9th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMA2024)
June 3-7, 2024, Lisbon, Portugal

MODERN APPROACHES TO MULTIPHASE FLOWS IN MICROFLUIDICS: BUBBLES, DROPLETS, WETTING, AND TRANSPORT IN COMPLEX MEDIA

S. AFKHAMI*, T. MARIC†, M. FRICKE†, M. HASHEMI††, P. RYZHAKOV††

* New Jersey Institute of Technology
www.njit.edu, shahriar.afkhami@njit.edu
†Technical University of Darmstadt, Germany
www.tu-darmstadt.de, maric@mma.tu-darmstadt.de
†† Technical University of Catalonia(UPC)/CIMNE , Barcelona, Spain
www.cimne.com, pavel.ryzhakov@upc.edu

Key words: multiphase, droplets, fluid dynamics, wetting, surface tension, interfaces

ABSTRACT

Microfluidic multiphase flows are crucial for many engineering systems, such as Lab-On-a-Chip, inkjet printers, fuel cells, microreactors, oil-gas/water transport and CO2 sequestration in porous media. In most such cases, the liquid-gas system forms a contact line with the solid surfaces. Tending to reach its equilibrium configuration, the three-phase system exhibits a dynamic behavior, which is particularly determined by its physicochemical properties [1]. The multiphase behavior, in particular, contact line dynamics in many of these microfluidic systems still needs to be fully understood. New numerical methods that can accurately handle contact line dynamics in complex geometries are under active development [2,3]. Theoretical models fall into three main categories: those focused on the microscopic scale, in particular molecular dynamics, mesoscopic descriptions like phase field models and those developed at the continuum level. Combining the outcomes of these three categories can improve modeling and physical understanding [4]. Some recent works tend to enrich the existing modeling approaches with the use of data-driven methods [5]. Development of the Machine Learning approaches [6] has opened new horzions for tackling challenges such as curvature approximation, model discovery for contact line dynamics, and optimization of complex microfluidic systems. Data-driven methods can also be a means for improving the efficiency of the numerical modeling of multiscale phenomena [7]. We will discuss the latest research on how data-driven methodologies can improve both microfluidic system designs and the understanding of complex multiphase flow dynamics.

Overall, the present mini-symposium will bring together researchers working on the different types of micro/meso and macroscopic modeling and simulation of multiphase flows in microfluidic applications as well as the emerging application of data-driven methods in multiphase microfluidics.

References

[1] Zhang, Yichuan, Mingming Guo, David Seveno, and Joël De Coninck. "Dynamic wetting of various liquids: Theoretical models, experiments, simulations and applications." Adv. in Colloid and Interf. Sc. (2023): 102861.
[2] Yi, Ding and Spelt: Numerical Simulations of Flows with Moving Contact Lines, Annual Review of Fluid Mechanics (2014) [DOI: 10.1146/annurev-fluid-010313-141338]
[3] S. Afkhami: Challenges of numerical simulation of dynamic wetting phenomena: a review, Current Opinion in Colloid & Interface Science, https://doi.org/10.1016/j.cocis.2021.101523, 2022
[4] Lacis et al.: Nanoscale sheared droplet: volume-of-fluid, phase-field and no-slip molecular dynamics, Journal of Fluid Mechanics, [DOI:10.1017/jfm.2022.219] (2022)
[5] Galan, E. A., Zhao, H., Wang, X., Dai, Q., Huck, W. T., & Ma, S. (2020). Intelligent microfluidics: The convergence of machine learning and microfluidics in mat. science and biomedicine. *Matter*, *3*(6), 1893-1922.
[6] Brunton, S. L., Noack, B. R., & Koumoutsakos, P. (2020). Machine learning for fluid mechanics. Annual review of fluid mechanics, 52, 477-508.
[7] Buhendwa, Aaron B., Deniz A. Bezgin, and Nikolaus A. Adams. "Consistent and symmetry preserving data-driven interface reconstruction for the level-set method." Journal of Computational Physics 457 (2022): 111049.