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# Digital Microfluidics Platform for Handling Sample Delivery of Enzymes using COMSOL Multiphysics 4.3a

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*Abstract:* **Enzymes are essential for our body to work efficiently. Enzymes are certain type of protein and these behave as catalyst in our body. But certain time enzymes are need to deliver at a particular site and perform there function so we need a certain mechanism or device to deliver them at that location. Here Digital Microfludics (DMF) is all about sample delivery of enzymes using COMSOl. to understood the enzyme delivery here we will perform the operation on a single droplet.**

## 1. INTRODUCTION

MEMS based devices have ability to rapidly analyse chemical and biological specimens. And these are small, inexpensive and portable devices that will make a significant impact in the fields of healthcare, the environment. Digital microfluidics is a fluid-handling technique in which discrete liquid droplets are manipulated on an array of electrodes.[1] In this technique, droplets serve as microreactors and can be used to implement low-volume biological applications. Digital microfluidics has the capacity to precisely control the position of many different reagents simultaneously, because it does not suffer from unwanted hydrostatic or capillary flows. There are two digital microfluidic device formats: two plate[2] closed devices and single-plate open devices. In two-plate devices. which are more common, droplets are sandwiched between two substrates; the bottom one carries the actuation electrode array while the top one comprises the ground electrode[4]. In single-plate devices, droplets are actuated on a single substrate that carries both the actuation and grounding electrodes. But the main disadvantage of the single-plate device is that if we need to dispense the droplet it can't dispense the droplet but this can be performed by the two plate devices.[4]

Since there is no predefined geometry for positioning ground electrodes relative to actuation electrodes in single plate devices, a wide range of designs employing different strategies have been reported. Changing the position of the grounding electrodes/wires on the device will change the intensity and distribution of the electric field in the vicinity of the droplet, which, in turn, should change the actuation force on the droplet and the maximum droplet speed that can be achieved. However, until now, there have been no studies on the optimum design of such devices.

Now the question arises how to manipulate a droplet in the digital microfluidics. Electro Wetting Of Dielectric (EWOD) is the solution of this. The principle of EWOD process is based on control of surface tension of a liquid-solid interface by applying electrical potential at the interface.

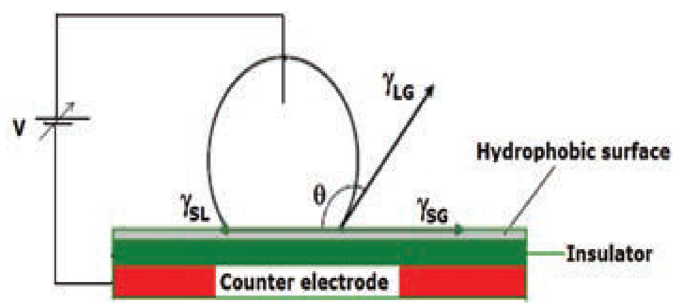


**Figure1. Single plate DMF**

A polarizable and conducting liquid droplets placed on a substrate with a dielectric hydrophobic layer on top of the electrode. By applying an electric potential upto 35 volt between the droplet and counter electrode, contact angle reduces due to effective changes of solid-liquid interface. energy [6] . This change in contact angle creates a pressure gradient across the droplet which drives the droplet toward the actuated electrode.

## 2. SELECTION OF MATERIALS AND DEVICE FORMATION

The standard DMF device is formed on a 400 um borofloat glass. This is followed by a 140 nm Chromium layer which is patterned to electrode arrays. The dimension of control electrodes are 2.2 x 2.2 $mm^2$ with a 30 µm gap between them. after that a silicon nitride layer of 400 nm is constructed on it. Above this silicon nitride layer a very thin layer of hydrophobic material i.e PTFE is used. If we will willing to make the Double Plate DMF then after the space of certain hundreds of um again a PTFE layer and above it a ITO layer followed by a glass layer if formed. Here the purpose hydrophobic layer is . to achieve the desired contact angle between the droplet and the surface and also reduces the solid-liquid interaction, and helps in the smooth motion of the droplet.

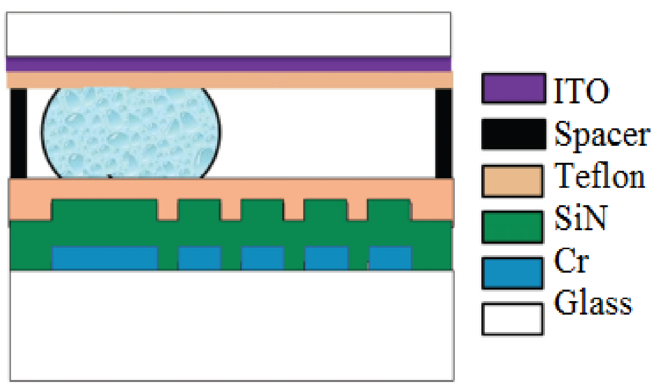


**Figure2. Double plate DMF**

## 3. PHYSICS BEHIND DROPLET ACTUATION:

To calculate the electric field and charge distribution on droplets in digital microfluidic devices, we solved the conservation of charge Eq. (1) and the Laplace Eq. (2) in the droplet and its surrounding media,

$$\nabla(\sigma \nabla V) = 0, \quad (1)$$

$$\nabla(\varepsilon \nabla V) = 0, \quad (2)$$

where □ =□*r*□*0* is (□r is the relative permittivity of the medium and □0 is permittivity of vacuum), σ is the electrical conductivity of the droplet, and *V* is the electric potential. Droplets were approximated as non-deformable spherical caps, so there was no need to solve the Navier–Stokes equation. Actuation forces were calculated by integrating the electro dynamic forces per unit volume over the whole droplet according to Eq.(3), assuming negligible magnetic fields.[7]

$$\mathbf{F} = \int_V \varepsilon(\nabla \cdot \mathbf{E})\mathbf{E} + \varepsilon(\mathbf{E} \cdot \nabla)\mathbf{E} - 0.5\, \nabla(\varepsilon \mathbf{E}^2)\, dv, \quad (3)$$

where **F** is the actuation force vector and **E** is the electric field.

The contact angle between a droplet and the device surface is dramatically reduced (i.e., wetted) when electrical potentials are applied, according to equation.

$$\cos\theta = \cos\theta_0 + \frac{\varepsilon}{2\gamma_{LG}\, t} V^2$$

where θ is the contact angle at any applied voltage, $\theta^0$ is the contact angle at zero voltage, ε is the permittivity of the dielectric layer, *t* is its thickness, $\gamma_{LG}$ is the liquid-gas surface tension, and *V* is the applied voltage.

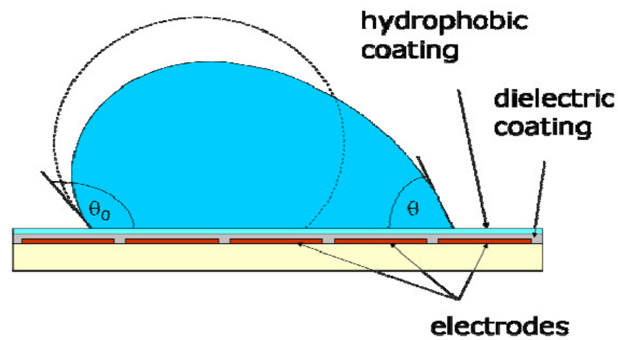


**Figure 3. Droplet Contact angle**

Contact angle change upon voltage application; when voltage is applied, contact angle decreases on droplet side on top of energized electrodes. When applying the voltage on the electrode then droplet will spread on the electrode.

***Simulation Results of DMF:***

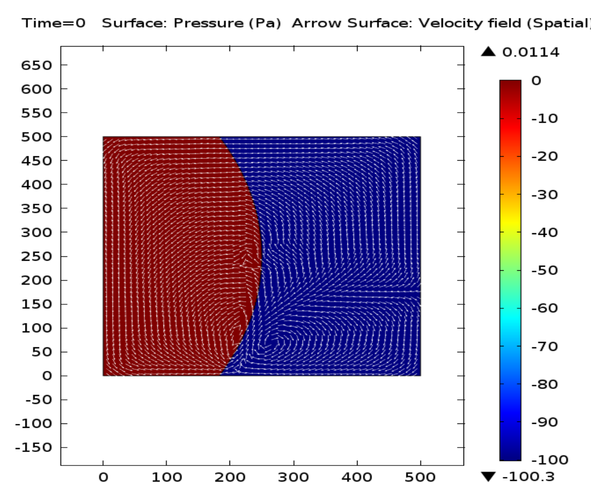


**Figure 4. Droplet actuation at time, t=0, Here we see that tha potential is uniform when the droplet is in contact with air surface.**

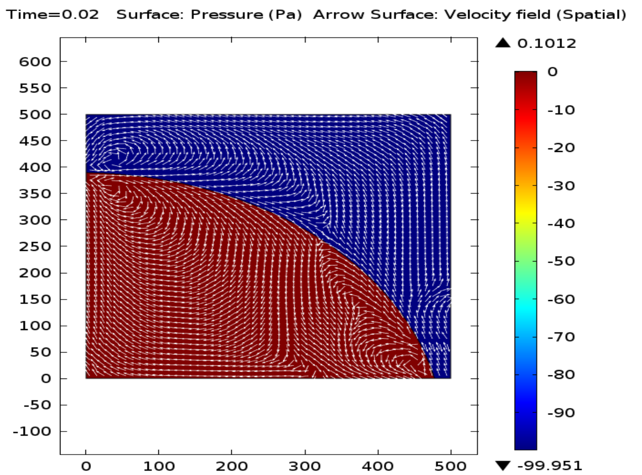


**Figure5. when potential is applied at time, t=0.02, as potential is applied the drop start to spread.**

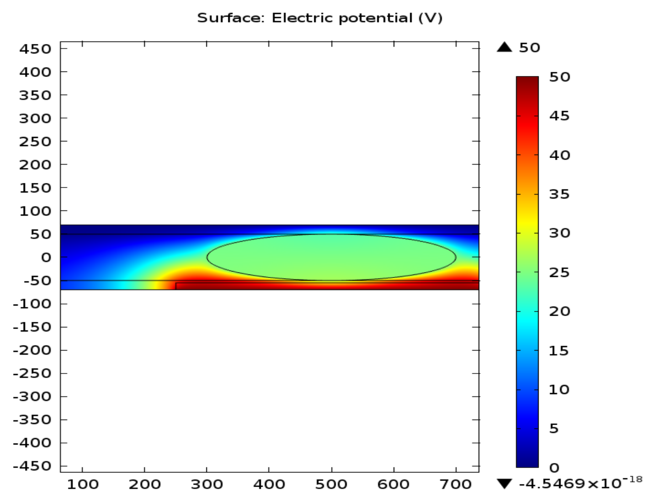


**Figure6. when water drop is placed on the electrode it shows the non-uniformity of the electric field.**

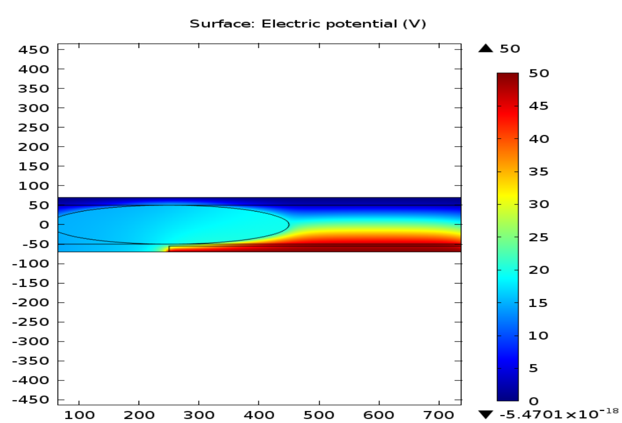


**Figure 7. when potential is applied on the electrode due to the change of electric field its contact angle with the surfaces changes and hence the droplet start to move towards other electrode on which potential is applied after removing potential and removing potential from the previous electrode.**

## 4. CONCLUSION

As we see in the simulation results as we apply the potential on the electrode the droplet starts to move. So like this when small droplet of enzyme of even range of few nm is placed on the DMF device due to the electric potential its start to move. And by this way we can transport enzyme to a particular site where it performs the defined operation. So it's a easy way to transport the enzyme droplet.

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