SELF-ASSEMBLY IN DRYING THE SESSILE COLLOIDAL DROPLET

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Deposition pattern form the evaporative colloidal droplet has many applications in the scientific and industrial applications, since it provides a possible method to produce important nanoscale devices or develop the detection technology. Despite the preliminary application of the pattern-forming phenomena to concentrating chemicals, coating, printing, spraying, drying, painting, biomedical sampling, etc., achieving deep understanding of the dehydrating self-assembly in the application is still lacking. Particle assemblies can be found in drying the colloidal droplet. Controlling the particle organization and the final deposit patterns can be achievable from further understanding of droplet evaporative dynamics. The process to form the configuration in the drying droplet has been investigated theoretically and experimentally. In the experiments, the suspensions of colloidal droplet with the particle size at nano-scale particles in the deionized water were prepared with surfactant or without the surfactant. The surfactant acts the medium to modify the sticking parameter. The colloidal suspensions are carried out by well stirring first and then putting in an ultrasonication bath to ensure the even initial dispersion of the particles in the base fluid. The clean silicon wafer was used as a substrate for the colloidal sessile droplet drying. Right after the suspensions were prepared, we placed a tiny sessile droplet to dry while the drying patterns were directly recorded with the optical microscope. The interesting spreading and evaporation dynamics were found in the colloidal droplets. The formation of branched particle aggregation, coffee ring, uniform coverage and combined structures was observed during the droplet evaporation for pinning and depinning three phase line. To understand the controlled parameters, a simulation on the basis of Monte Carlo method is developed to explain the phenomena. The mathematical models respectively investigate the pinning and depinning behaviors to mimic a sessile colloidal droplet evaporation. The particle, liquid, vapor, and substrate interaction are considered. To understand the controlled parameters, we have developed the simple approaches: the two-dimensional (2D) Kinetic Monte Carlo (KMC) and Diffusion Limited Aggregation (DLA) models, to explain the various drying patterns from the colloidal droplets. We have used 2D KMC model to simulate the evaporation-induced fractal-like 2D structures found in drying the colloid droplets with the depinning three-phase line. The simulation shows a good consistency with the fractal structures observed in the experiments. Based on the nature of sticking between particles in the base fluids in a drying droplet, the diffusion limited cluster-cluster aggregation (DLCA) process by coupling with the biased random walk has been employed to investigate the particle aggregation. We have managed to simulate the experimentally observed transition from the uniform pattern to the coffee ring from the nanofluid droplets as a result of adding surfactant in the nanofluids. In addition, the 2D models have been translated into three-dimensional (3D) KMC and DLCA models. The advance of 3D models is discussed.