Abstract

The application of electric field has emerged as one of the most efficient techniques to mobilize liquid drops in lab-on-a-chip devices and biological assays. In this dissertation, efforts have been made to analyze the electrostatic actuation of droplets in different scales and scenarios though lamped parameter based **analytical approach**, **computational modeling** of electro-hydrodynamics, **molecular dynamic simulation** and **experimental investigation**.

First, the motion of a sessile droplet along an inclined surface under the electric actuation force is **analytically** modeled using an equivalent capacitance network. The interplay between the gravitational pull and the electrostatic force is analyzed by varying the actuation voltage, substrate wettability, inclination and droplet volume. Based on this, the voltage map for the steady droplet motion over a humped surface is obtained.

The electro-hydrodynamics of droplet motion and merging has been studied **computationally**. The internal circulation and interface deformation during droplet upclimbing along an inclined surface have been simulated. The electric phenomenon is coupled with the hydrodynamics by the inclusion of the volumetric electrostatic body force as a source term in the two-phase momentum equations. The hydrodynamics of droplet coalescence driven by liquid dielectrophoresis is also investigated.

Molecular dynamic simulations are performed to analyze the influence of the external electric field on the transition of the wetting mode over pillar-arrayed surfaces. The interdependence of the energy barrier of wetting transition and the electrostatic force is analyzed by varying the pillar arrayed texture on a charged base substrate. The mechanism of the wetting transition on a surface having heterogeneous pillar-array is analyzed. Translation of a sessile nano-droplet under the external electric field is also investigated. The frequency of shifting of the charged region below the drop and the magnitude of the assigned charge on the substrate are varied to understand the drop dynamics.

Finally, an **experimental investigation** has been made to device a low cost electrowetting arrangement for the actuation of droplets. The electrodes are fabricated by wet etching of the copper coated FR4 board. PDMS and commercially available polyethylene layer is used to insulate the droplet from the bare metal surface. The electrowetting surface is infused with n-Undecane to reduce the contact angle hysteresis. The feasibility of droplet actuation by this arrangement has been demonstrated and the associated limitations have been identified.

Keywords: Electrowetting, Liquid dielectrophoresis, Electromechanical approach, Droplet, Volume of fluid method, Molecular dynamic simulations, Maxwell stress, Energy minimization.