AUTOMATED ELECTROWETTING BASED DROPLET DISPENSING WITH GOOD REPRODUCIBILITY

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ABSTRACT

Electrowetting based droplet on-chip dispensing is presented. On-chip reservoir and droplet formation channel are designed to facilitate droplet creation. The mechanism and conditions in which droplet can be formed are analyzed. The droplet volume variations are tested over a range of interfacial tension and number of pinch off electrode. The results show that droplet volume reproducibility is degraded significantly when liquid-oil interfacial tension is reduced. And droplet volume is a function of number of pinch off electrode and the timing of control sequence.

Keyword: droplet dispensing, electrowetting, volume reproducibility

INTRODUCTION

Electrowetting refers to the modulation of interfacial tension by electric field. It can be used to manipulate unit droplet in digital microfluidic [1]. Electrowetting based droplet on-chip dispensing was first demonstrated in [1,2]. By activating electrodes successively at the liquid front followed by deactivating the electrodes behind and activating electrodes in the reservoir to retract the liquid, droplet pinch-off is accomplished. The paper presents the analysis and performance of the droplet on-chip dispensing

DESIGN AND ANALYSIS

To assist the droplet formation, a physical boundary of on-chip reservoir and formation channel is defined by a gasket layer on the bottom plate of electro-wetting chip. The boundary can restraint the liquid spreading during droplet formation process, on the other hand, it facilitates the conformation of liquid front to the electrode dimension, making it possible to generate uniform size droplets. The electrodes design makes sure that there is an overlap of electrodes between these in reservoir and channel so that minimum dead volume would be left in the reservoir and the control sequence for liquid protrusion formation could be predictable. The chip is shown in Figure 2.

Successful droplet formation includes two parts: finger formation and droplet pinch off. To be able to form a finger, the electro-wetting force has to overcome the pressure difference caused by curvature difference between the reservoir and the finger front.

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Mathematically,

$$\frac{1}{R_1} - \frac{1}{R_2} + \frac{\varepsilon_0 \varepsilon}{2\gamma_{LO} td} V^2 > 0$$

Where R_1 and R_2 are the radius of curvature of reservoir and liquid front respectively. Figure 1 show the estimated effect of pitch size on the minimum required actuation voltage to induce protrusion of 0.1M KCL solution from reservoir of 2mm radius, contact angle hysteresis is taken into account for the effect of threshold voltage.

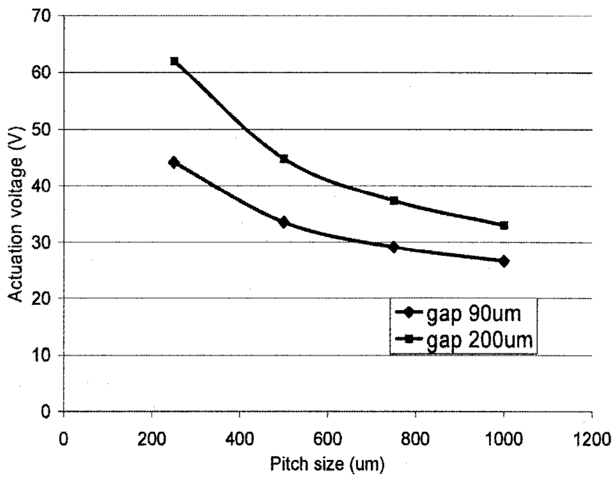

Figure 1 The estimated effect of pitch size on the minimum required actuation voltage to induce protrusion of 0.1M KCL solution from reservoir of 2mm radius with contact angle hysteresis taken into account for the effect of threshold voltage.

It suggests that to dispense droplet from on-chip reservoir sandwiched between two plates, there is a limitation of the minimum droplet size that can be created under specified actuation voltage. Also, small gap is favorable to finger formation.

RESULTS AND DISCUSSION

Figure 2 show the time sequence of 0.1M KCL droplet formed from an on-chip reservoir. Dispensing performance is tested for a variation of pitch size (500um,750um) and gap (90um,200um), the effect of pitch size on the minimum required actuation voltage shown in figure 2 is consistent with experiment observation. When the channel width defined by the gasket layer is scaled down to around 200um, it is difficult to induce protrusion. It also shows that the droplet volume and volume reproducibility are subject to the variation

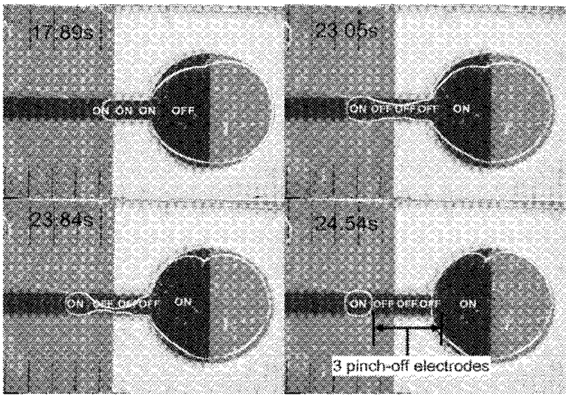

Figure 2 - Droplet of 0.1M KCl solution with 0.01% Triton-X dispensed from on-chip reservoir of 4mm diameter into the channel of 750μm pitch electrode

of pinch-off electrode number, liquid-oil interfacial tension and time sequence of pinch off process.

Effect of interfacial tension on droplet volume variations. Different solutions with varying interfacial tension are tested to investigate their effect on droplet volume and volume reproducibility. Surfactant Triton X-100 with 0.01% or 0.1% concentration is added to the 0.1M KCL solution to vary the interfacial tension. The interfacial tension between water and mineral oil with no surfactant, 0.01% and 0.1% Triton X are 52,10,2.5 dynes/cm respectively. It presumes a similar change of interfacial tension between KCL solution and silicon oil. For 0.1M KCL solution, 17 sample droplets were generated sequentially under 55V voltage in a fully automated manner, while 8 and 6 droplets were generated for KCL solution with 0.01% and 0.1% Triton X. The measurements of volume are shown in Figure 3. The reproducibility are 3%,12% and 15% respectively for simple 0.1M KCL solution, KCL with 0.01% and 0.1% Triton-X respectively. It suggests that reducing the interfacial tension between liquid and oil tend to degrade the volume reproducibility. Presumably, it is due to the factor that solution with small interfacial tension is easy to be affected by variation of the initial condition and the timing of control sequence. .Another observation is that larger droplets tend to be generated when interfacial tension is small.

Effect of pinch-off electrode on the droplet volume variations. It shows that droplet volume is subject to the variations of the number of pinch off electrodes. The mean volume is 73nl and 53nl respectively for droplets of 0.1M KCL solution generated with three and two pinch-off electrodes.

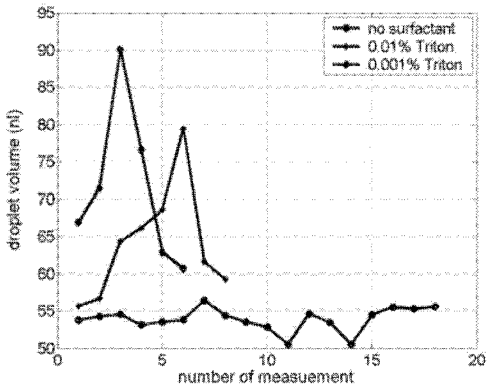

Figure 3. Droplet volume variation with varying solution of interfacial tension and number of measurement

Effect of timing sequence on the droplet variations. It is observed that the time and control sequence used to induce protrusion and eventually pinch off droplet also affect the droplet volume.

CONCLUSION

Electrowetting based droplet on-chip dispensing is presented. The dispensing process starts with the protrusion formation where liquid column is induced from reservoir by energizing a sequence of electrodes, then droplet is formed by deactivating intermediate electrodes and activating electrode in the reservoir to retract liquid. The mechanism of the dispensing process determines that there is a limitation on the minimum size of droplet that can be generated under specified actuation voltage, since the protrusion formulation requires that certain voltage is needed to overcome the pressure difference caused by curvature difference. Droplet volume reproducibility is tested over operational parameters such as liquid oil interfacial tension, the timing of the control sequence and number of pinch off electrodes. It indicates that when interfacial tension is reduced, volume reproducibility is degraded. The volume variation is also a function of number of pinch off electrodes and the timing of control sequence.

REFERENCE

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