

Rising Plumes, Layering Transitions and Squeeze-Out Patterns in Soap Films

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Foams are common materials in everyday life like in food, cosmetics and detergents. They are comprised of individual soap film lamellae whose interfaces are stabilized by amphiphilic or surface active molecules (surfactants). The drainage behavior of individual lamellae can have a significant influence on foam stability.

Initially a single free-standing soap film lamella has a film thickness of few micrometers and undergoes hydrodynamic drainage caused by gravity and capillary forces. In the hydrodynamic regime the fluid dynamics is coupled with the surfactant dynamics via the interfacial tension σ . Presumably this coupling is also the main cause for dynamic (instability) patterns near the film border that do resemble rising "lava plumes" and are known in literature as "Marginal Regeneration" [1,2]. Our recent studies on aqueous soap films indicate that these moving patterns may have a substantial contribution to the drainage rate also changing the scaling exponent of the film thickness as function of time $h(t)$ [3].

As thinning films become less than ≈ 100 nm thick (termed "black films" because of their low optical reflectivity) their behavior is getting increasingly influenced by molecular properties. Soap films that contain surfactant micelles (with few nanometers diameter) often thin in steps (layering transitions) and not continuously anymore. Usually the thinning regions expand in the lateral directions with a circular or elliptical shape. Recently we observed a novel layering transition expanding with a fractal pattern in soap films that contain the aggregating polymeric additive poly-(ethylene oxide) which is very common in industrial soaps and foams.

This instability is triggered by the final thinning transition and linked to the degree of association between surfactant and polymer additive. It generates constant growth fractal patterns whose dimension correlates with the bulk viscosity of the fluid inside the soap film lamella. A mapping to the Saffman-Taylor instability [4] reveals the critical viscosity contrast for a phase segregation into polymer-rich and polymer-poor phases. A secondary instability for high polymer molecular weights causes the fractal phase to self-assemble into a macroscopic 2-d array of flattened nanodroplets with distinct 4-fold packing symmetry.

References

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