Evaporation from Microreservoirs

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ABSTRACT

As a result of very large surface area to volume ratios, evaporation is of significant importance when dealing with lab-on-a-chip devices that possess open air/liquid interfaces. For devices utilizing a reservoir as a fluid delivery method to a microfluidic network, excessive evaporation can quickly lead to reservoir dry out and overall device failure. Predicting the rates of evaporation from these reservoirs is difficult because the position of the air/liquid interface changes with time as the volume of liquid in the reservoir decreases. Here we present a two-step method to accurately predict the rates of evaporation of such an interface over time. First, a simple method is proposed to determine the shape of an air/liquid meniscus in a reservoir given a specific liquid volume. Second, computational fluid dynamics simulations are used to calculate the instantaneous rate of evaporation for that meniscus shape. It is shown that the rate of evaporation is strongly dependent on the overall geometry of the system, enhanced in expanding reservoirs while suppressed in contracting reservoirs, where the geometry can be easily controlled with simple experimental methods. Using no adjustable parameters, the model accurately predicts the position of the inner moving contact line as a function of time following meniscus rupture in poly(dimethylsiloxane) reservoirs, and predicts the overall time for the persistence of liquid in those reservoirs to within 0.5 minutes. The methods in this study can be used to design holding reservoirs for lab-on-a-chip devices that involve no external control of evaporation, such that evaporation rates can be adjusted as necessary by modification of the reservoir geometry.

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