Droplet spreading on rough, permeable substrates

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Abstract

Wetting of permeable substrates by liquids is an important phenomenon in many natural and industrial processes. Substrate heterogeneities may significantly alter liquid spreading and interface shapes, which in turn may alter liquid imbibition. A new lubrication-theory-based model for droplet spreading on permeable substrates that incorporates surface roughness is developed in this work. The substrate is assumed to be saturated with liquid, and the contact-line region is described by including a precursor film and disjoining pressure. A novel boundary condition for liquid imbibition is applied that eliminates the need for a droplet-thickness-dependent substrate permeability that has been employed in previous models. A nonlinear evolution equation describing droplet height as a function of time and the radial coordinate is derived and then numerically solved to characterize the influence of substrate permeability and roughness on axisymmetric droplet spreading. Because it incorporates surface roughness, the new model is able to describe the contact-line pinning that has been observed in experiments but not captured by previous models.

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