

T-Shape Electrode Design for an Open Type Electro-Wetting on Dielectric

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Abstract. *This work proposes the electro-wetting on dielectric (EWOD) design for manipulating the movement of 5 microliter DI water droplets on a T-shaped electrode layer. The fabrication methods for open-type EWOD are mentioned in detail. With the attached voltage and frequency control equipment, the created EWOD device could precisely manipulate the droplet movement on top of the device as expected.*

Keywords:

Open Type EWOD, Electrode, Manipulation of Droplet, Electro-Wetting on Dielectrics

1. Introduction

An open typed electro-wetting on dielectric (EWOD) device can manipulate and control the movement of droplets as small as micro to nano liters by utilized the induce electrical force between two parallel electrodes to disturb the wet contact angle of droplets; thus causing the droplet to morph and move in Fig 1. An open type EWOD device is composed of substrate layer, positive and negative electrode layers, dielectric and hydrophobic layer as shown in Fig. 2.

Because of the structure is not complicate and the ability to manipulate tiny droplets, an open typed electro-wetting on dielectric technique is widely used in many applications especially in biochemical engineering (-i.e. in Lab on a chip PCR [1], enzyme assays [2] and proteomics [3] in mechanical micro-actuation [4] and on-chip cooling for electronics circuit pad [5]. The common EWOD fabrication is composed of three processes: the fabrication of electrode layers by light photolithography and sputtering technique, fabrication of dielectric layer by spin coating, and fabrication of hydrophobic layer by Teflon-AF spin-coating. In this work, silver due to its high electrical conductivity and cheap prices was used to replace the precious materials [6] such as gold [7] and platinum [8] to create the electrode layer. The paralleled positive and

negative electrodes in Fig. 1 are the crucial component used to create the induced electrical force. Parylene [9] and Polydimethylsiloxane [10] are two materials with high dielectric constant and are commonly used to create the dielectric layer. The hydrophobic characteristics of EWOD surface are normally created by spin-coating of Teflon-AF [11], which can improve the wet contact angle of the droplet to be greater than 110 degrees.

In this work, the suitable electrode design for manipulate the liquid droplet with the volumetric size of 5 microliter was designed to have T-shaped pattern in order to demonstrate the capability of EWOD devices to move the droplet in 90 degree turn condition. The fabrication of such device is mentioned in details.

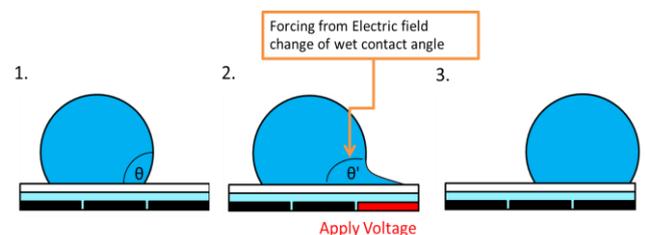


Fig. 1: the droplet movement on an open typed electro-wetting on dielectric (EWOD)

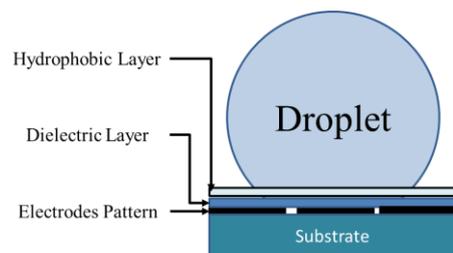


Fig. 2: configuration of an open-type EWOD device

2. EWOD Fabrication

An open-type electro-wetting on dielectric device is composed of three layers: first is the silver electrode layers deposited on top of a glass substrate. Second is the dielectric layer and finally is the hydro-phobic layer. The fabrication steps could be done as follows.

2.1 Fabrication of electrode layers

2.1.1 Design of electrode layout on top of light protecting mask for photolithography

In this step, the size of electrodes and gap between each electrode must be appropriately designed to match the droplet size. Of course, the tiny electrodes cannot handle large droplets, while the oversize electrodes cannot create the appropriate connection of electrical field between two adjacent electrodes. Therefore, the size of each electrode depends directly on the size of wetted area of liquid droplet with spherical shape as in Fig. 3. The relation between the wetted area (the cut-sphere area) and the electrode area is shown in Eq. (1),

$$V_{cutsphere} = (\pi/3)h^2(3r-h) \quad (1)$$

Figure 2 also shows the geometrical relation of the droplet wetted on top of a flat surface as follows,

$$h = \frac{L_1}{\sin \theta_A} - \frac{L_1 \cos \theta_A}{\sin \theta_A} \quad (2)$$

and

$$r = \frac{L_1}{\sin \theta_A} \quad (3)$$

Therefore,

$$h^2(3r-h) = \left[\frac{L_1^2}{\sin^2 \theta_A} (1 - 2 \cos \theta_A + \cos^2 \theta_A) \right] \left[\frac{L_1}{\sin \theta_A} (2 + \cos \theta_A) \right]$$

,which can rewrite as

$$h^2(3r-h) = \frac{L_1^3}{\sin^3 \theta_A} (1 - \cos \theta_A)^2 (2 + \cos \theta_A) \quad (4)$$

Substituting Eq. (4) into (1) leads to

$$L_1 = \sin \theta_A \sqrt[3]{\frac{3V}{\pi(1 - \cos \theta_A)^2 (2 + \cos \theta_A)}} \quad (5)$$

By using Eq. (5) to design the electrode size for handle 5 micro-liter droplets with wetted contact angle of

110 degree, we have the wetted area radius of 1.16 mm or the wetted area of 4.22 square-millimeters, while leads to the electrode size of 2.05 mm as demonstrated in Fig. 4.

The suitable gap size between two adjacent electrodes can be selected from the relation in Fig. 5 [12]. In this work, the ratio between gap size and electrode size is kept at 5% and applied voltage should be use between 120-500 V to avoid the dielectric breakdown.

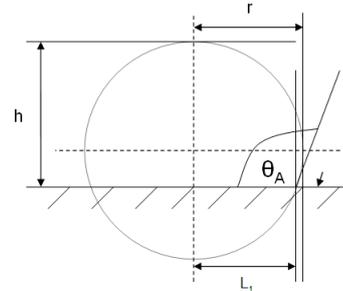


Fig. 3: the geometrical relation of wetted area for spherical shape droplets

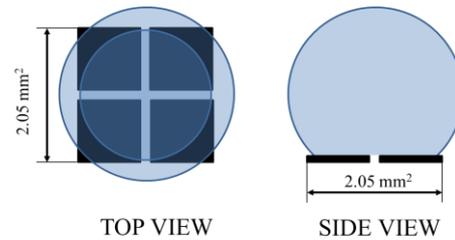


Fig. 4: the selected electrode size

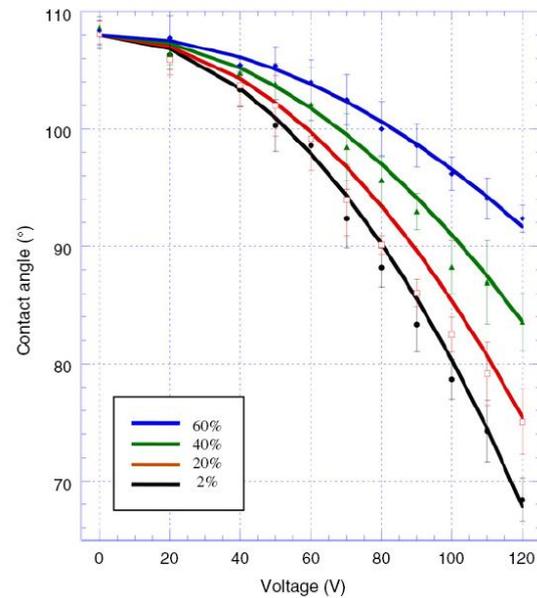


Fig. 5: the relation between wetted contact angles and required applied voltage at various ratios of gap and electrode sizes [12]

From the geometrical relation as mentioned, the light protecting mask for photolithography was created as shown in Fig. 6, given that the gap size is 50 micron and the electrode size is 1 mm.

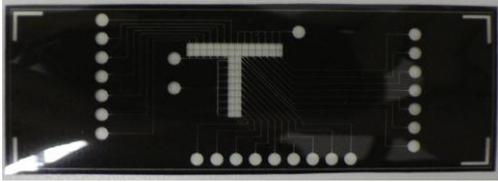


Fig. 6: the designed light protecting mask for photolithography

2.1.2 Creating the electrode layout

In this work, a glass slide was used as the perfect substrate. The light sensitive AZ film (liquid photoresist) with 10 micron in thickness was coated on the glass slide by spin-coating at 1,250 rpm for 30 seconds. After spin-coating to create the AZ film, the designed light protecting mask was attached to on top of the film. The UV light was then applied on the mask aligner machine for 3 seconds. Then the AZ solvent was applied; thus leaving the electrode layout on top of the glass slide as shown in Fig. 7.

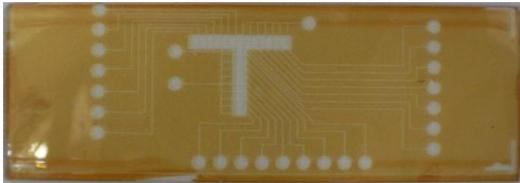


Fig. 7: the electrode layout on top of glass slide

2.1.3 Creating electrodes by sputtering

To deposit silver on top of glass slide, chromium was selected as bonded material between silver of 99.995% pureness and glass surface. The silver media was coated with chromium before sputtering on glass slide in order to prevent the oxide layer between silver and chromium. The duration for sputtering was set at 30 min to create the silver electrode with the thickness of 3 microns. After completing the sputtering process, the un-desired deposited silver was cleaned by acetone in ultrasonic bath. The complete electrode layer is presented in Fig. 8.

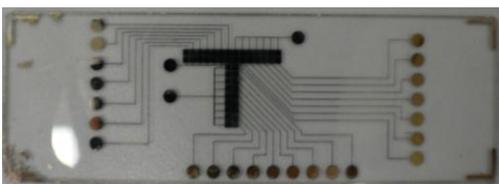


Fig. 8: the created silver electrode

2.2 Fabrication of dielectric layer

Polydimethylsiloxane (PDM) prepared by mixing silicon elastomer base with silicon elastomer curing agent with the ratio 10:1 was spin-coated on the electrode layer at 4,000 rpm for 30 seconds by spinner. Then the coated glass slide was baked on heat plate at 95°C for 60 min. The 5-7 µm polydimethylsiloxane layer was left to be dielectric layer.

2.3 Fabrication of hydrophobic layer

Teflon AF was spin-coated at 1,000 rpm for 30 second to create hydrophobic layer with the thickness of 100 nm. To stabilize the layer, the coated glass slide was baked on a heat plate at 95°C for 60 min and. The Teflon coated surface could provide the large wetting contact angle of droplet, thus increasing the hydrophobic property of the surface and reducing the surface tension of the droplet. After completing the fabrication of hydrophobic layer, the created EWOD device is ready for manipulating droplet movement.

3. Component of EWOD Controlling Devices and Testing Conditions

EWOD controlling devices are composed of three important devices connecting in series as in Fig. 9. Those three devices are

1. Function/Arbitrary Waveform Generator
2. Power Amplifier
3. Switching Transformer

The EWOD device was tested at the supplied frequency of 400 Hz and at the voltage of 250 V. (The testing conditions comply with a relation between Viscosity of droplet and minimum applied voltage required to manipulated droplet [13] as show in fig.10.) A size of DI water droplet was 5 µL.

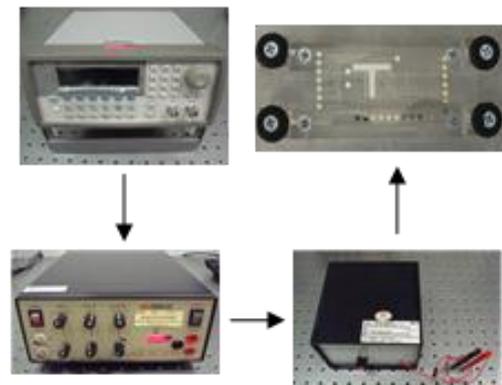


Fig. 9: diagram of EWOD controlling devices

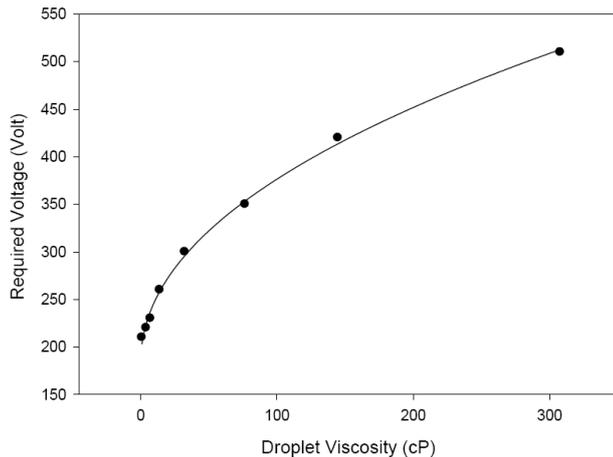


Fig. 10: the minimum applied voltage required to disperse diluted viscous liquids [13]

4. Test Results

The created T- shape open type EWOD device with silver electrodes as shown in Fig. 11 was under experimental test. During the test, a DI water droplet was applied and moved along the T shape configuration of EWOD device.

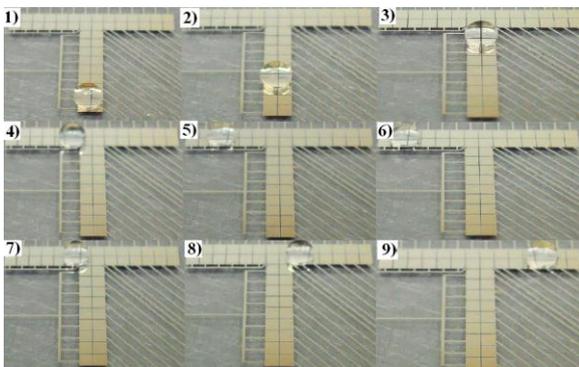


Fig. 11: water droplet movement on top of created EWOD device

5. Conclusion

Figure 11 shows the effectiveness of EWOD device to move 5 microliter DI water droplets along the electrode shape. The device could successfully move the droplet to the left and right direction of the T-shaped junction.

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