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NUMERICAL ANALYSIS OF LIQUID FILM EVAPORATION IN MICRO CAVITIES

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Liquid film evaporation in a micro cavity, which occurs in inkjet fabrication of micro and display devices [1], is numerically simulated by solving the conservation equation of mass, momentum, energy and mass fraction in the liquid and gas phases. In the inkjet process, liquid droplets including the functional materials are deposited on the substrate with micro cavities and dried (or evaporated) to recover the functional materials. Despite extensive studies of inkjet applications, a general predictive model for liquid film evaporation applicable to inkjet fabrication has not yet been developed.

In this study, a sharp-interface level-set method is presented for computing the liquid film evaporation in cylindrical or rectangular cavities. The method for tracking the liquid-gas interface is modified to include the effects of evaporation at the liquid-gas interface and contact angle at the liquid-gas-solid contact line. The matching conditions of velocity, stress, temperature and mass fraction at the phase interfaces are accurately imposed by incorporating the ghost fluid method based on a sharp-interface representation.

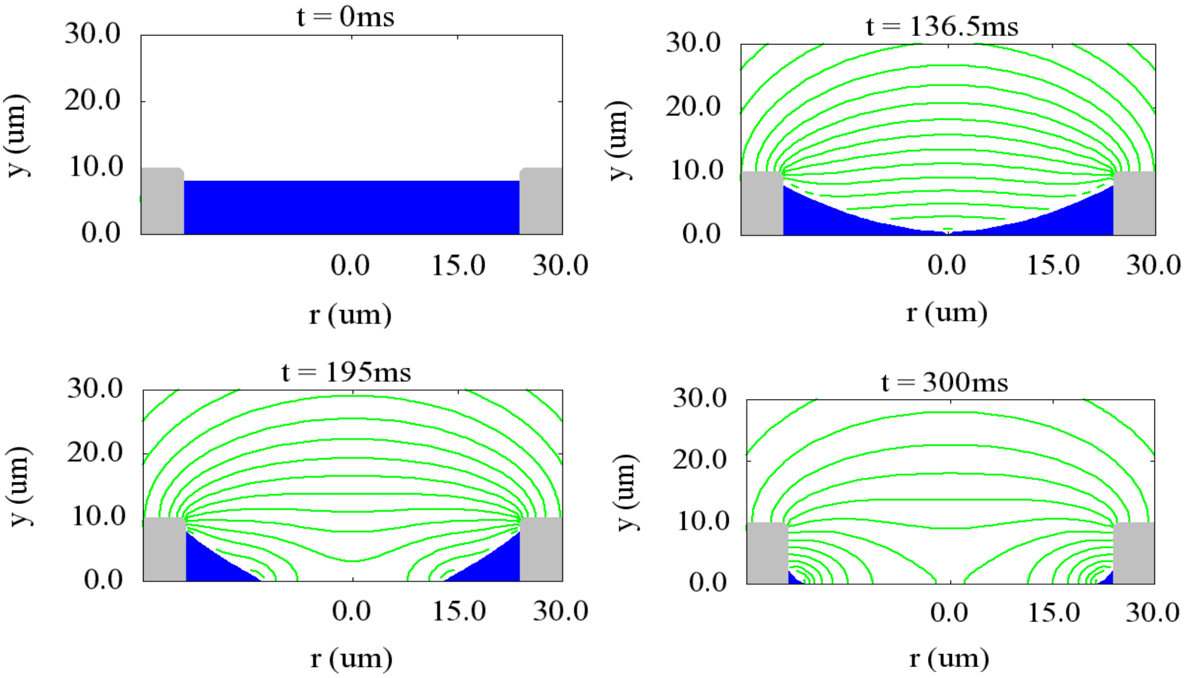


Fig 1. Liquid-gas interfacial motion and the associated vapor mass fraction field at $\theta = 90°\sim30°$

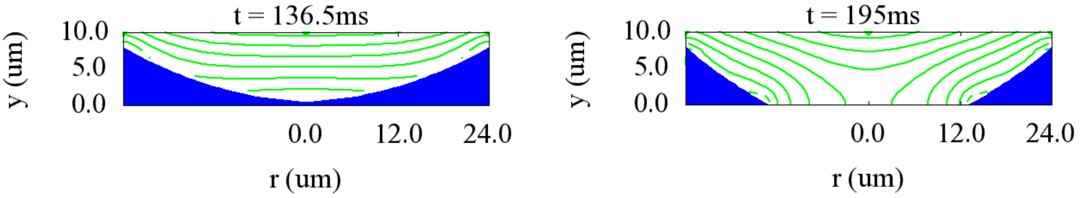
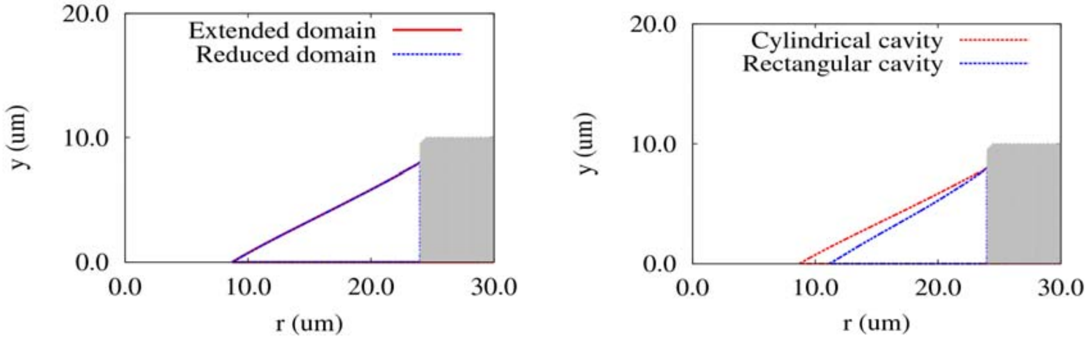


Fig 2. Numerical results with the modified boundary condition for mass fraction at $\theta = 90°\sim30°$



(a) (b)

Fig 3. Comparison of the interfaces at $t = 150$ms: (a) with different sizes of computational domain for a cylindrical cavity and (b) with different cavity geometries.

Fig. 1 shows the evolution of an evaporating liquid-gas interface in a cylindrical (or axisymmetric) cavity with dynamic contact angles varying in the range of 90-30°. The computational domain is chosen as a region of $r \leq 426$um and $y \leq 1560$um. Uniform meshes with 1um are used near the cavity whereas nonuniform meshes with the ratio of two adjacent intervals of 1.1 are used for the other regions. The initially uniform liquid film is deformed to have a concave shape as the liquid volume decreases with evaporation while the liquid-gas-solid contact line sticks on the side wall. Thereafter, the liquid-gas interface starts to contact the bottom wall in the center of the cavity, and the contact line moves down the side wall as the contact angle is decreased to the receding contact angle of 30°.

In this study, efforts are made to reduce the computational domain to the region inside the cavity, $r \leq 24$um and $y \leq 10$um, by introducing the effective mass transfer resistance for the truncated outer region. The effective resistance is numerically estimated by comparing with the computation over the extended domain. The results are plotted in Figs. 2 and 3(a). The results for the interfacial motion and mass fraction obtained from the reduced and extended domains shows no significant differences. This means that the effective mass transfer resistance can be used to reduce the computational domain and thus to save the computing time. The present method is also proven to be applicable to three-dimensional computation of liquid film evaporation in a rectangular cavity, as shown in Fig. 3(b).

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REFERENCES

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