Design and Simulation of High-Throughput Microfluidic Droplet Dispenser for Lab-on-a-Chip Applications

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Abstract

Introduction: Due to its low cost, high efficiency and high resolution, Digital Microfluidic Biochip (DMFB) has been widely used in Lab-on-a-Chip (LoC) for disease diagnosis and treatment applications. However, traditional microfluidic samples in front-end of Lab-on-a-Chip devices are generally analog continuous flow. In order for it to be processed by digital microfluidic chip, a droplet dispenser acting as an analog-to-digital converter is needed. To speed up the conversion process, a high-throughput which can simultaneously dispense multiple droplets in parallel is needed.

In this paper, a high-throughput microfluidic droplet dispenser used to convert analog microfluidic flow into digital droplets is proposed. It can simultaneously dispense multiple droplets from analog flow. 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 applications. 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 [1]. The proposed dispenser can overcome such problems. The working principle of the microfluidic droplet dispenser is analyzed. A COMSOL Multiphysics® model (after meshing) of the dispenser is shown in Figure 1. The analog flow from the inlet (cylinder shape) is converted to digital droplets via electrowetting. In this device design, the parallel output electrode channels are cross activated for high throughput. More parallel channels are possible to achieve even better throughput.

Use of COMSOL Multiphysics: A COMSOL® simulation is used to verify the function of the droplet dispenser. In this work, we used the Laminar Two-Phase Flow, Level Set (tpf) physics interface to simulate the movement of the droplet on the EWOD.

Results: A set of optimized design parameters of the droplet dispenser are achieved. Results of

the COMSOL simulation (volume fraction of water) are showed in Figure 2. The comparison of volume flow of two different activation schemes (parallel and cross activation) is shown in Figure 3 and 4 respectively. The results show that cross activation strategy leads to more stable droplet dispensing.

Conclusions: In this paper, the design and simulation of a high-throughput analog-to-digital microdroplet dispenser for Lab-on-a-Chip application is proposed. The proposed droplet dispenser has multiple output electrode channels. Taking analog fluid flow as input, it can quickly convert it into multiple digital droplets for DMFB (digital microflulidic biochip) processing. COMSOL software is used to understand the mechanism of dispensing and verify the function of the dispenser. Simulation result shows the designed droplet dispenser can quickly dispense digital droplets from analog flow for DMFB processing.

Reference

[1]. C. Wu, et al., "Analog to Digital Microfluidic Converter", Proceedings of the 2009 European COMSOL Conference, 2009.

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[3]. J. H. Song, et al., "A Scaling Model for Electrowetting-on-Dielectric Microfluidic Actuators", Microfluidics and Nanofluidics, 2009, Vol. 7, pp. 75-89.

Figures used in the abstract

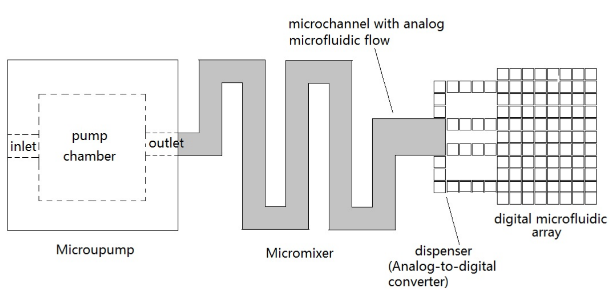

Figure 1: Design of high-throughput microfluidic droplet dispenser (analog-to-digital converter).

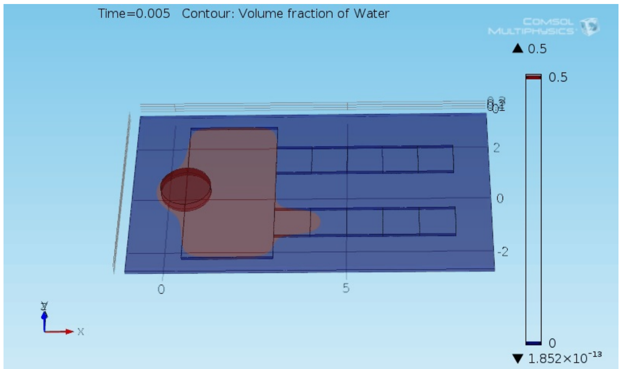

Figure 2: COMSOL simulation results of droplet dispensing.

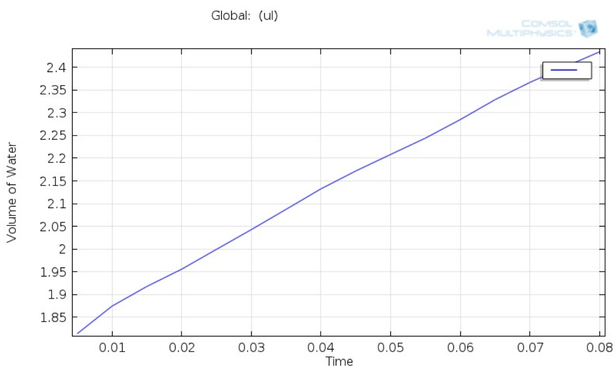

Figure 3: Simulated fluid volume change for parallel dispensing scheme.

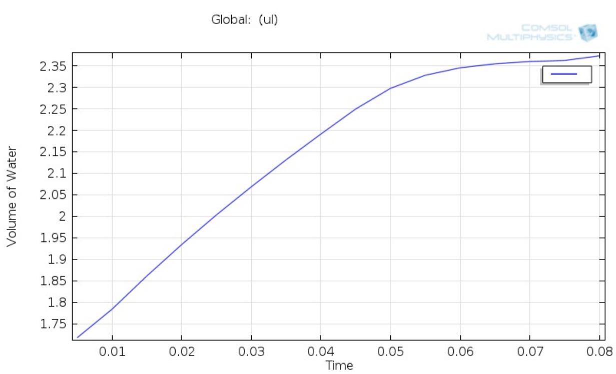

Figure 4: Simulated fluid volume change for alternate dispensing scheme.