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

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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 mesocsopic 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 μm, kinematic viscosity of 1.0 cSt. and interfacial tension γ 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].

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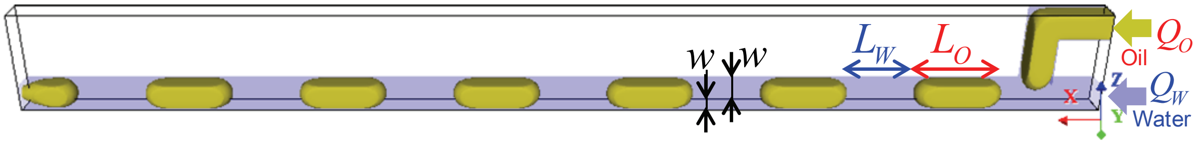

Fig. 1 A snapshot of two-phase slug droplets formation in microchannel with T-junction and with square cross-sectional area w^2 at volumetric flow rate ratio $Q_O/Q_W = 1$ [9].

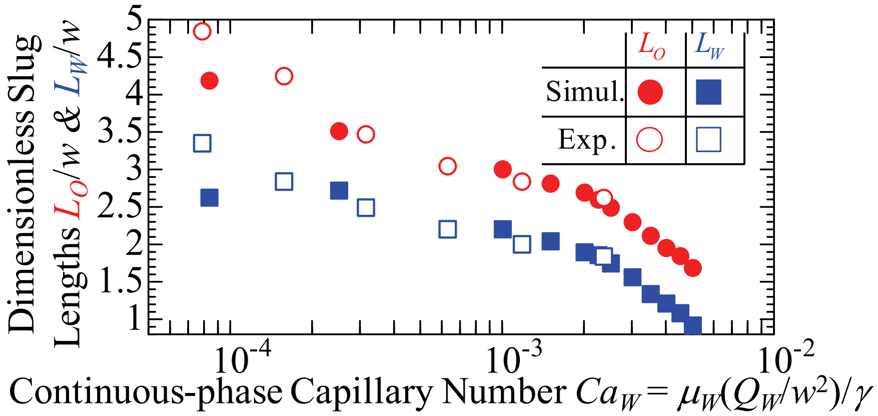

Fig. 2 Variations in length of silicone oil L_O and water L_W for capillary number Ca_W [9].