Stability of Evaporating Films in the Absence of Gravity - Isolation of Instability Mechanisms.

A. D. Narendranath[1], J. S. Allen[1] and J. C. Hermanson[2], [1]Michigan Technological University, Houghton, MI, USA (jstallen@mtu.edu), [2]Department of Aeronautics and Astronautics, University of Washington, Seattle, WA, USA (jherm@aa.washington.edu)

The stability of an evaporating film is of interest in a number of technologies and processes from coatings, paints, and food products to low-gravity systems such as water recovery systems. Physical mechanisms may stabilize or destabilize the films. Some of these mechanisms are gravity, surface tension and interface curvature, Marangoni stresses, buoyancy-induced convection, and vapor recoil. There is a need to understand under what thermal conditions each mechanism become important. In normal gravity with a stable upward facing, evaporating, thin liquid film, the destabilization mechanisms are difficult to isolate and study due to the overwhelming stabilization of gravity. Nonetheless, these destabilization mechanisms do affect the film in a terrestrial environment. A classic examples is the 'crinkling' of paint as it dries. Another example occurs in soft lithography processes in which surface waves are permanently left in a layer of photoresist after drying. In reduced gravity, the absence of a strong stabilization mechanism may result in a complete loss of a film, as has been observed in evaporation of sludge for water recovery. [ref]

The stability, convective structure and heat transfer of upward facing, evaporating, thin liquid films are being studied experimentally and modeled analytically. Various heating conditions, constant wall superheat, bulk superheat, and impulsive superheat, have been used to try and isolate destabilization mechanisms. Analytically, we are relaxing the periodic boundary condition normally used in order to investigate the effect of boundary geometry on film stability particularly in the absence of gravity where instability wavelengths may grow to the size of the boundary.

Access to quality, long-duration, (3-5 minutes) low-gravity environment would enable the isolation and study of destabilizing mechanisms on large-area liquid films.

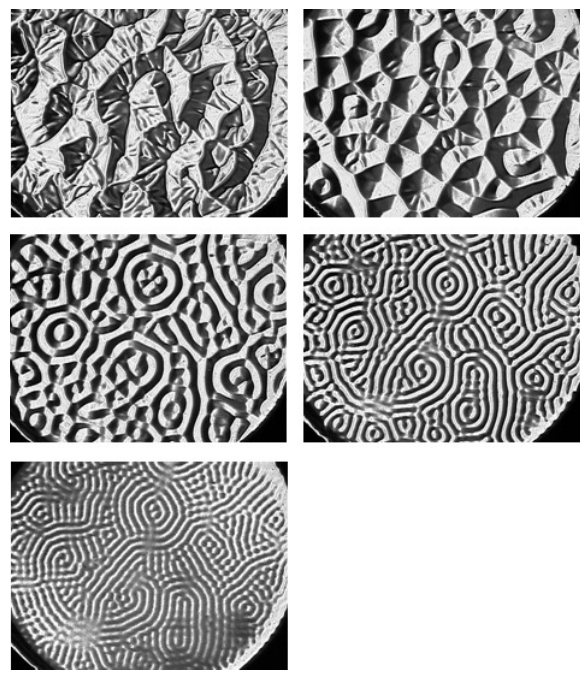

Figure 1: Progression of convective instability patterns as an evaporating liquid film thins. The images were acquired using double-pass schlieren imaging.