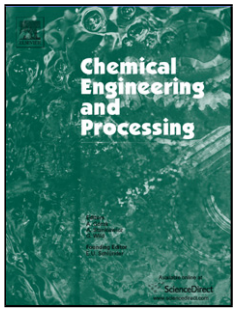

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<AT>Numerical study of Janus droplet formation in microchannels by a lattice Boltzmann method

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<ABS-HEAD>Highlights► Developed color-gradient LBM method with successful simulation of Janus droplet formation in a flow-focusing microhannel. ► Demonstrated the mechanism of Janus droplet formation mode with the Capillary number. ► Performed a deep investigation of the dynamic behavior of dispersed thread in the droplet forming process. ► Revealed the evolution behavior of each part of dispersed thread.

<ABS-HEAD>Abstract

<ABS-P>A ternary lattice Boltzmann method based on the color-gradient model was successfully established to numerically investigate the Janus droplet formation in a Y-junction microfluidic device. We first validated the model by comparing the simulation results of contact relationship of mono-dispersed droplets with the theoretical solutions, and then studied Janus droplet formation and the breakup dynamics in Y-junction numerically. The results showed that the Janus droplet size obeys a scaling law during the formation. The dynamic behavior of dispersed thread, including the thread tip and minimum width of thread, revealed that the breakup of the thread is a self-thinning process. The evolution of the minimum width of dispersed thread is dominated by evolution time in a power law relationship. The deep investigation of each dispersed thread indicated that the dynamic behavior of each thread is identical before the final pinch-off in the formation process.

<KWD>Keywords: Droplet-based microfluidics; Janus droplet; Lattice Boltzmann method; Multiphase flow; Hydrodynamics

<H1>1

<H1>2

<H1>3. Introduction

Janus droplet, the precursor of Janus particle (JP) before its solidification or chemical treatment, has attracted a wide range of academic interest over the past ten years. Such a particle possesses the unique architectural property of at least two opposite sides of different chemistry [1]. The lack of centrosymmetric structure provides more extensive applications than a mono-property structure. A number of applications have been reported in the fields of biomedicine [2], material science [1], surface chemistry [3] and so on. It can be foreseen that more extensive conceivable applications based on the combination of two different chemistry hemispheres will be opened up. The formation of these exquisite structures can be divided into several categories according to their generation process. Selective surface modification [4,5] controlled surface nucleation [6,7] or deposition [8] to achieve the Janus structure, which takes several procedures by evaluating another chemical composition combined to the hemisphere of the initial particle. In addition, two distinct particles or colloids are able to be manipulated by dielectrophoretical manipulation [9] or hydrodynamic property [10] to generate Janus particle, called the self-assembled particle technique. However, these techniques encounter great challenge to scale up the productivity, which preclude these methods for widespread applications.

The droplet-based microfluidic technique has become a promising method for Janus droplet preparation at micron dimension due to its distinguishing advantages for manipulating micro-droplet hydrodynamics. One of the advantages is the capability to produce highly mono-dispersed Janus micro-droplet in a single-step with high throughput [11] and controlling the droplet size and anisotropic shapes with more flexibility. This technique for Janus droplet generation can be catalogued into two methods according to the Janus droplet formation process: indirect method [12,13] and direct method [14-16]. For the indirect method, the Janus droplet is fabricated from an engulfing double emulsion structure generated in a microchannel in advance. For the direct method, two immiscible disperse phase streams adhering to each other enter the microfluidic flow-focusing device, being sheared into Janus droplet by another flow at the orifice [14,17]. Nisisako et al. [14,18] used the direct method to provide Janus particles for varieties of systems, which