Interfacial Investigations of Interacting Immiscible Fluids and Gels

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Abstract:

Fluidic interfaces are ubiquitous and relevant to our everyday lives. From the moment the toothpaste (a non-Newtonian fluid) touches the bristles of the brush to drinking a glass of water before going to bed, our lives are intertwined with multiple fluids. The present thesis aims to understand the fundamental interactions in immiscible complex fluidic systems when subjected to different external perturbations. Subsequently, the gained knowledge was used to develop multifunctional designs capable of being applicable in next-generation electronic devices. Firstly, the dynamics of an extended meniscus of a thin liquid film when subjected to an AC electric field were studied. It was observed that, unlike in the case of droplets, the thin film spread and retracted, in line with the magnitude of the applied voltage-frequency combination. Secondly, the evaporation dynamics of a water droplet when placed atop a viscoelastic liquid film without any imposed temperature gradient was investigated. Consequently, the droplet self-propelled in random directions, and during the later stages of the evaporation, the liquid polymeric film underneath the droplet crumpled and wrinkled like a sheet of plastic foil. Thirdly, the interaction of multiple droplets atop deformable substrates was probed, by studying the condensation dynamics of water droplets atop materials with different rheological attributes. It was observed that droplets over liquid films self-propelled in a swarm-like manner without coalescing. Fourthly, smart hydrogels, which were thermal and electro-responsive were synthesized, for use in flexible electronics applications. The hydrogels were doped with graphene to augment their structural and electrical properties. Extensive experiments were undertaken to optimize the material properties and device design for harnessing the biomechanical energy of the user. Finally, the thermal performance of the synthesized hydrogels was also investigated to assess their suitability for use in flexible thermal management systems of the future. It is believed that the fundamental findings of the present thesis will shed light on the dynamics of interacting multiphasic droplets and films. Also, the application-oriented aspects of this thesis will be useful for designing systems capable of tackling the energy and thermal management problems associated with the electronic devices of the future.

Keywords: *Liquid thin films, electrowetting, viscoelastic liquids, deformable soft substrates, hydrogels, evaporation, condensation, triboelectric nanogenerator, vapor chamber.*