# Fast Evaporation of Spreading Droplets of Colloidal Suspensions

K. L. Maki and S. Kumar
Department of Chemical Engineering & Materials Science
University of Minnesota, Minneapolis, MN 55455

Presented at the 16th International Coating Science and Technology Symposium,
September 9-12, 2012, Midtown Atlanta, GA[1]

When a coffee droplet dries on a countertop, a dark ring of coffee solute is left behind, a phenomenon often referred to as the "coffee-ring effect". A closely related yet less-well-explored phenomenon is the formation of a layer of particles, or skin, at the surface of the droplet. In this work, we explore the behavior of a mathematical model that can qualitatively describe both phenomena. We consider a thin axisymmetric droplet of a colloidal suspension on a horizontal substrate undergoing spreading and evaporation. The lubrication approximation is applied to simplify the mass and momentum conservation equations, and the colloidal particles are allowed to influence droplet rheology through their effect on the viscosity. By describing the transport of the colloidal particles with the full convection-diffusion equation, we are able to capture depthwise gradients in particle concentration and thus describe skin formation, a feature neglected in prior models of droplet evaporation. The highly coupled governing system of equations is solved using a finite-difference scheme based on a moving overset grid method. Whereas capillarity creates a flow that drives particles to the contact line to produce a coffee-ring, Marangoni flows can compete with this and promote skin formation. Increases in viscosity due to particle concentration slow down droplet dynamics, and can lead to a significant reduction in the spreading rate.

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