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Analysis of Electrowetting Phenomenon Using Image Processing Tool

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Abstract

Electrowetting has gained popularity in present days for its wide range of applications. This phenomenon can be described as change in the contact angle of solid-electrolyte interface caused by an application of potential difference between solid and the electrolyte. Application of voltage causes a hydrophobic surface to behave like hydrophilic surface. The electric energy counterbalances the free surface energy and lowers the surface tension [1, 2, 3]. The wide range of application of this phenomenon starts from electronic display, liquid lens with variable focal length in cellular phones, cameras, switches for optical fibres to biomedical applications like tumour detection, endoscopy etc. It is easy to operate and has fast response. In this paper we are studying the change in contact angle of the miniscule droplet with respect to variation in applied voltage in MATLAB 7.10.0 platform [4]. Image Processing tools are used on the liquid droplet obtained experimentally to find the angle made by the liquid meniscus with the horizontal plane. An algorithm is developed for automatic detection of boundary and measurement of the contact angle of the miniscule droplet. The experimental finding and the results obtained from the developed algorithm are in good agreement with each other. The guiding equation for the proposed work is based on Young- Lippmann equation.

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Keywords: Electrowetting; contact angle; miniscule droplet; sessile, Image processing.

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1. Introduction

Electrowetting is a well known phenomenon for manipulating sessile droplets. Application of voltage leads to change in contact angle of the miniscule droplet. For measuring the contact angle gonniometer is used. This instrument captures the image of the droplet via a camera attached to it and then displays contact angle. Gonniometer is an expensive instrument and not readily available. In this paper we have developed an algorithm in MATLAB using Image processing tools for measuring the contact angle of the liquid droplet and compared with the experimental readings obtained from gonniometer.

2. Theory

Gabriel Lippman discovered the electrowetting phenomenon in the year 1875. He studied the behavior of mercury and some other liquids over surfaces that are variably charged. The term Electrowetting was first coined by G. Beni and S. Hackwood in the year 1981. In 1993 Electrowetting on Dielectric (EWOD) was studied by Bruno Berge [1]. Electrowetting is a means of droplet manipulation. On application of a potential difference between the electrode and electrolyte, electric double layer (EDL) is formed. This EDL is of order 1nm to 10nm thick. In this phenomenon positive charges accumulate on the interface of solid side and layer of negative charge is formed in the electrolyte. The layer of opposite charges formed near the solid-liquid interface is termed as EDL. Since this is a spontaneous process the surface energy gets lowered. The spreading of the electrolyte on the solid gives rise to phenomenon called electrowetting. There is a limit to the increase in voltage, if voltage is increased beyond limit this process will breakdown since a current starts flowing from the electrode to the electrolyte. To avoid this problem a dielectric layer is placed between the electrode and liquid. In 1990s Berge formulated an equation of EWOD combining Lippmann equations with the Young equation [2]:

$$\cos\theta = \cos\theta_0 + \frac{\varepsilon_r \varepsilon_0}{2D\sigma_{lv}} V^2 \qquad (1)$$

Where θ is the contact angle at a particular voltage, θ_0 is the contact angle without application of voltage, ε_r and ε_0 is the relative dielectric constant of electrolyte and dielectric constant of vacuum respectively, D is the thickness of the dielectric film, σ_{lv} is the surface tension of liquid-vapour. The ability of liquid to maintain contact with a solid surface is called wetting.The three interfacial tensions acting on droplet of water on a surface are shown in fig1(a) and (b). It is a result of intermolecular interactions when the liquid and solid surfaces are brought together. A balancing force between adhesive and cohesive forces determines the degree of wettability. When an interface exists between a liquid and a solid, the angle between the surface of the liquid and the outline of the contact surface is described as the contact angle. The contact angle is 0° for complete wetting. The solid is said to be wettable if contact angle is in between 0° and 90° and not wettable if beyond. Contact angle theoretically approaches the limit of 180° in case of ultra hydrophobic materials. The wettability of a surface or material is measured by Contact angle [3].

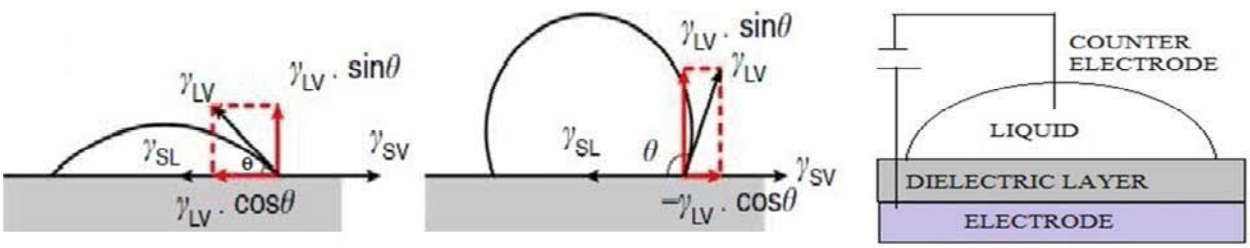

Fig.1.(a) θ<90^0 Hydrophilic Fig. 1.(b) θ>90^0 Hydrophobic Fig. 1.(c) EWOD

Fig. 1.Three interfacial tensions acting on droplet of water on a surface