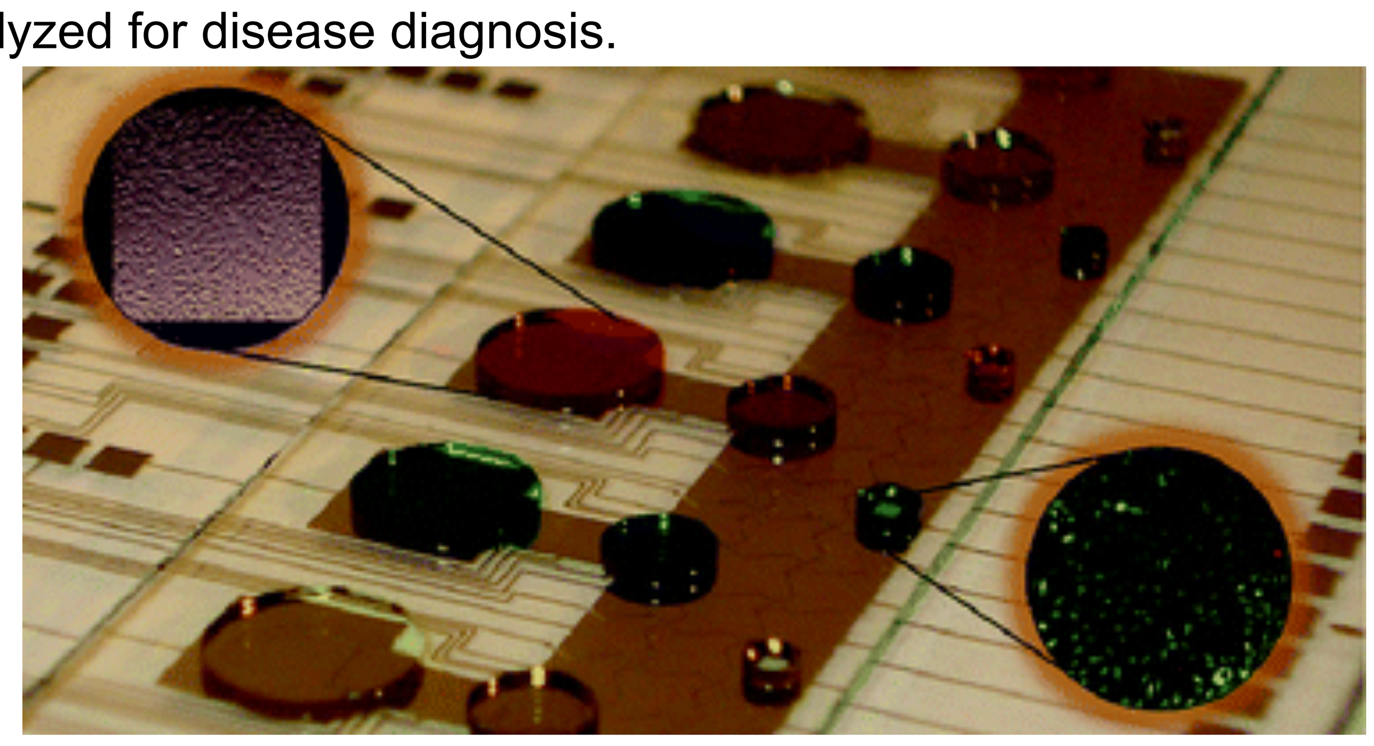
Abstract

In this poster, a high-throughput microfluidic droplet dispenser used to convert analog microfluidic flow into digital droplets is reported. The droplet dispenser is connected to the outlet of a micropump, and utilizes electrowetting to convert the continuous analog microfluidic flow into individual droplets. The generated droplets will then be input into a Digital Microfluidic Biochip (DMFB) for Lab-on-a-Chip application. Direct connection between continuous flow (capillary or micro-channel) and electrowetting-on-dielectric (EWOD) network has two drawbacks: there is no droplet-volume control, and liquid excess in case of overpressure cannot be evacuated. The proposed dispenser can overcome such problems. The working principle of the microfluidic droplet dispenser is analyzed. A set of optimized design parameters of the droplet dispenser is achieved. COMSOL multiphysics simulation is used to verify the function of the designed droplet dispenser.

Introduction

Digital microfluidics manipulating individual droplets can significantly improve the resolution and efficiency for disease diagnosis and drug delivery. However, the original blood sample is still input as continuous analog flow. Microfluidic devices can handle tiny volumes of liquid as either continuous flows in micro-channels or droplets on hydrophobic surfaces. Up to now, most lab-on-chips (LOC) have been implemented with only one of these two technologies. However, by analogy with microelectronic systems, one can easily understand that, depending on operations, both technologies have their own advantages and drawbacks. As a consequence, systems that can convert a continuous flow into droplets and, reciprocally, that can convert droplets into continuous flows have to be studied.

The proposed high-throughput microfluid droplet dispenser acts as a analog-to-digital converter for microfluidic devices. It can quickly convert continuous analog microfluidic flow into individual digital droplets with a high throughput. Such device is very useful at the front-end of the lab-on-a-chip devices because it can quickly convert the analog blood sample into digital droplets so that they can be manipulated and analyzed for disease diagnosis.



http://pubs.rsc.org/en/content/articlelanding/2010/lc/c002147d#!divAbstract

Fig. 1. Manipulation of digital microfluidic droplets in DMFB

Device Design of Microfluidic Droplet Dispsenser

The proposed microfluidic droplet dispenser is designed to be connected to the outlet of a micropump, and utilizes electrowetting to convert the continuous analog microfluidic flow into individual droplets. The generated droplets will then be input into a Digital Microfluidic Biochip (DMFB) for Lab-on-a-Chip application. The structure is shown in Figure 2. Traditional drop dispenser can only dispense one droplet at a time. The proposed droplet dispenser has multiple outlets, thus it can dispense multiple droplets simultaneously in all directions. This greatly improve the efficiency and leads to improved throughput.

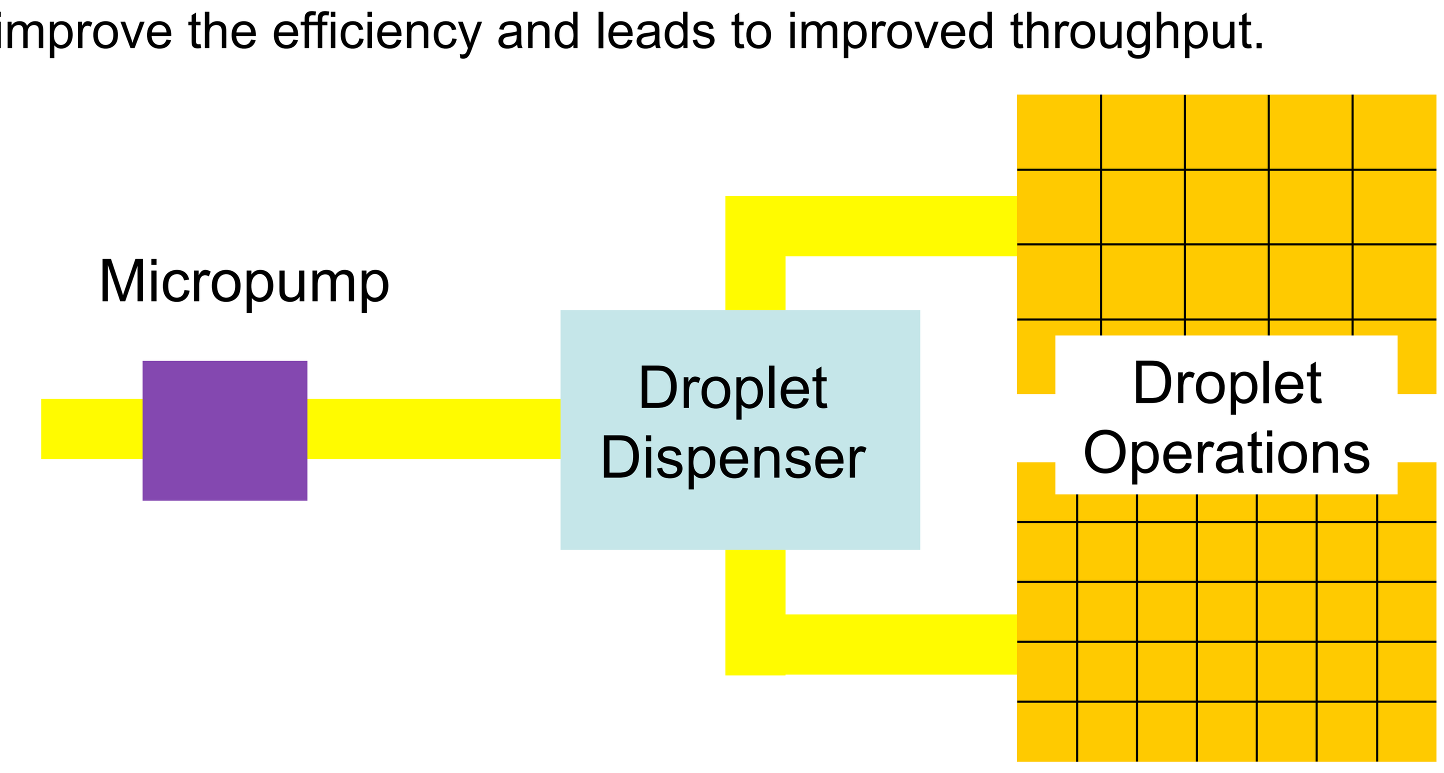


Fig. 2. High-throughput Microfluidic Droplet Dispenser connectting analog microfluidic flow to digital microflufidic biochip (DMFB)

Theoretical Analysis

The working principle of droplet dispenser is based on electro-wetting, in which the voltage applied to the ionized droplet induces electrostatic force and hange the contact angle of the droplet.

Young's Equation

$$\gamma_{s1} + \sigma_{12}\cos\theta_0 = \gamma_{s2}$$

$$\gamma_{s1} - \frac{\varepsilon V^2}{2d_f} + \sigma_{12}\cos\theta_{ew} = \gamma_{s2}$$

$$\cos\theta_{ew} = \cos\theta_0 + \frac{\varepsilon V^2}{2\sigma_{12}d_f}$$

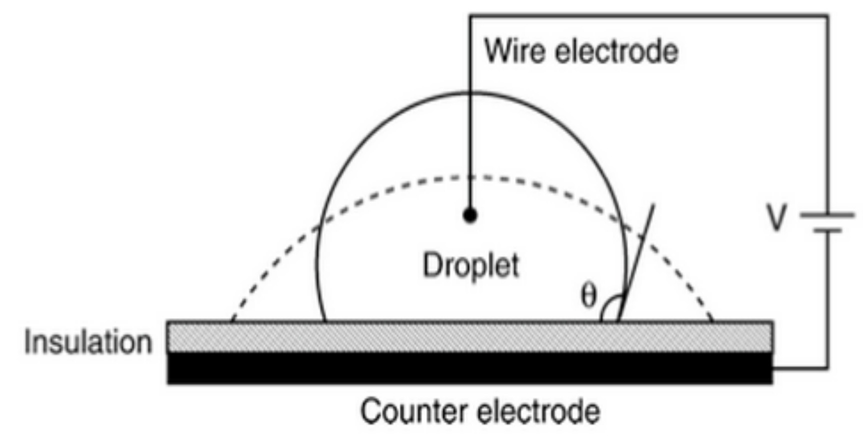


Fig. 3. Electrowetting of droplet

θ_0 : the equilibrium contact angle,

γ_{s1},σ_{12}, and γ_{s2} : the interfacial tensions between the solid and fluid 1, fluid1 and fluid 2, and the solid and fluid 2, respectively.

ε : the permittivity of the dielectric, V : the potential difference applied,

d_f : the dielectric thickness.

Utilizing electrowetting, we can apply voltage in the electrodes next to analog fluidic reservoir in certain consecutive sequence, so that electrowetting will drive the microfluid to separte into individual droplets, hence analog flow is dispensed to digital droplets by the dispenser. The detailed theoretical model is analyzed in [1], as shown in Fig. 1. It will be helpful to guide us in the device design.

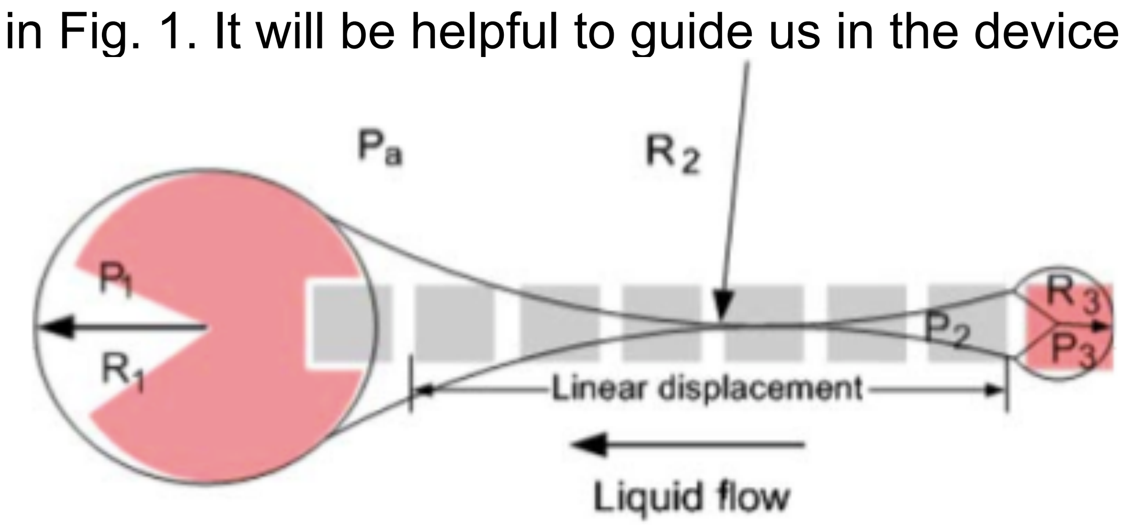


Fig. 4. Theoretical model for droplet dispensing [1]

COMSOL Simulation

COMSOL simulation is used to simulate the dispensing process of the droplet dispenser. The velocity and pressure distribution inside the dispenser is shown in Fig. 3 and 4 respectively.

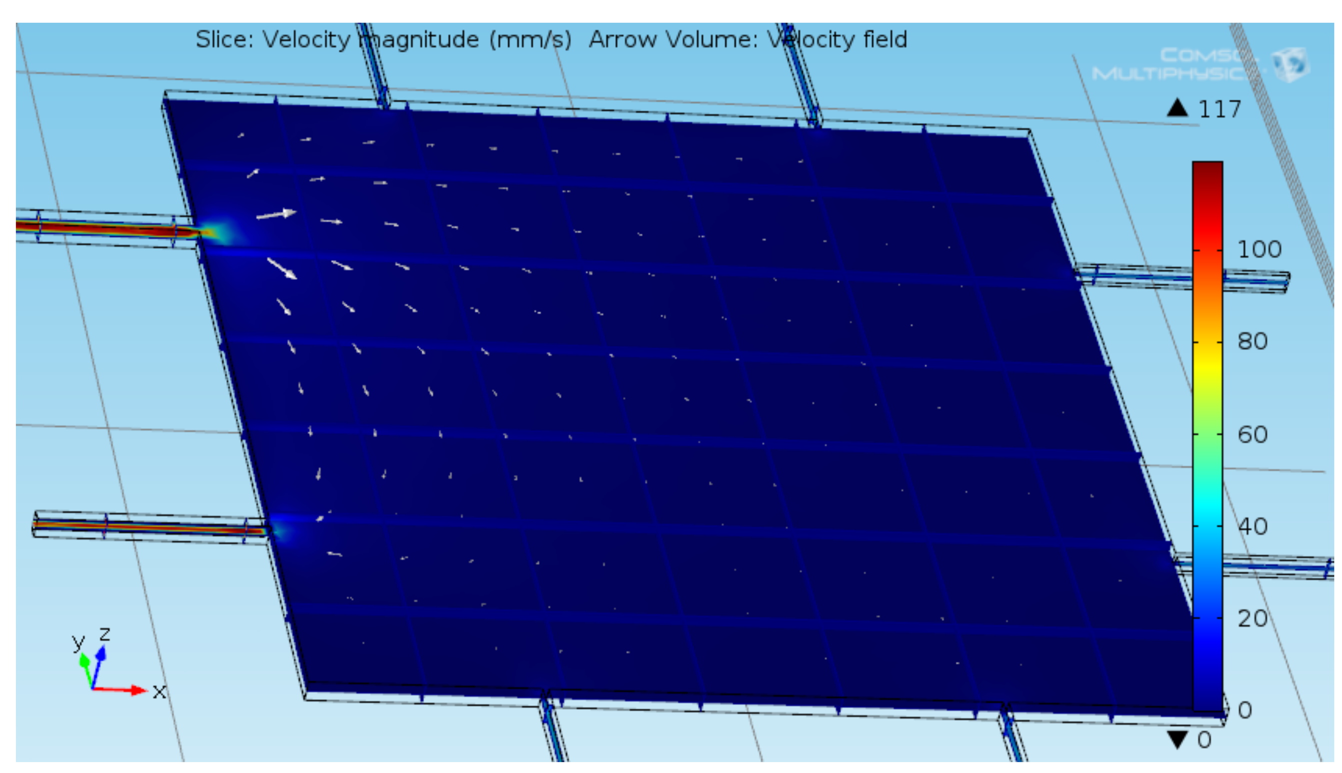


Fig. 3. COMSOL simulatio of velocity filed of microfluid inside dispenser

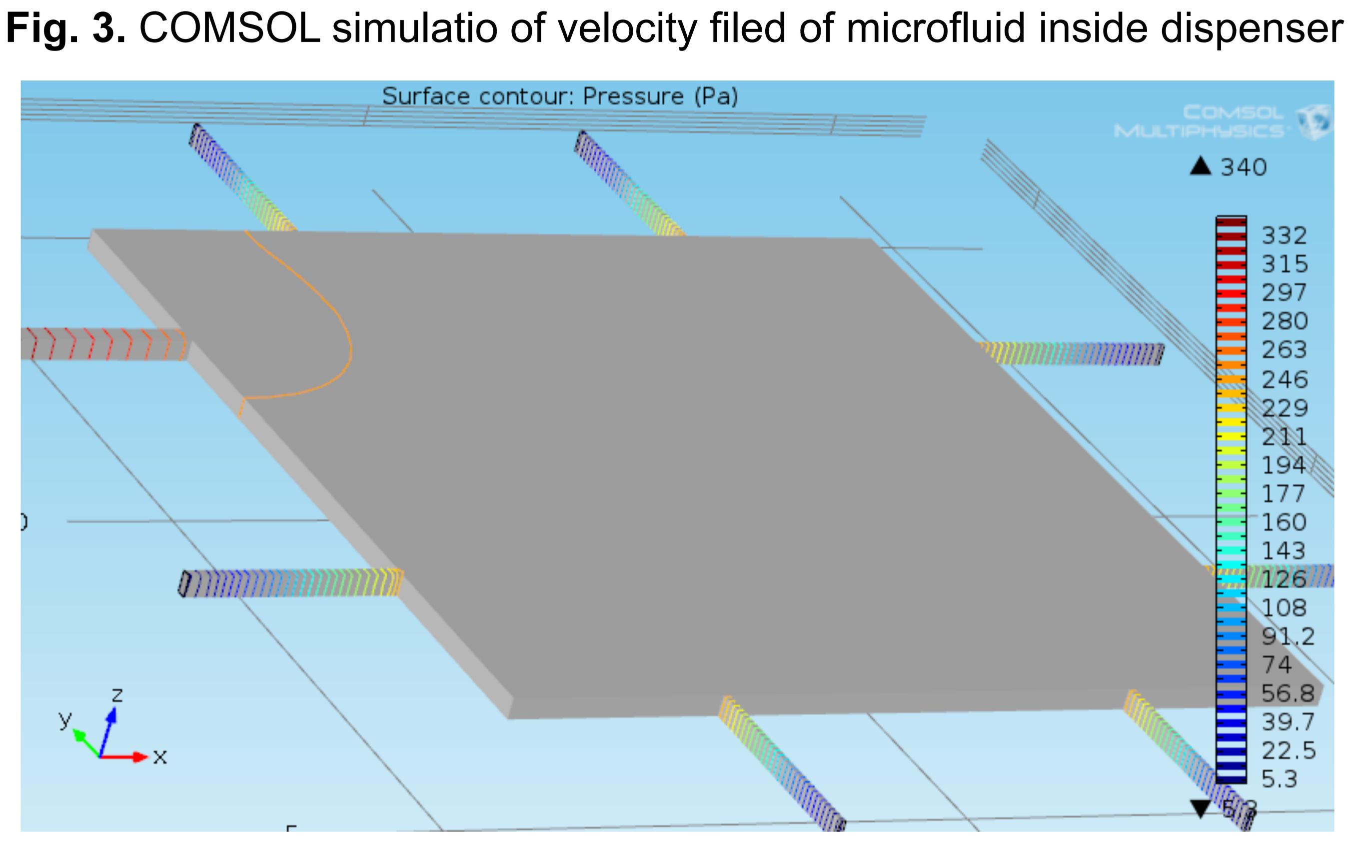


Fig. 3. COMSOL simulatio of pressure distribution inside the dispenser

Conclusion and Future Work

In this poster, a high-throughput microfluidic droplet dispenser for Lab-on-a-Chip application is proposed. The structure and the working principle of the device is analyzed. COMSOL multiphysics is used to simulate performance of this device. The research of the device is still in early stage and we will continue to improve the device in the future.

Reference

[1] Song et al, "A scaling model for electrowetting-on-dielectric microfluidic actuators", Microfluidics Nanofluidics Research Report, Nov. 12, 2008.