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Capillary-Flow Dynamics in Open Rectangular Microchannels[1]
PANAYIOTIS KOLLIOPOULOS, KRYSTOPHER JOCHEM, DANIEL JOHNSON, WIESLAW SUSZYNSKI, LORRAINE FRANCIS, SATISH KUMAR, University of Minnesota — Capillary flow of liquids plays a key role in many applications including lab-on-a-chip devices, heat pipes, and printed electronics manufacturing. Motivated by these applications, we combine theory and experiment to examine capillary-flow dynamics in open rectangular microchannels. SEM and profilometry are used to highlight the complex free-surface morphology. We develop a self-similar lubrication-theory-based (LTB) model accounting for this complexity and compare its predictions to those from the modified Lucas-Washburn (MLW) model, as well as experimental observations over a range of channel aspect ratios λ and equilibrium contact angles θ. For large λ the two models are indistinguishable, whereas for smaller λ the LTB model agrees better with experiments. The LTB model is in better agreement with experiments at smaller θ, although as $\theta \to \pi/4$ it fails to account for important axial curvature contributions to the free surface and the agreement worsens. Finally, the LTB model also predicts the dynamics of fingers which extend ahead of the meniscus. These findings elucidate the MLW model limitations and demonstrate the importance of accounting for the complex free-surface morphology in open microchannel capillary flows.

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