Measured Vapor Distributions Above Sessile Drops and Implications for Vapor Transport

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Abstract: Sessile drop evaporation is an important topic for a wide variety of applications, including spray cooling, coating, combustion, ink jet printing, and surface patterning. The evaporation of a sessile drop involves many physical processes and for many conditions, the rate of evaporation is determined by the transport rate of the vapor away from the drop surface. While vapor transport is known to involve diffusion and convection, the manner in which these transport processes interact to control the evaporation rate is not well defined. The goal of this study is to obtain quantitative information from measured vapor concentration distributions about the rates of vapor phase diffusion and convection.

With knowledge of the vapor distribution, the gradient may be computed in order to evaluate the diffusive flux. The diffusive flux was integrated along the surface of a cylindrical control volume surrounding the drop to obtain the net rate of diffusion out of the control volume. Only the component normal to the surface was employed to compute the total diffusive rate from the control volume. For a steady-state condition the evaporation rate is equal to the sum of the vapor transport by diffusion and convection and therefore by comparing the diffusion rate to the evaporation rate the strength of convection may be inferred. Furthermore, by varying the dimensions of the control volume, regions where convection and diffusion are high may be determined.

The rate of diffusion computed from the measured vapor distribution is compared to the diffusive rate assuming that convection is negligible, which is a common assumption in modeling sessile drop evaporation. In the case of diffusion-only transport, the vapor distribution is described by the solution to the Laplace equation. The diffusion rates computed from the vapor measurements are much different than what is computed for diffusion-only evaporation. Consequently, in order to account for the overall evaporation rate, convection must be occurring and the common modeling assumption of diffusion-only evaporation is not valid. The results suggest the convective flow is downward over the drop and radially outward at the side of the drop.

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