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Observation of the Time-Invariant Nature of Evaporating Thin Films: Insights from SPR Imaging

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Extended Abstract

The evaporating thin film (ETF) plays a critical role in heat dissipation due to the substantially enhanced evaporation flux. Despite its fundamental importance in interfacial evaporation dynamics, direct experimental characterization of the ETF [1-3] has remained a significant challenge, resulting in a limited understanding of its temporal evolution. This presentation provides the first direct experimental evidence demonstrating the time-invariant nature of ETF profiles during the pinning stage of droplet evaporation, offering novel insights into interfacial evaporation mechanisms using the surface plasmon resonance (SPR) imaging [4-5]. The ultra-thin liquid film profiles are measured under varying surface wettability conditions through a self-assembled monolayer (SAM) on a gold substrate. A theoretical model incorporating kinetic theory and the augmented Young-Laplace equation is also employed to quantitatively examine the finite evaporation flux in the ETF region. The findings reveal that the ETF profile remains time-invariant during the pinned stage, exhibiting local equilibrium characteristics, and theoretical predictions show good agreement with experimental observations. Notably, it is found that surface wettability has a minor influence on variations in ETF profiles, and the disjoining pressure is found to be higher on hydrophilic substrates, contributing to further thinning of the ETF. Furthermore, these findings indicate that higher surface wettability enhances ETF thinning, thereby improving heat dissipation via maximum evaporation flux.

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