Modeling Contact Line Dynamics in Evaporating Menisci

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Abstract

The Constrained Vapor Bubble is a fundamental fluid mechanics experiment that is scheduled to run aboard the International Space Station starting in August 2009. The experiment is focused on looking at evaporation and condensation processes at the contact line and how processes that occur on the macroscale affect the transport processes occurring on the microscale at the contact line. Understanding the transport processes that occur at the contact line are of critical importance to a number of fields including evaporative self-assembly, coating, heat and mass transfer operations, boiling, fuel cell operations, and fundamental fluid mechanics.

Since the contact line is a region of film thickness on the order of 100 nm and evaporation and condensation processes are driven by temperature differences only on the order of 10^{-4} K, measurements are difficult and multi-scale modeling is critical to tying in how changes on the macroscale affect what occurs at the contact line. This presentation will discuss a model we have developed for evaporation at the contact line. The model solves a nonlinear, fourth-order evolution equation for the film thickness and from that predicts the contact angle, interfacial curvature, fluid flow and evaporation rate from the meniscus surface. We compare the results of the model with experimental, ground-based data and discuss extensions of the model to handle Marangoni convection, meniscus oscillation, and fluid velocity profiles within the meniscus.

Table 1
Experimental Heat Flux Data on Rough Surfaces

	q_{avg}" x 10^5 (W/m^2)	
	0.25 W	**0.75 W**
Smooth	2.50	3.27
30 min etch	2.88	3.80
60 min etch	3.00	3.80
Deposited oxide	2.90	4.10

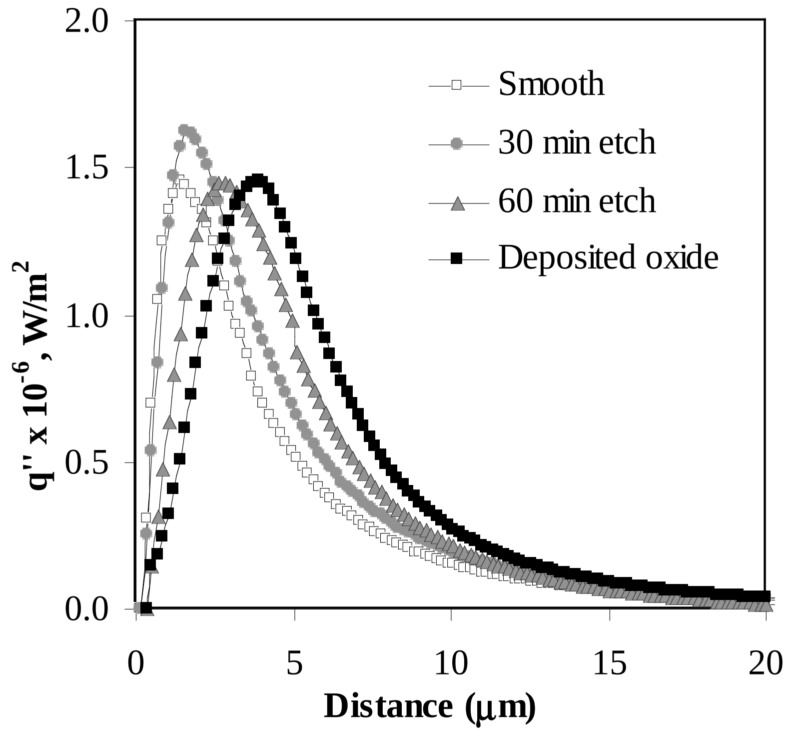

Figure 1 Predictions of heat flux profiles for the surfaces in Table 1.