Heat Transfer in an Oscillating Meniscus

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Abstract

Experimental data for oscillations occurring at the three phase contact line of an evaporating HFE 7000 meniscus on a silica substrate is presented. The frequency of the oscillations were found to depend on the local value of the evaporative heat flux. The thickness, slope, and curvature of the vapor-liquid interface were determined using an interferometry technique, which allowed us to calculate the disjoining pressure and the capillary pressure along the meniscus as a function of time. These pressure variations have the same frequency and phase as the oscillations. Steady-state and transient models have also been successfully compared with the experimental data. Using an evolution equation, it has been shown that the evaporating meniscus of a perfectly wetting film can be unstable due to thermo-capillary induced stresses that could be the origin of the observed oscillations. A transient model shows inerent dryout and rewetting as the meniscus recedes and oscillations driven by small perturbations in solid surface temperature. The complementary experimental and modeling results give considerable insight concerning the three-phase contact line region. Figure 1 shows an experimental sequence of an oscillating meniscus. The figure was compiled from 2000 individual frames. Figure 2 shows a COMSOL simulation of the film thickness profile for an oscillating, evaporating meniscus. The simulation was based on a weak form boundary simulation of the film thickness evolution equation tied to a 2-dimensional simulation for heat transfer in the substrate.

Figures used in the abstract

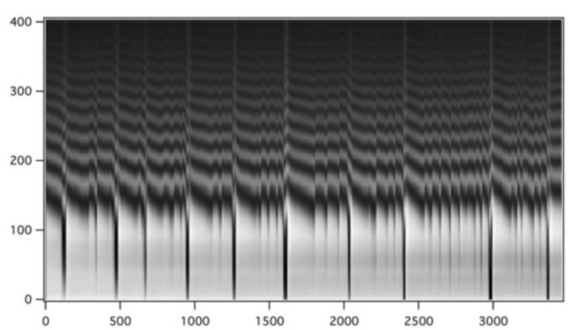

Figure 1: Experimental time sequence of an oscillating evaporating meniscus.

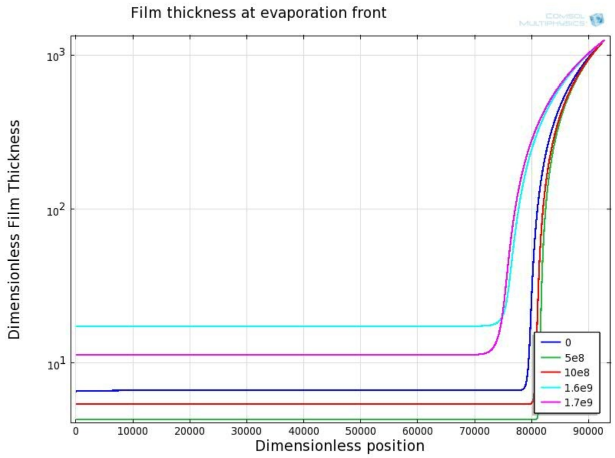

Figure 2: COMSOL simulation of an oscillating meniscus.