Abstract Submitted
for the DFD11 Meeting of
The American Physical Society

Diffusion-Controlled Evaporating Perfectly wetting meniscus

JEAN-PIERRE NJANTE, STEPHEN MORRIS, UC Berkeley — The Stefan diffusion theory is often used to predict the evaporation rate from capillaries. Following Derjaguin et al (Bull. Rilem, 1965), we show here that because the simple diffusion theory does not include mass loss from the precursor film, it significantly under-estimates mass loss from small (μm-sized) capillaries. We make the following simplifying assumptions. (a) Diffusion is rate limiting; as a result, liquid and vapor at the interface are in local thermodynamic equilibrium. (b) The system is effectively isothermal; though evaporation induces liquid temperature differences, they are kinetically negligible. (c) Transport of the evaporating molecules is by axial-diffusion only. At a given axial location x, the total mass flow $\dot{m}$ is the sum of the flow within the thin liquid film and that occurring by diffusion within the gas $-\dot{m} = \frac{h^3}{3\nu}\frac{dp_\ell}{dx} + \frac{\rho_s D}{\rho R T_w}(a-h)\frac{dp_\ell}{dx} = constant$ where ν is the kinematic viscosity, R the gas constant, D the diffusion coefficient, ρ the liquid density, T_w the wall temperature, $2a$ the channel gap thickness, and ρ_s the saturation density. The interface shape $h(x)$ is related to the liquid pressure at the interface $p_\ell(x)$ by the normal stress equation $P_a - p_\ell = \gamma \frac{d^2h}{dx^2} + \frac{A}{h^3}$ where P_a is the total gas pressure and A the Hammaker constant. Our model differs from that of Derjaguin et al because including surface tension γ allows us to calculate the shape of the whole meniscus, and so to relate our results for mass loss to that given by standard theory.

Jean-Pierre Njante
UC Berkeley

Date submitted: 01 Aug 2011 Electronic form version 1.4