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Simulations of the dynamic deposition of colloidal particles from a volatile sessile drop

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Abstract

Hypothesis

The deposition of particles from a volatile liquid drop atop a substrate is primarily governed by the advection and diffusion of the particles in the liquid. Colloidal particles may further coagulate and adsorb to the substrate during the deposition process. The external geometry and the internal composition of the particulate deposit are then determined by an interplay between these four mechanisms.

Simulation

We simulate the process of deposition by solving the governing transport equations. We explore the interplay between the different mechanisms mentioned above. In particular, we study the contribution of the diffusion of colloidal particles and aggregates to the morphology of the deposit, which was neglected in a previous study.

Findings

The rates of diffusion and coagulation of each specific aggregate are dependent on its size. Hence, the transport equation uniquely correlates to each population of aggregates. The overall transport problem, alongside the rates of particle and aggregate adsorption and liquid evaporation, determines the geometry of the deposit. Moreover, the local rate of particle coagulation determines the internal composition of the different aggregate populations in the deposit. Our results appear to be in qualitative agreement with previous experimental findings.

Keywords: pattern, deposition, adhesion, coagulation, diffusion, evaporation, suspension, colloids, drop

1. Introduction

Deposits of colloidal particles from a drop of volatile carrier liquid appear in different qualitative shapes. The main mechanisms, contributing to the shape of the deposits, are associated with the flow in the drop which is caused by the volatility of the carrier liquid. The flow advects the particles toward the edge of the drop [1–3], opposing the particle diffusive flux that regulates variations in the particle concentration. Here we use simulation to examine the deposition of colloidal particles that may further coagulate and adsorb to the substrate.

There are several studies on the contributions to the shape of the deposit from particle coagulation and particle adsorption onto the substrate or onto the free liquid surface by using different methods to alter surface forces in volatile suspensions.

More specifically, Bhardwaj et. al., [4], Dugyala and Basavaraj [5], Moraila-Martínez et. al., [6], and Marín et. al., [7] studied the connection between the pH of colloidal suspensions in a volatile liquid, and thus the connection between the zeta potentials on particles and on the substrate, and the shape of the deposit. Anyfantakis et. al., [8] employed charged surface active species to alter the zeta potential of the particles and hence the shape of the deposit. Moreover, Nguyen et. al., [9] and Kuncicky and Velev [10] varied the electrical double layer forces in colloidal suspensions by adding electrolytes. Bhardwaj et. al., [4] and Crivoi and Duan [11, 12] further employed theoretical models to study the contributions to the shape of the deposit from surface forces and particle aggregation in volatile suspensions.

Accounting for the volatility of the liquid, that

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