Determining stress during finger propagation in 2D foams

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We investigate the formation of fingering patterns in a radial Hele-Shaw cell filled with quasi-two-dimensional polydisperse foam of very small liquid content. Air is used as the low-viscosity driving fluid, in both radial and parallel-channel geometries. Using high speed imaging (up to 2000fps), we directly observe the topological rearrangements on the size scale of single bubbles at the air-foam interface. We find that the growth process of the finger can be discretized as successive elementary T1-type edge exchanges between neighboring bubbles at the interface of the advancing finger. Compared to the prominence of the T1, film rupture events are rare.

Unlike other viscoelastic materials, foams give away direct information about their rheology through deformations of the bubbles that constitute the foam. Analyzing the statistical distributions of bubble properties yields insight in the behavior of the foam as a whole. Using a coordinate system moving with the finger, we obtain good spatial resolution for quantities such as the rate of T1 events, measures of local bubble anisotropy (e.g. the texture tensor), and connectivity. The deviatoric stress tensor in the material can be deduced from these data. The results are compared to continuum theory in the viscous liquid and elastic solid limits, shedding light on the continuum behavior of foam as a viscoelastic material, by virtue of exploiting bubble geometry.

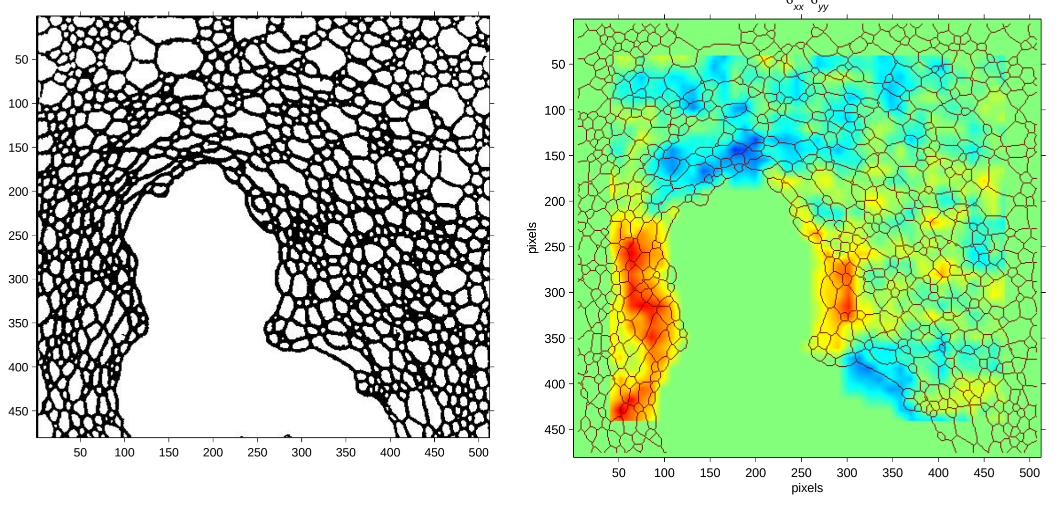

FIG. 1. Left: Snapshot of advancing finger in a 2-D Hele-Shaw cell filled with foam. Right: The bubble shapes have been analyized to yield the $\sigma_{xx} - \sigma_{yy}$ component of the deviatoric stress tensor, whose magnitude is color-coded in the figure.