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Nanoscale flows on open chemical channels

JOEL KOPLIK, City College of New York

We investigate the nano-scale flows of low-volatility liquids along "chemical channels": patterns of completely-wetting solid embedded in a planar substrate, and sandwiched between less wetting solid regions. In the case of a long, straight wetting stripe, we use molecular dynamics simulations as basic computational tool, comparing the results to a simple long-wavelength approximation and a full stability analysis based on the Stokes equations. The different approaches are qualitatively consistent, and we find that while thin liquid ridges are stable both statically and during flow, a (linear) pearling instability develops if the thickness of the ridge exceeds half of the width of the channel. In the flowing case periodic bulges propagate along the channel and subsequently merge due to nonlinear effects. However, the ridge does not break up even in the unstable case, and the qualitative behavior is unchanged when the fluid can spill over onto a partially wetting exterior solid region. For more complicated patterns involving the splitting or merger of wetting stripes, we again find that liquid flows continuously along the wetting region despite the pearling instability. In this case, intriguing switching dynamics is found for moving pearls at junctions.