NUMERICAL SIMULATION OF TWO-PHASE FLUID MOTION IN MICROCHANNEL BASED ON PHASE-FIELD MODEL

Naoki Takada¹*, Junichi Matsumoto¹ and Sohei Matsumoto¹

¹ National Institute of Advanced Industrial Science and Technology (AIST), Namiki 1-2-1, Tsukuba, Ibaraki 305-8564, Japan, naoki-takada@aist.go.jp, http://www.aist.go.jp/


In this study, Allen-Cahn (AC) and Cahn-Hilliard (CH)-type diffuse-interface advection equations based on phase-field model (PFM) [1-5] are examined for computational fluid dynamics (CFD) simulation of motions of microscopic immiscible incompressible isothermal two-phase fluid contacting solid surface with heterogeneous wettability. For solving an AC equation revised in conservation form, a lattice-Boltzmann method (LBM) [6,7] based on fictitious mesoscopic particle kinematics is adopted [8]. The revised AC and CH equations without interfacial curvature-induced diffusion flux are tested through simple benchmark problems of two-phase interface advection [8,9]. It is confirmed that both the volume and the shape of fluid with interfacial finite thickness have been well conserved during the advection on a spatial structured grid not only by the CH equation, but also by the AC equation that is equivalent to a one-step conservative level-set equation [5].

In addition, for developing a novel micro-fabrication process of flexible thin-film display MEMS (Micro-Electro-Mechanical-Systems) device [10], liquid-liquid two-phase slug droplets formation in T-junction microchannel with square cross section and hydrophilic solid walls [11] is investigated through three-dimensional CFD simulation using a PFM-based interface-tracking method [9]. It numerically solves the revised AC equation with Navier-Stokes equations by use of the semi-Lagrangian-formed LBM scheme to second-order accuracy in both space and time [6,7]. The ratio of volumetric flow rate of dispersed phase to that of continuous phase is fixed at 1.0 within low Reynolds, capillary and Weber numbers for silicone oil-pure water system with hydraulic diameter $w$ of 100 $\mu$m, kinematic viscosity of 1.0 cSt. and interfacial tension $\gamma$ of 41.6 mN/m. The major findings are as follows: (1) The PFM-based method predicts well pressure increase inside spherical droplet proportional to interfacial curvature in agreement with the Laplace-law solution; (2) The continuous-phase (water) and dispersed-phase (oil) slug droplets (Fig.1) become shorter at nearly-constant length difference between them as their flow rates are increased; (3) Their lengths and each phase volume fraction in the simulation agree well with experimental data (Fig.2) [9].

REFERENCES

[2] N. Takada and A. Tomiyama, A numerical method for two-phase flow based on a phase-


---

**Fig. 1** A snapshot of two-phase slug droplets formation in microchannel with T-junction and with square cross-sectional area $w^2$ at volumetric flow rate ratio $Q_O/Q_W = 1$ [9].

**Fig. 2** Variations in length of silicone oil $L_O$ and water $L_W$ for capillary number $Ca_W$ [9].