144f Dip-Coating of Chemically Micropatterned Surfaces in the Presence of Soluble Surfactant

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Free-surface microfluidic flow on chemically heterogeneous surfaces is used extensively in such fields as nanotechnology, sol-gel processing, patterned colloidal deposition, microfluidic devices and sensors, and microelectronics, with applications ranging from photolithography to controlling the self-assembly of hierarchically organized nanostructures. Chemical surface heterogeneity can be used to confine liquids to particular regions on the substrate. Such confinement induces a significant lateral curvature of the liquid free surface, which can have significant quantitative and qualitative effects on fluidic behavior. Dip-coating is a simple and effective way to coat these patterned surfaces with fluid. The recent theoretical analysis by Davis [1] of the dip coating of a pure fluid onto vertical, wetting stripes surrounded by non-wetting regions quantified the experimentally observed deviations from the classical Landau-Levich result. These deviations were shown due to the significant lateral curvature of the free surface near the liquid bath and the streamwise change in this lateral curvature along the stripe. Emerging applications of microfluidic flow on micropatterned surfaces often include the presence of surfactants, either as integral parts of the process (*e.g.,* to stabilize solutions of carbon nanotube arrays) or as undesired impurities. Gradients in the surfactant concentration can induce Marangoni stresses at the liquid-vapor interface, which can significantly modify the coating dynamics and thickness of the entrained liquid film. In this work, the selective dip-coating of surfactant solutions onto chemically micropatterned surfaces is examined theoretically and numerically for a convective-equilibrium model of surfactant transport. Matched asymptotic expansions are used to determine the thickness of the entrained liquid film as a function of stripe width, withdrawal velocity, liquid and surfactant properties, and bulk surfactant concentration. Effects of these factors are assessed through variation of the Peclet number, Capillary number, Marangoni factor, and equilibrium constant (K) for surfactant adsorption at the liquid-vapor interface. The limits $K \to 0$ and $K \to \infty$ recover the results for a pure liquid [1] and an insoluble surfactant, respectively. Intermediate values of K yield film thicknesses between these limiting results. The increase in film thickness is limited by a multiplicative factor of $4^{1/3}$ with respect to the case of a pure fluid, which indicates that Marangoni stresses have a smaller influence than on homogeneous surfaces. Physical explanations are provided for these numerical and theoretical results.

References: [1] J. M. Davis, "Asymptotic analysis of liquid films dip-coated onto chemically micropatterned surfaces," *Phys. Fluids* **17**, 038101 (2005).