Inertial Dispensing Mechanism for Droplets On Chip

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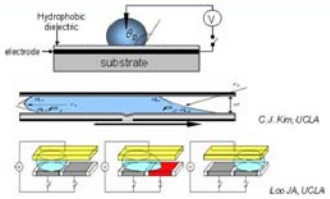
Abstract

The research presented here explores dispensing of droplets for digital microfluidic lab-on-a-chip applications using inertial force. ElectroWetting-On-Dielectric (EWOD) is an attractive underlying actuation mechanism that allows microfluidic operations such as moving, cutting, merging, and creating droplets on chip. More applications are possible if processed droplets can be printed from the chip onto another surface, likely a target substrate. An existing printing technology demonstrated with EWOD chip is known as soft printing, where the EWOD chip is lowered until the droplet contacts the target surface, causing the droplet to be transferred to the surface without any solid-to-solid contact. But soft printing is limited by the inability to print onto rough or uneven surfaces; our new device overcomes these limitations by avoiding the solid-liquid-solid interface. The basic principle behind our droplet dispensing mechanism is to provide a pattern of acceleration and deceleration to the droplets such that inertial force can overcome adhesion force, resulting in droplet detachment from the device. To obtain the pattern of acceleration necessary for droplet dispensing, we explored different types of experimental setups including piezoelectric stack actuator, solid-to-solid impact, and mechanical stop. The dynamics of droplet detachment were analyzed using a high-speed video camera. The displacement, velocity, and acceleration characteristics of the stage housing the EWOD were obtained. This new way of dispensing droplets might open up new application possibilities in nanotechnology and biomedical areas.

Background



Principle of EWOD

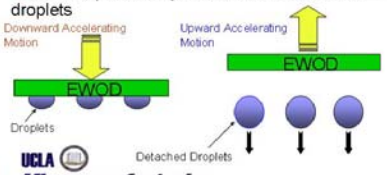
- Manipulation of the surface tension using electric potential
- The contact angle of the droplet can be changed, which creates differences in pressure to drive a droplet in a particular direction

Advantage of using EWOD

- Discrete volume and precise concentration control
- Less complex than continuous-flow microfluidic device (NO mechanical moving parts)
- Lower reagent consumption and fast reaction time

Principle of printing droplets from EWOD

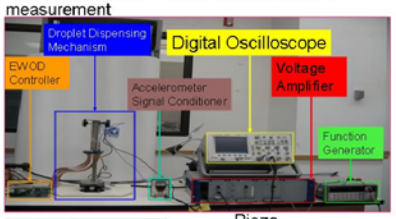
- Surface tension, which is the dominant force in micro scale, prevents droplets from detaching from the nozzle
- Needs to provide a pattern of acceleration to the droplets

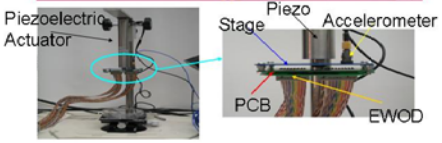


Methods

Piezoelectric stack actuator

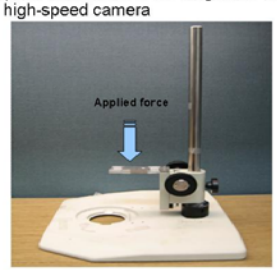
- Design a platform to hold the piezo actuator and a stage to mount the EWOD onto the piezo
- Drive the piezo actuator with a square wave to generate the maximum acceleration
- An accelerometer is used for acceleration measurement





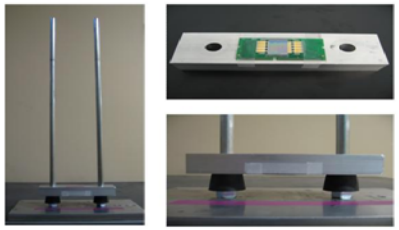
Solid-to-Solid Impact

- An EWOD device is attached to the underside of the aluminum bar which is held fixed to the platform
- An impact force is applied directly above the bar
- Capture the motion of the stage and droplets with high-speed camera



Mechanical Stop

- A glider setup was built
- Rubber material was used as a mechanical stopper
- Drop glider from different height
- Capture the motion of the stage and droplets with high-speed camera



Results and Discussion

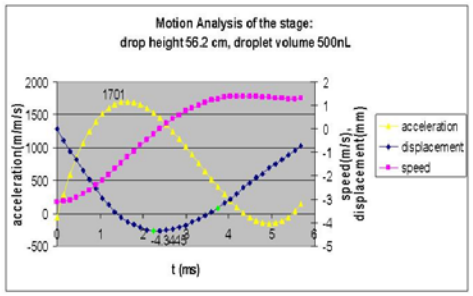
Piezoelectric stack actuator

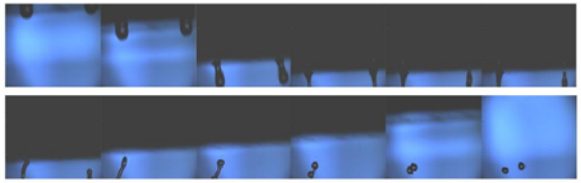
- Droplets do not print
- Acceleration of the piezo has no significant effect on the droplets (initial downward acceleration is approximately 2 to 4 G's)
- When piezo is driven at high frequency, we observe minimal vibration in the droplets (maximum acceleration difference ~ 20 G's)

Solid-to-Solid impact

- Droplets can be printed
- Difficult to determine the force being applied as it varies from trial to trial
- Stage rebounds back down to hit the droplet in the act of detaching
- Cantilever effect

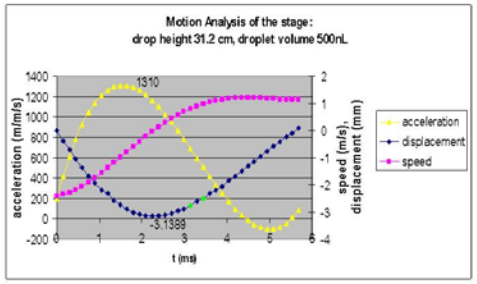
Mechanical stop

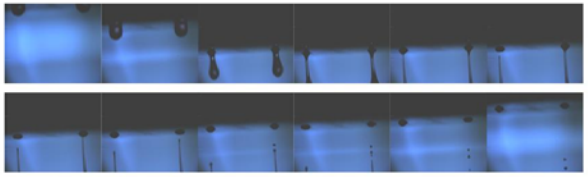




High dropping distance (case: 56.2 cm)

- Larger impact force → droplet detachment at solid-liquid interface occurs before completion of necking and droplet splitting
- Most of the droplet is transferred from the nozzle to the target substrate
- Because the system has more energy and a larger impact force, errors due to setup flaws are more pronounced (i.e satellite droplets scatter farther)





Low dropping distance (case 31.2 cm)

- Less impact force → longer necking → droplet splitting without complete detachment at solid-liquid interface
- Droplet residue at the nozzle
- Preliminary results suggest satellite droplets are more precise (landing in the same spots as the main droplets)


3 printed droplets (Height = 56.2cm)


3 printed droplets (Height = 31.2cm)


3x3 array (Height = 39 cm)


Letter M (Height = 41.2 cm)

Future Works

- Improve on the design of the mechanical stop
- Experiment with different actuators which can provide similar pattern of acceleration required for droplet printing
- Study how different volumes of droplet affect printing
- Study the difference in the dynamic of the droplets in relation to the acceleration applied to the stage

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