PATTERN FORMATION AND MORPHOLOGY CONTROL DURING EVAPORATION OF DROPLETS ON SOFT INTERACTING SURFACES

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Abstract

Evaporation of a suspension or solution droplet over rigid non-interacting substrates results in a peripheral deposit widely known as ‘coffee stain' due to a combination of thermo-capillary flow and Marangoni flow. The thesis reports various fundamental aspects of the droplet evaporation dynamics, final deposition patterns as well as different types of instability appearing at the three-phase contact line (TPCL), the droplet free surface or at the droplet base during evaporation of a solvent, solution, or suspension droplets over soft interacting/lubricant-infused substrates. Here we report unique contact line instabilities during the spreading of a highly volatile good solvent droplet over a soluble substrate induced by Marangoni flow and Benard convection which gets suppressed over a thick substrate (Chapter 2). Apart from the contact line instability patterns, the free surface of a highly concentrated solution or suspension droplet over a rigid non-interacting substrate may show instability patterns due to the deformation of a viscoelastic polymer/colloid skin at the droplet free surface. Here we report such surface instability patterns while studying the evaporation of dilute polymer solution droplets over soft swellable (Sylgard 184) substrates due to rapid solvent loss via diffusive penetration of solvent into the substrate along with evaporation (Chapter 3). Interestingly, a swellable bilayer substrate with differential swellability like UVO-treated Sylgard 184 substrates results in the formation of surface wrinkles, when swelled with a droplet of suitable solvent. We here report a facile technique to make the swelling-induced wrinkles permanent via evaporation of polymer solution droplets of varying initial concentration ($\boldsymbol{C_i}$) (Chapter 4). Further, we have also investigated the confinement effect of substrate stripe patterns on the swelling dynamics as well as the orientation of the permanent wrinkle patterns after the complete evaporation of solution droplets over patterned UVO-treated Sylgard 184 substrates of varying feature height (Chapter 5). Apart from studying droplet evaporation on soft interacting substrates both dissolving and non-dissolving, we have studied another interesting category of surfaces i.e., lubricant-infused slippery surfaces. Such lubricant-infused surfaces possess a movable droplet/lubricant/air contact line, which satisfies the Neumann configuration. We have fabricated the slippery surfaces by infusing oil over positive rose petal patterned sticky Sylgard 184 surfaces to prevent the rupture of the oil layer under an aqueous droplet. We show here that the wetting ridge dimensions depend on $\boldsymbol{h_E}$, which in turn strongly influences both the nature of the contact line dynamics as well as the evaporation time ($\boldsymbol{t_E}$) of a pure water droplet over such slippery surfaces (Chapter 6). Extending this study, we further investigated unique colloidal self-assembly mechanisms and final deposit patterns at the droplet base and the droplet free surface depending on $\boldsymbol{h_E}$ and $\boldsymbol{C_i}$ during the evaporation of aqueous colloidal suspension droplets over such slippery surfaces (Chapter 7).