ABSTRACT

The aim of this dissertation is to study the electrically-driven droplet wetting and spreading dynamics on soft and slippery surfaces. The following three important aspects are studied: (*i*) Electrically modulated wetting and spreading dynamics of a nano-suspension on a soft solids; (*ii*) Electrically-modulated reversible spreading on a soft biomimetic surface; *(iii)* Electrically-driven blood spreading and its application in determining the erythrocytes sedimentation rate (ESR).

The wetting of solid surfaces can be manoeuvred by altering the energy balance at the interfacial region. While the electric field acts favourably to spread a droplet on a rigid surface, this tendency may be significantly suppressed over soft surfaces, considering a part of the interfacial energy being utilized to deform the solid elastically by capillary forces. In this study, a unique mechanism has been proposed by virtue of which addition of nano-particles to the droplet brings in a favourable recovery of the electro-spreading characteristics of a soft surface, by realizing an alteration in the effective dielectric constant of the interfacial region. The experimental results further demonstrate that this mechanism ceases to be operative beyond a threshold volume fraction of the particle suspension, due to inevitable contact line pinning. A theory has also been developed to explain the experimental observations.

After investigating the droplet spreading on soft materials, reversibility of the sessile droplet under applied electric field has been explored. Electrically-driven spreading of droplets is severely challenged by the lack of controllability in completely reversing the droplet motion on withdrawal of the applied voltage by switching it from 'ON' to 'OFF' condition. Circumventing these compelling constraints, a completely controllable reversibility of electrically-modulated droplet spreading has been demonstrated by infusing a stable oil layer on soft polymeric surface using the replica of a biologically inspired rose-petal template. A universal scaling law for time dependence of the droplet radius has been derived, premised on viscous dissipation over interfacial scales.

After studying the electrospreading behaviour of Newtonian droplet, an attempt has been taken to investigate the spreading characteristics of a power law fluid (here, human blood). The rheology of blood acts as one of the rate controlling factors for the electrically-driven blood dynamics on a rigid hydrophobic surface, in addition to the strength of the applied electrical potential. A theory has been proposed to corroborate the experimentation findings which elucidates the spreading behavior of a sessile blood drop. Also, a rapid and highly energy efficient method is proposed for simultaneous determination of hematocrit and ESR on a microfluidic chip, deploying electrically driven spreading of a tiny drop of blood sample. This unique approach estimates these parameters by correlating the same with the time taken by the droplet to spread over a given radius, reproducing the results from more elaborate laboratory settings to a satisfactory extent. This novel methodology is equally applicable for determining higher ranges of ESR such as high concentration of bilirubin, samples corresponding to patients with anemia and patients with some severe inflammation.

The results and conclusions from the present thesis facilitate the research community to understand the fundamental principles and mechanisms leading to augmentation in wetting and spreading dynamics on the soft solid and the slippery surface under imposed electric field. The presented findings are likely to open up the proposition of realizing a completely controllable reversible electro-spreading dynamics of droplets as applicable to a plethora of emerging applications encompassing biologically-inspired fluidics, electronics and medical science.

Keywords: Electrowetting, Electric field, Dielectric, Sessile droplet, Soft solid, Colloidal-suspension, Slippery surface, Blood, RBC, Erythrocytes sedimentation rate (ESR)