Multiphysics Simulation of Droplet Formation in OLED Inkjet Printing

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1 Background and objective

OLEDs offer self-emission, high contrast, fast response, and flexibility, while inkjet printing enables maskless, material-efficient, and large-area fabrication. However, the microsecond-scale droplet formation and breakup process is difficult to fully capture experimentally. This work uses COMSOL Multiphysics to investigate transient droplet ejection and breakup and identify the effects of key driving and structural parameters.

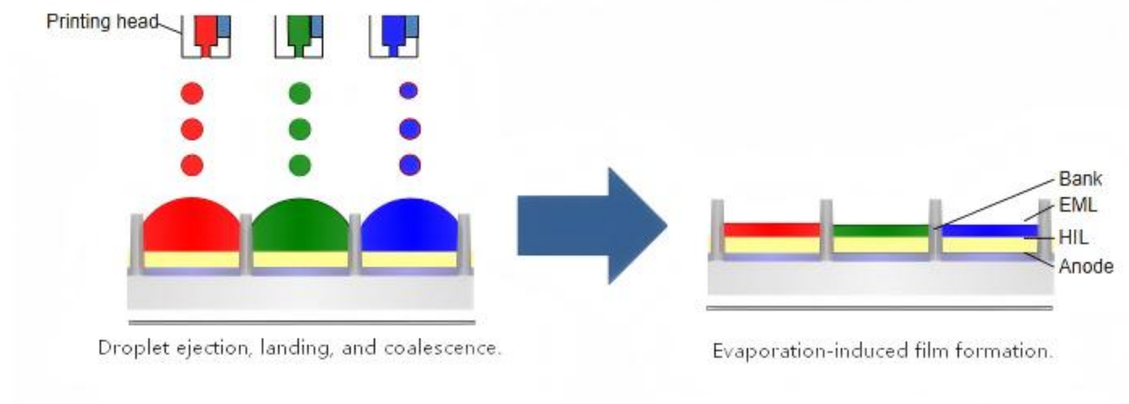


Figure 1. OLED inkjet printing process.

2 Printhead and multiphysics model

A transient multiphysics model was established in COMSOL based on a Chevron-type piezoelectric printhead, in which adjacent PZT segments have opposite polarization directions. Electrostatics, Solid Mechanics, Laminar Flow, and Level Set were employed to describe the sequential process of electrical actuation → wall deformation → fluid motion → liquid–air interface evolution.

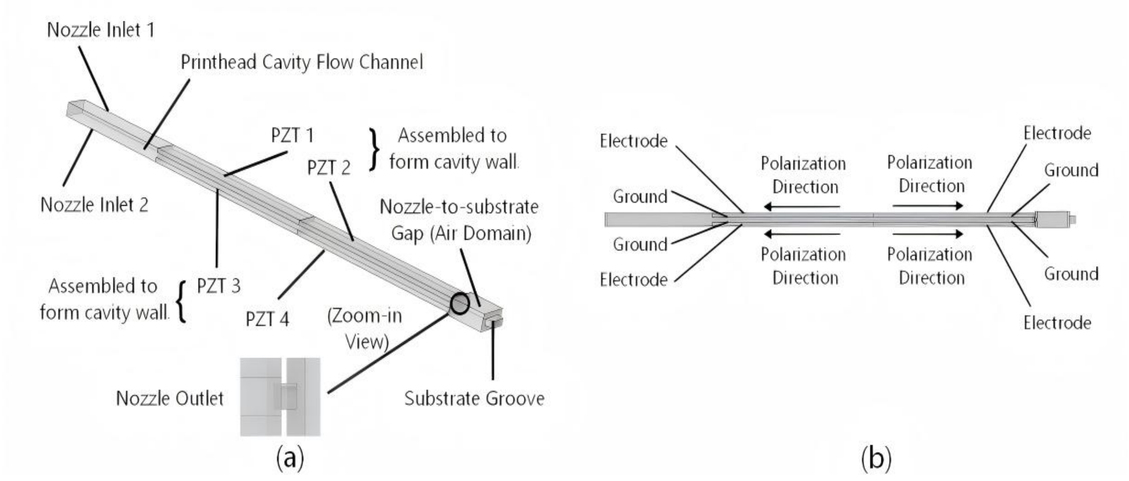


Figure 2. Printhead geometry (a) and electrical configuration (b).

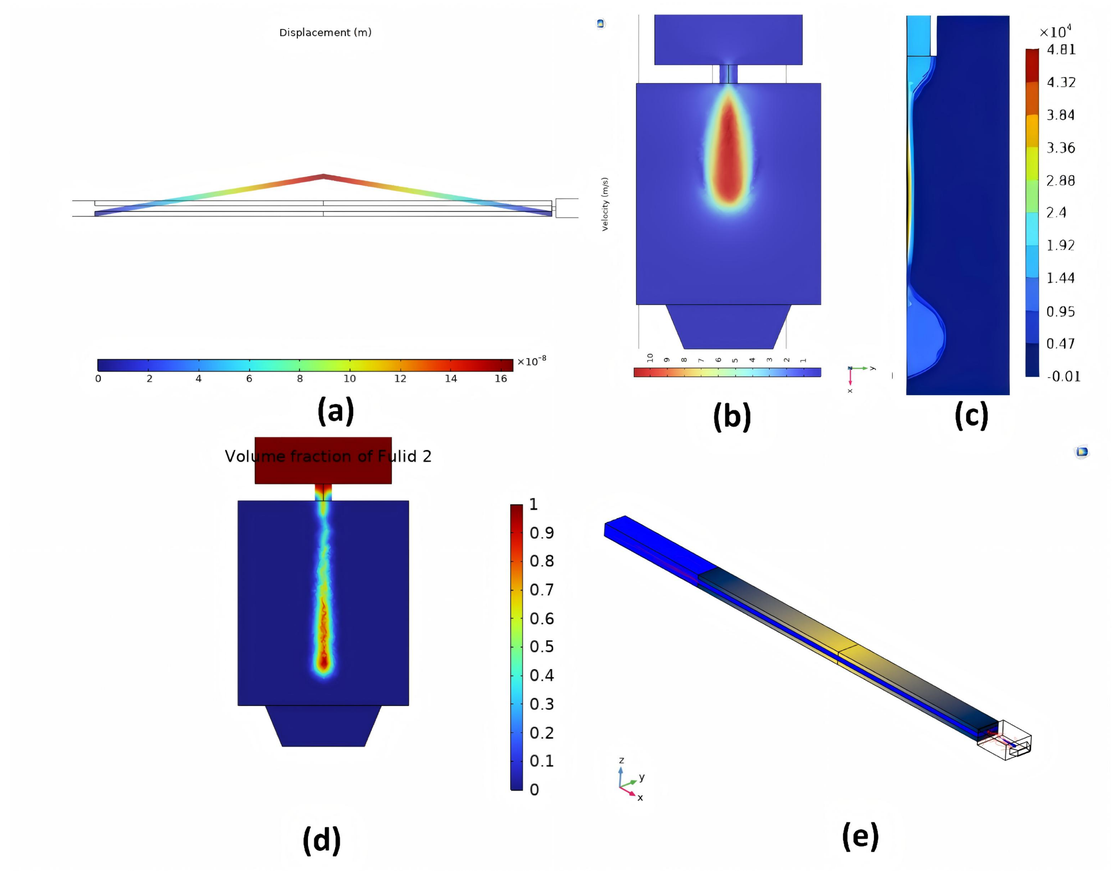


Figure 3. Deformation, velocity, pressure, two-phase flow and overall model output.

3 Results and discussion

High-precision droplet breakup in the OLED printhead is governed by the dynamic interplay among piezoelectric actuation, fluid inertia, and capillary surface tension. Parametric sweeps indicate that driving voltage and PZT splicing position determine fluid kinetic energy and wall volume displacement, where moderate voltage and midpoint PZT placement yield stable inertia-driven breakup without premature necking or structural constraint. Meanwhile, tuning pulse width and falling-edge ratio balances ejection momentum with retraction suction and acoustic wave superposition, effectively optimizing droplet morphology while mitigating satellite formation and jetting failure.

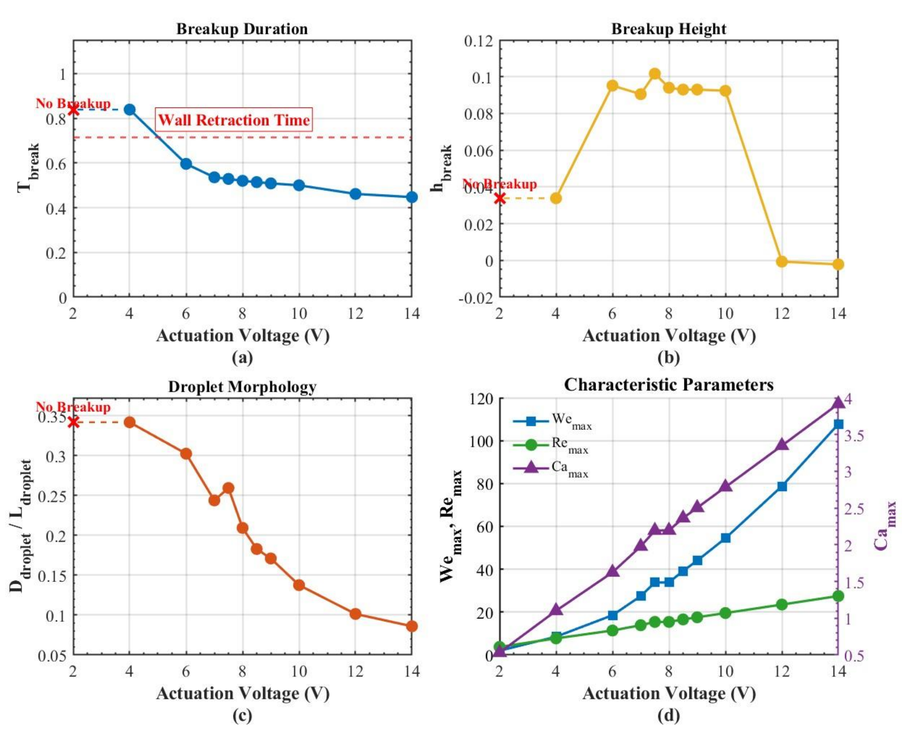


Figure 4. Representative parametric-analysis result: droplet breakup characteristics versus peak driving voltage.

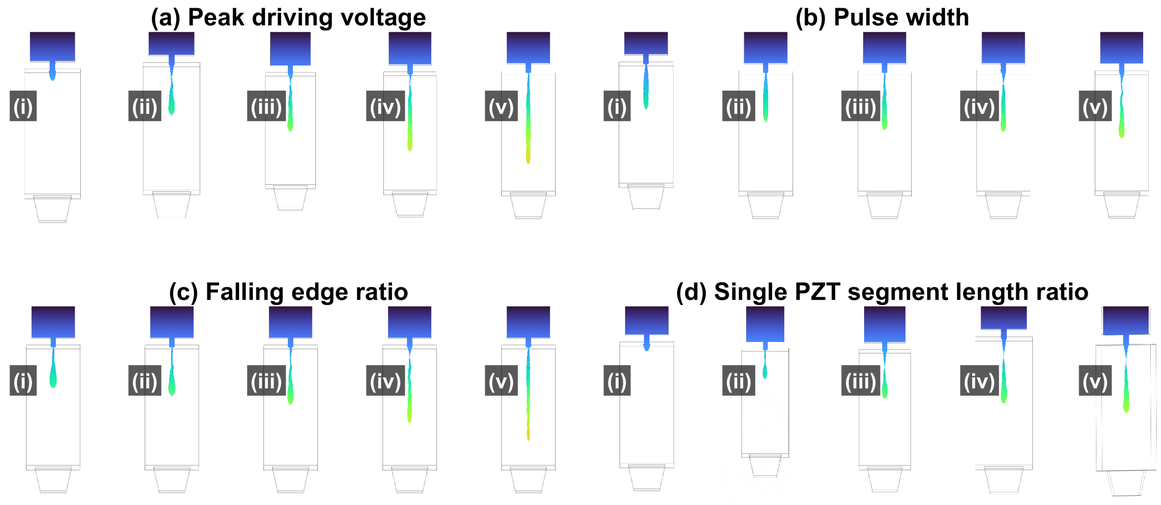


Figure 5. Droplet morphologies at the breakup instant under varying parameters: (a) peak driving voltage (i: 2 V, ii: 6 V, iii: 8 V, iv: 10 V, v: 12 V); (b) pulse width (i: 0 μs, ii: 5 μs, iii: 15 μs, iv: 25 μs, v: 40 μs); (c) falling edge ratio (i: 12.5%, ii: 25%, iii: 37.5%, iv: 62.5%, v: 87.5%); and (d) single PZT segment length ratio (i: 5%, ii: 15%, iii: 25%, iv: 35%, v: 45%).

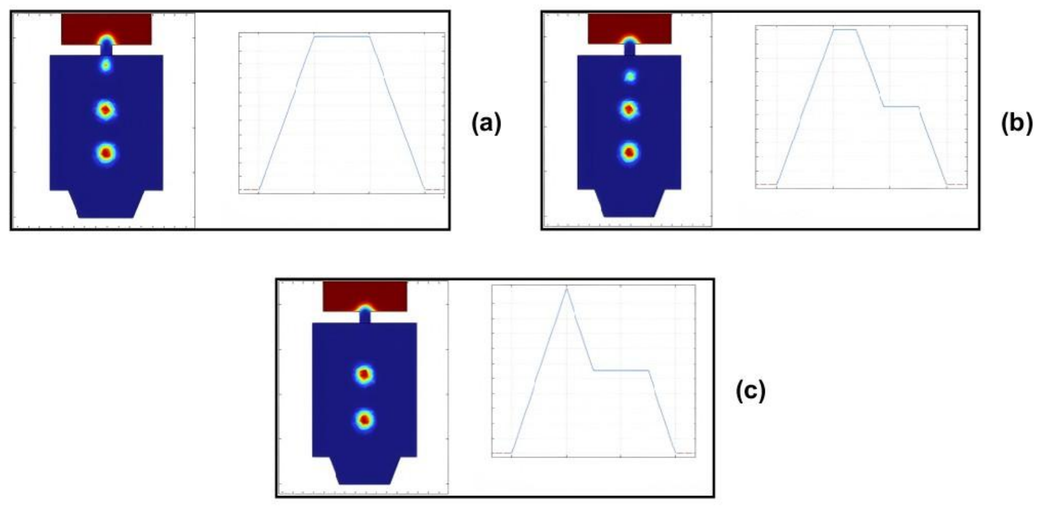


Figure 6. Droplet breakup under different actuation waveforms (introducing a stepped voltage-fall profile): (a) standard single pulse, (b) Step Waveform 1, and (c) Step Waveform 2.

4 Conclusions

Multiphysics simulation provides deep engineering insights into the complex fluid dynamics of OLED inkjet printing, offering robust methodological support for high-precision printhead design and advanced manufacturing optimization.

References

[1] Liang H et al., ISCTIS 2026, pp. 1443–1453.
[2] Banerjee S et al., Chemistry—An Asian Journal 20(4), e202401291 (2025).
[3] Yang Z et al., Research 6, 0248 (2023).

Acknowledgments

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