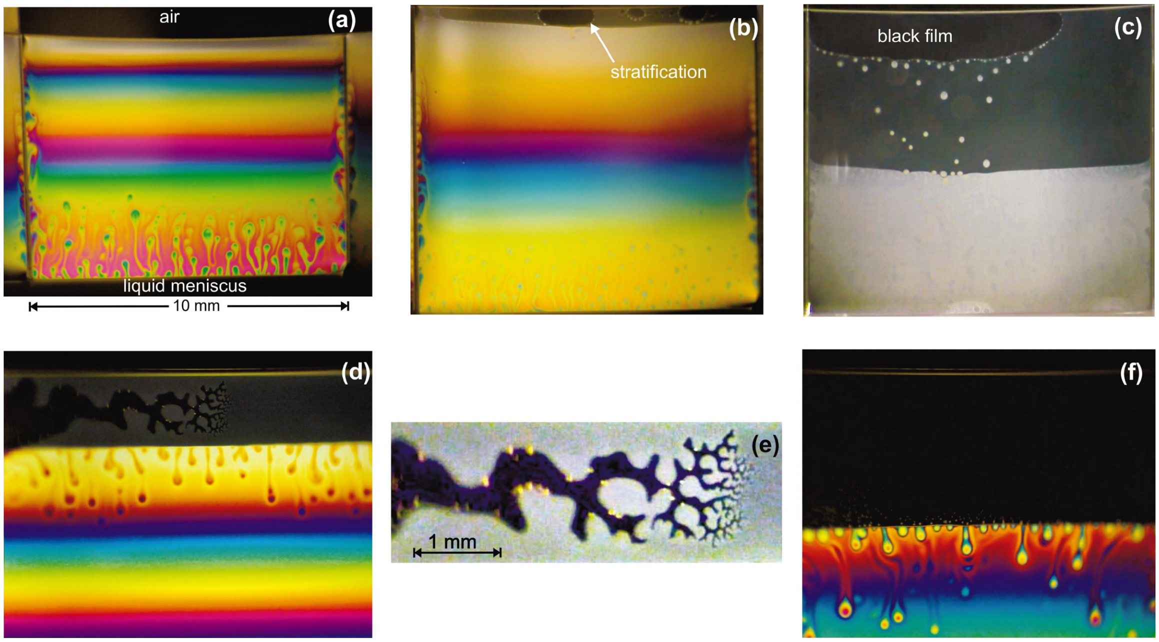

Images of the Floating World: Drainage Patterns in Thinning Soap Films

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Biological and industrial foams often contain polymeric additives that substantially modify the rheological and drainage behavior within individual lamella. There are, however, few controlled studies of entrainment and drainage in polymeric soap films[1,2] which thin not by gravity but by capillary and disjoining pressures. In this study, aqueous soap films containing SDS surfactant (sodium dodecyl sulfate) above the critical micellar concentration (a–c) and with small amounts of 1 M mol. wt. PEO polymer (polyethylene oxide) (d–f) were entrained at constant speed on a polyester fiber (18 μm OD) frame. Film thicknesses ranged from tens of nanometers (black film) to several μm. The interference colors by white light illumination were used to reconstruct the interfacial shape for comparison with theoretical predictions. Detailed quantitative studies were obtained with a modified optical setup.[3,4]

The fingering patterns at the vertical and bottom edges of the film (a–b), stemming from marginal regeneration, evolve from Marangoni instabilities[5–7] caused by a surfactant surplus in the meniscus region (bottom edge). Black films, which are thinner than a quarter wavelength of visible light, appear as expanding holes in the upper film (c). These stratified regions grow in size to produce droplets, which decorate the black film circumference and fall toward the visible film border (light gray), a process resembling falling snow.

The presence of surfactant–polymer complexes, as with SDS/PEO, modifies the entrainment and drainage[3,4,8] dynamics. Above the edge undergoing marginal regeneration in (d) there propagates from left to right a dendritic instability [(e): magnified and enhanced image of (d)], which advances as a fractal front into the black film. The front propagated a distance of 1 cm with an approximate speed of 100 μm/s. The region behind the advancing front likely represents a collapsed state[8] in which the less mobile polymer is denuded of surfactant micelles which collect along the serpentine boundary. This boundary rapidly undergoes a transition from fractal to nonfractal shape (e), as numerous droplets (yellow) decorate the shrinking periphery. The thickness fluctuations at the regeneration border in (f), which flow much more slowly than in (a) due to the polymer-enhanced viscosity of the film, create striking patterns resembling floating plumes.

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