Desiccation of sessile particle-laden droplets: beyond 'coffee-ring effect'

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The review is devoted to our recent results in simulation of the processes during desiccation of the sessile droplets [1–6]. Our special attention is focused on two particular cases when evaporation is inhibited by a mask [1] or by an obstacle [2] and when a droplet contains both dissolved substances and suspended particles [4].

Desiccation of the sessile droplets attracts a great attention of the researchers due to a wide range of application from nanotechnology to medical tests. When the concentration of the solute is high enough to ensure good adhesion and strong anchoring (pinning) of the triple line, a drop is desiccating with constant base.

Simple models were proposed to describe temporal dynamics of both the shape of the drop and the volume fraction of the colloidal particles inside the drop [3–6]. The concentration dependence of the viscosity is taken into account [4–6]. It is shown that the final shapes of the drops depend on both the initial volume fraction of the colloidal particles and the capillary number. Drying processes of sessile droplets of blood serum (i.e. colloids with the salt admixture) on a solid hydrophilic horizontal substrate are studied [4]. The simulation of spatial distribution of the components in the droplet of biological fluid drying on a substrate is performed using advection–diffusion equation. The proposed model explains the redistribution of components in a sessile drop of biological fluid when it dries. Competition between advection and diffusion leads to large particles (protein) accumulating at the edge of the drop, while solutes (salts) are distributed more uniformly across the diameter of the sample [4]. In our model, we simulate an experiment. A thin colloidal sessile droplet is allowed to dry out on a horizontal hydrophilic surface. A mask just above the droplet predominantly allows evaporation from the droplet free surface directly beneath the holes in the mask. We consider one special case, when the holes in the mask are arranged so that the system has rotational symmetry of order m. Advection, diffusion, and sedimentation are taken into account. The simulation demonstrates that the colloidal particles accumulate below the holes as the solvent evaporates. Diffusion can reduce this accumulation [1]. Drying processes of colloidal film on a solid substrate under a solid disk are studied [2]. A model is proposed to describe temporal dynamics of both the shape of the film and the volume fraction of the colloidal spherical particles inside the film. Initially, the system is single-phase (liquid), then in the area, where the volume fraction of the colloidal particles reaches critical value, solid phase forms. This area holds the shape, prevents the hydrodynamic flows and evaporation from its free surface. In liquid area viscosity and diffusivity depend on the volume fraction of the particles. The rate of solvent mass loss per unite surface area per unite time from the film by evaporation under a disk was obtained numerically from the Laplace's equation for the vapor concentration in the area over the film. During the first desiccation stage the volume of the film under the disk is liquid; the rest of the film becomes solid. When the whole volume of the film becomes solid dried film has a dip below the disk [2].

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