MANIPULATION OF SESSILE DROPS BY ELECTROWETTING

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Electrowetting refers to the decrease in the contact angle of a liquid drop on a surface when an electrical potential difference is applied between the drop and an underlying electrode. Typically a thin ($\approx 1\mu$m) dielectric layer separates the drop and the planar electrode and the designation Electrowetting-on-Dielectric or EWOD [1] is used to describe the system.

In this work, we first provide a theoretical explanation of EWOD and a slight refinement of the Young-Lippmann equation that describes electrowetting. The derivation is based on minimization of the total energy (interfacial and electrostatic) of the sessile drop [2], which requires knowing the electrical capacitance of the drop. To find the latter, including corrections to the simple parallel-plate capacitance from the wetted region on the surface, we use matched asymptotic expansions and conformal mapping to find the electric field and surface charge distribution in the vicinity of the contact line. The corrections due to the fringe capacitance on the Young-Lippmann equation are shown to be very small, unless the thickness of the dielectric layer becomes comparable to the characteristic size of the drop.

We then report on experimental manipulation of drops (microliters in volume) on our photolithographically-fabricated EWOD slides that incorporate arrays of individually addressable electrodes in the substrate. In addition to the embedded electrodes, thin gold lines are deposited on top of the dielectric layer [3]; these enable the drops to be grounded without the need for inserting a wire into them or confining them with a top plate electrode.

Experiments are performed on shape oscillations of the drops, as well as on translating the drops horizontally from one electrode to a neighboring one under AC forcing. Through high-speed video and image analysis, we show that depending on the frequency of the applied alternating field, single or multiple modes of oscillation may be excited. Super- and sub-harmonic signals are evident in some of the response signals. By extracting the contact angle and diameter of the wetted region as a function of time from the video sequences, synchronized with the known applied AC field, low-dimensional dynamical-system descriptions of the shape oscillations, in the form of closed limit-cycle curves in a three-dimensional space, emerge for certain forcing parameters. For the translating drops, it is seen that at a fixed RMS voltage, regardless of the AC frequency, the overall translational speed of the drop from one electrode to the next is the same. However, the time-resolved movement appears to be snail-like and capillary waves of different wavelengths persist along the surface of the translating drops at different forcing frequencies.

References

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