Microelectrodes for Microdroplet Motion Based On Electrowetting: A Review on Design

ABSTRACT

The technology is growing rapidly whereby the researchers all over the world have discovered the smaller scale of technology. In micro-nanotechnology, the microfluidic manipulation become useful in many field of applications and one of the most advanced method is electrowetting. The observation and review on the design of microelectrode for droplet motion based on electrowetting with different shapes, sizes and fabrication regarding on the different application are hereby reported.

INTRODUCTION

Electrowetting principles applied to very small amounts of liquids on solid surfaces whereby the scale can be reached up to nanoscale. Electrowetting principally controls the wettability of liquids on solid surfaces using electrical potential. The fabrications of solid surfaces and applied electric potential have a big role in determining the effectiveness of the electrowetting. In order to manipulate the microfluidic droplet, the microscale tools are needed such as microelectrodes, microvalves, microspinner and microspray. These tools used to supply the charge of electric potential to the droplet whereby it can control the hydrophobic and hydrophilic of droplet. In many studies of electrowetting, the type, shape and size of microelectrodes designed must be examined before the start of experiments.

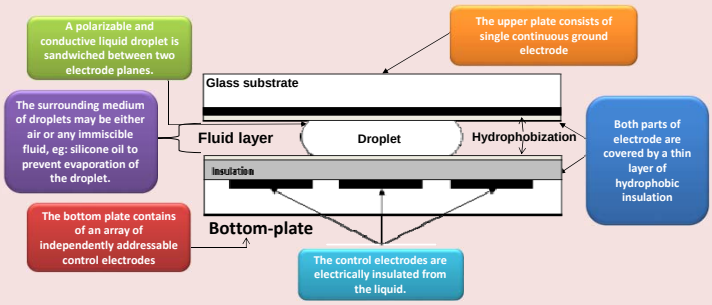
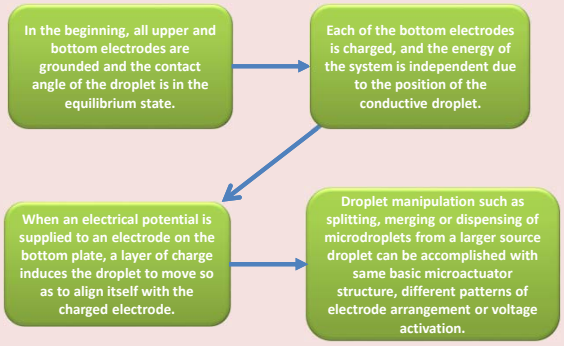


Figure 1: Schematic diagram of electrowetting on dielectric (Pollack, M. G. et al. (2000) Applied Physics Letters, 77(11), 1725-1726).

Flow of operation:



- Pollack et al. investigated the effect of different parameters such as electrode pitch, channel height, applied voltage and surrounding media on the droplet movement.
- In addition, analytical and numerical studies have been performed to clarify and strengthen the empirical results. Several researchers focused on derivation of equations for the droplet in the equilibrium condition placed on a substrate .
- Nadim developed the mathematical models to estimate the magnitude of forces and velocities achieved by electrowetting.
- Numerical investigation of electrowetting in microchannels was conducted by Arzpeyma et al. to simulate behaviour of droplet under electrowetting actuation.
- Another numerical study has been performed to verify the effect of adding the dynamic contact angle model by Motamed et al.
- Current research focus on the analysis of droplet behaviour when actuated with different electrode shapes.

METHODOLOGY

A review on a study of electrowetting device, electrical microfluidic manipulation and electrowetting on microelectrode is done in order to sort out the significant and importance of the electrode design in microdroplet motion based on electrowetting.

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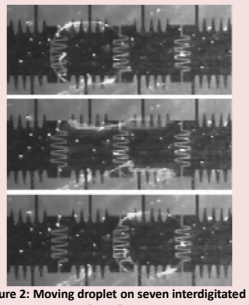

Figure 2: Moving droplet on seven interdigitated (Pollack, M. G. et al. (2000) Applied Physics Letters, 77(11), 1725-1726).

A designed prototype device fabricated and tested that consist of a single linear array of seven interdigitated control electrodes at a pitch of 1.5mm. The control electrodes were formed by patterning a 2000-Å-thick layer of chrome on glass using standard microfabrication techniques. Droplets (0.7–1.0 µl) of 100 mM Potassium Chloride, KCl were dispensed onto the array. Moving droplets are imaged from the top looking through the ITO ground electrode at 33ms intervals. In the first frame 80V is applied to the electrode which right underneath the droplet, whereby adjacent electrode is grounded. In the next frame, the charged electrode has been switched to the adjacent electrode and current charged electrode is grounded. The switching charged electrode makes the droplet moving continuously until the last charged electrode.

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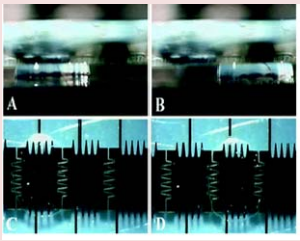

Figure 3: Moving droplets are imaged from side views (a), (b) and top view (c), (d) at 66ms interval. The side-view image is seen through the air, while the top-view is seen through the transparent ITO ground electrode is bathed Si oil (Pollack, M. G. et al. (2002) Lab Chip, 2(2), 96-101).

A 800-nm-thick film of parylene C was included to provide insulation all over the control electrodes and both top and bottom plates which had a 60-nm-thick top-coating of Teflon AF 1600. The control electrodes were patterned in a 200-nm-thick layer of chrome on a glass substrate using standard microfabrication techniques and the top-plate consisted of a glass substrate coated with a conducting layer (RS < 20 Ω/square) of optically transparent indium tin oxide (ITO) to form the ground electrode. The droplet transfer process is shown in this Figure 3 for a 900 nl droplet of 0.1 M KCl solution with electrode pitch L = 1.5 mm, gap spacing h = 0.3 mm and droplet diameter D = 1.9 mm.

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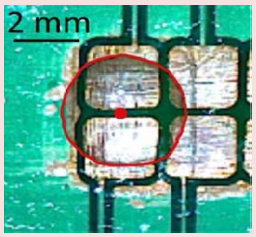

Figure 4: An imaged of the EWOD electrodes and a 3.5 µl droplets bridges the electrode pair (Li, Y. et al. 2014).

The capacitive sensor is fabricated using a standard (FR-4, glass epoxy) double-sided PCB process (Advanced Circuits, Tempe, AZ, USA). The electrodes are 2.3 mm x 2.3 mm square bare copper spaced 0.3 mm apart as seen in the Figure. A plastic layer (15µm thick Saran Wrap) is used as the dielectric layer for the electro-wetting device. This designed electrode is operated pairing together with the above and below electrode.

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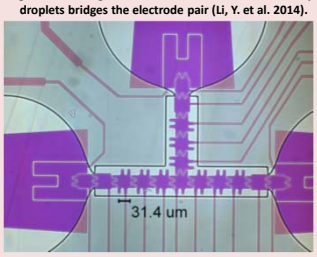

Figure 5: 5: 33µm electrode design with rounded interlocking fingers of 18µm long, 6µm wide, and 3µm spaces between electrodes (Lin, Y. Y. et al. (2012) Sensors and Actuators B: Chemical, 173, 338-345)

The electrode size in Figure 5 was designed in micro-scale width (L) of 33µm, with an 18µm base and 6µm round interlocking shapes. A 3µm space is used between electrodes because of the photo mask limitation of 3µm features. The reservoir electrode was designed with a trapezoidal shape with wide margins toward the neck, which provide larger wetting area, to provide more force and improve the droplet dispensing from the reservoir. The neck electrode was slightly larger than the channel electrodes with three fingers on the opening side, allowing for a bigger overlapping area, which contributed in a larger electrowetting force. The reservoir neck opening helped to focus the extracted liquid finger and to assist pinch off of the liquid at the neck during liquid dispensing from a reservoir.

FINALLY

DESIGN:

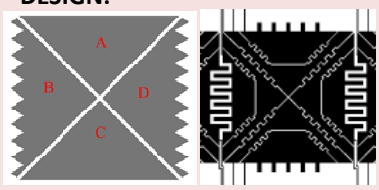

Figure 6: (Left) Part of the new electrode design consists of 4 triangle electrodes with the names of A, B, C and D. (NAM Yunus et al., JESTEC Oct 2014). (Right) The mask of more electrodes (On-going).

Our proposed design is to develop and refine the fundamental liquid handling such as concentrating, merging splitting, separating and moving the droplet techniques on electrowetting platform of LoC device by providing a high aspect of precision, reproducibility, multi-volume transportability and controllability of droplet manipulation. The device consists of 4 triangle shapes, which constitute the unit square electrode shape as shown in Figure 6. The dimension of unit-sized electrode pitch is designed in 1 mm while the gap between each inner electrode is 10 µm and the gap between each square are 25 µm. To avoid droplet stranding over the electrode areas, a few interlocking dents are designed between the inner electrodes and a unit-sized square electrodes. This is based on the analytical model proposed by J Berthier and C Peponnet (2006) and the work shown in Figure 5.

CONCLUSION

The role of the electrode shapes in electrowetting operation is observed and reviewed, which it can control the microdroplet motion; manipulate the droplet structure such as splitting, merging and transporting. Additional, the electrode shape can determine the wettability of the plate surface, which it must, corresponds with the objective of the experiment carry out. In this paper, there are a few designs and specifications of electrode shape based on its own application.

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