MODELLING DYNAMIC OF ELECTROWETTING IN LAB-ON-A-CHIP FOR BIOMEDICAL APPLICATONS

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INTRODUCTION

Electrowetting on dielectric (EWOD) is the basis of many important microfluidic technologies including lab-on-a-chip technology which offers a platform for developing diagnostic applications, DNA and protein analysis with the advantages of portability, reduction of the sample volumes, faster analysis times and low power consumption. In this study, electrowetting phenomenon in a microchannel was investigated numerically by considering dynamic behavior of the tri-phase contact line using molecular-kinetic theory [1].

METHODS

The flow is modeled as incompressible, laminar, three-dimensional and Newtonian. Mass conservation and Navier-Stokes equations for this flow can be written as:

$$\nabla . \vec{V} = 0 \quad (1)$$

$$\partial \vec{V} / \partial t + (\vec{V} . \nabla) \vec{V} = \frac{-1}{\rho} \nabla p + \upsilon \nabla^2 \vec{V} + \frac{1}{\rho} \vec{F}_b \quad (2)$$

$$\partial f / \partial t + (\vec{V} . \nabla) f = 0 \quad (3)$$

$$\nabla^2 \psi (x, y, z) = 0 \quad (4)$$

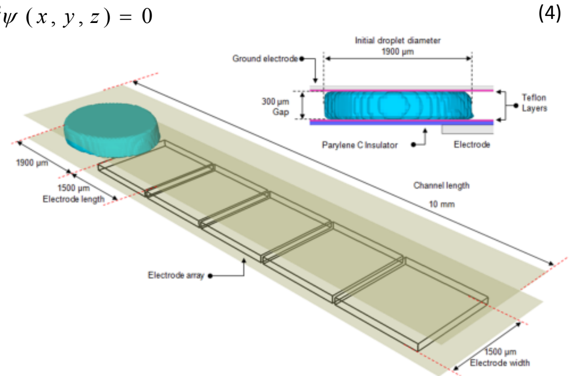

Figure 1: Schematic diagram of the computational domain.

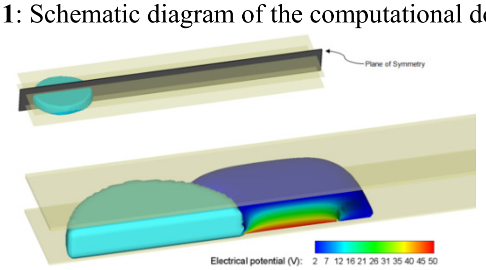

Figure 2: Electric potential distribution around a moving droplet.

The calculation procedure assumes that electrical and dynamic effects could be considered independently and the total effect could be studied by superimposing both two effects.

$$\cos \theta = \cos \theta_0 + \frac{C}{2\gamma} \psi^2 \quad (5)$$

Where θ_0 and θ are contact angles before and after actuation, C is the capacitance (per unit area) of the media, ψ is the applied voltage between the liquid and the electrodes and γ is the surface tension between the droplet and the surrounding gas.

$$U = K^0 \lambda^3 \gamma (\cos \theta_s - \cos \theta_D) / k_B T = \gamma (\cos \theta_s - \cos \theta_D) / \xi$$

Where k_B, T and K^0 are the Boltzmann constant, absolute temperature and characteristic frequency respectively and $\xi = k_B T / K^0 \lambda^3$ is the coefficient of wetting line friction [1].

RESULTS AND DISCUSSION

Results (figures 3-6) show that ignoring dynamic features of wetting in microscale leads to an overestimation of the effect of electrical actuation on various parameters. Leading edge contact angle predicted by dynamic model is larger than what is calculated by the static model while trailing edge contact angle is less than that of the static one. Study of droplet aspect ratio showed larger values in the static simulation. In terms of velocity, static model predicts faster movement in comparison with the dynamic model.

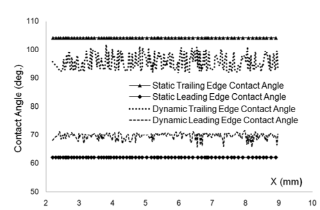

Figure 3: Computed contact angles.

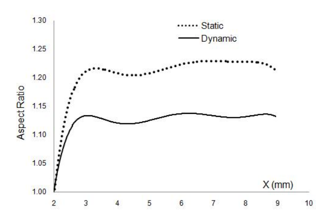

Figure 4: Aspect ratio of droplet along microchannel.

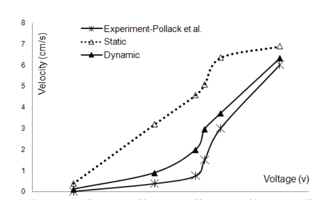

Figure 5: Comparison of droplet velocity as a function of voltage by experiments.

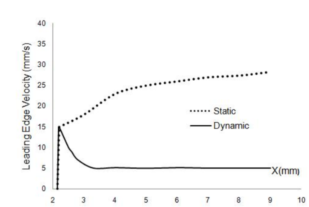

Figure 6: Comparison of droplet's leading edge velocity.

REFERENCES

1. Blake TD. J Colloid and Interface Science. 229:1-13, 2006.