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Dynamic Contact Angles in Low Voltage Electrowetting-on-Dielectric Systems

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Electrowetting-on-dielectric (EWOD) is a useful phenomenon in which the apparent contact angle of a conductive liquid upon a dielectric-coated electrode changes in response to an applied electric voltage. Large electrowetting effects can be achieved when the dielectric film has small thickness, large permittivity, and high breakdown field strength [1]. Dynamic contact angles describe three phase boundary motion giving “advancing” and “receding” contact angles, with their difference defining contact angle hysteresis (CAH). Industrially CAH plays an important role in coating processes, immersion lithography, and inkjet printing [2].

We studied the contact angle behavior using both a static and a dynamic configuration in order to investigate contact angle saturation and CAH. Contact angle saturation is the limiting angle where the applied voltage no longer modifies the contact angle. The static measurements consisted of optically measuring the contact angle of a droplet placed on a horizontal substrate through a Ramé-Hart goniometer system; the dynamic measurements extracted the contact angle through the Wilhelmy plate method using a Krüss tensiometer. Both measurements were taken at various applied voltages. The changing contact angle was modeled according to the Lippmann – Young (LY) curve at low voltage: $\cos(\theta) = \cos(\theta_0) + cV^2/2\gamma$; where c is capacitance, V is applied voltage, γ is the gas-liquid interface tension, and θ_0 is the equilibrium angle. The LY fitting is shown to model the wetting of a fluropolymer/aluminum oxide stack well until the system exhibits contact angle saturation (Fig. 1).

The thicknesses of both components in the dielectric stack (aluminum oxide + fluropolymer) were varied between 10-60 nm for the oxide and 20-100 nm for the polymer; thickness values were confirmed by ellipsometry and corroborated by the LY fitting. Our previous work on aluminum oxide failure describes the electronic and ionic behavior of this system, allowing for characterization of contact angle through the current flowing during the dynamic measurement. The complete electrowetting behavior, both dynamic and static, of a sample can be captured in a plot of cos(θ) vs. the electrowetting number (EN), defined as a dimensionless unit giving the ratio of electrostatic (c^*V^2) to surface tension (2γ) forces. The dynamic angles similarly show an ideal LY fitting, with the CAH remaining approximately constant with applied voltage (Fig 2).

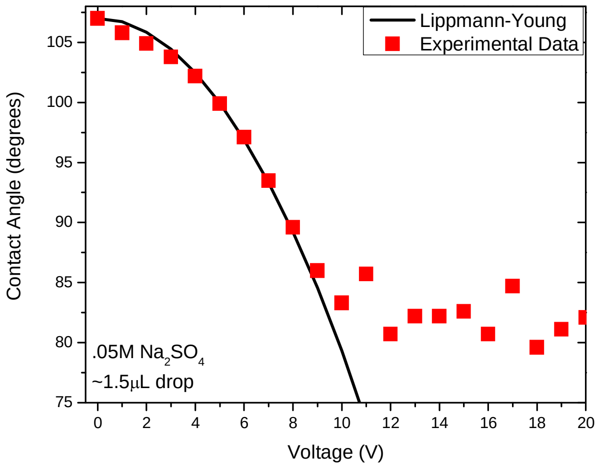

Figure 1: Contact Angle of a .05M Na_2SO_4 1.5μL droplet on 20nm cytop/32nm aluminum oxide stack using a gold needle top contact modeled with the theoretical Lippmann-Young relationship

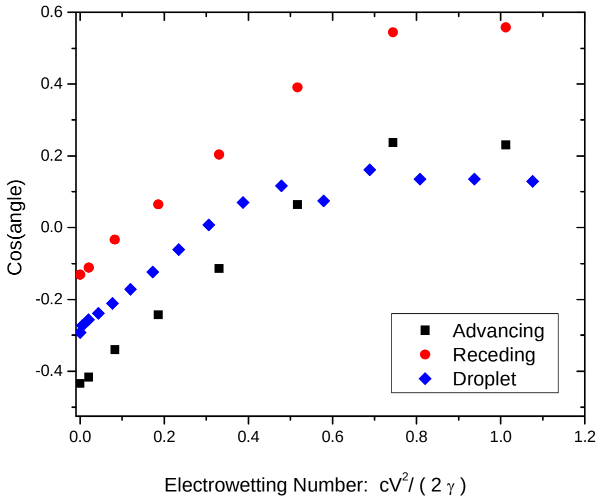

Figure 2: : The relationship between droplet and Wilhelmy plate testing configuration for a 20nm cytop/32nm aluminum oxide stack in .05M Na_2SO_4 electrolytes.

References

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