(a)

(b)

(c)

(d)

(e)

(f)

Streamlets and Branching Dynamics in Surfactant Driven Flow

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The spreading of a surface active film on a liquid layer of higher surface tension is known to produce an unusual fingering instability.[1–3] Calculations based on linear stability and transient growth analysis suggest that Marangoni and capillary stresses cause dramatic variations in film thickness.[4,5] These variations resemble dendritic streamlets of liquid which undergo repeated branching. Despite the similarity to viscous fingering patterns, the physical mechanisms controlling flow and instability are quite different.

In this experiment, a 10 μm layer of glycerol, with surface tension 63.4 dyn/cm, was first spin-coated onto a cleaned 10 cm silicon wafer. The wafer was raised toward a chromium-nickel wire (142 μm diameter) which was stretched between two posts and positioned in the focal plane of a microscope fitted with a 540 nm bandpass filter. The wire was coated with a film of oleic acid. Since the surface tension of oleic acid is 32.5 dyn/cm, it spontaneously spread across the surface of the glycerol rapidly thinning the liquid layer. Figures (a)–(f) depict various examples of plume or fingerlike patterns that form during the spreading process. The sequence of periodically spaced circular patterns shown in (a)–(c) are droplets of oleic acid (250 μm diameter) caused by a Rayleigh instability as the wire was lifted from the glycerol layer. Each photograph spans ~2.5 mm; the contour lines represent interference fringes. In (e), streamlets appear just ahead of the oleic drop in a region strongly thinned by the initial spreading front. The thinner the initial glycerol layer, the more ramified the spreading patterns which develop, as seen in (f).

[1] A. Marmur and M. D. Lelah, Chem. Eng. Comm. **13**, 133 (1981).
[2] S. M. Troian, X. L. Wu, and S. A. Safran, Phys. Rev. Lett. **62**, 1496 (1989).
[3] M. Cachile and A. M. Cazabat, Langmuir **15**, 1515 (1999).
[4] O. K. Matar and S. M. Troian, Phys. Fluids **11**, 3232 (1999).
[5] B. J. Fischer and S. M. Troian, Phys. Fluids (submitted).