EVAPORATION OF A SESSILE DROPLET LADEN WITH PARTICLES ON A SOFT VISCOELASTIC SUBSTRATE

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ABSTRACT

When a droplet containing dispersed particles dries out, it leaves behind a solid residue of these particles, with the most commonly found pattern to be a thin ring-shaped stain; introducing the widely known term of coffee-stain or "coffee-ring" effect[1]. The formation of the evaporation-driven spatial solid distribution in the final deposit is crucial due to its diverse applications including disease diagnostics[2], the controlled evaporative self-assembly[3], inkjet printing[4] and coating[5]. Understanding and controlling particle distribution in evaporative deposits are the primary goals of most studies conducted so far. Substrate elasticity adds further complexity to the way it affects droplet evaporation in the presence of non-interacting particles in the bulk, to be able to control the deposition patterns. In this work, we investigate the dynamics of a particle-laden volatile droplet residing on a compliant substrate described by the Kelvin-Voigt model. The effects of vapor diffusion in the atmosphere, evaporative cooling, thermocapillarity and the effect of particles on rheology are fully considered. We propose a model based on lubrication theory to derive evolution equations for the droplet profile, the displacement of the elastic solid and the profile of deposited particles and particle concentration in the bulk. These evolution equations are coupled with the Laplace's equation for the vapor concentration in the gas phase solved in 2D. We perform a thorough parametric analysis to investigate the complex flow dynamics ranging from symmetry breaking to sustained droplet oscillations. We show that these phenomena are determined by a delicate interplay between the substrate softness, the capillary and Marangoni forces, particle transport in the bulk and rheology.

KEYWORDS: droplet evaporation, particle deposition, lubrication theory, thermocapillarity

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