Simulation Examination for Multilayer Flow System

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Abstract—**In this study, we compared the observation experiment of a liquid-liquid interface with a simulation result about the three-phase micro channel used for an extraction reaction. As a result, each flow rate ratio greatly influences the formation of the three-phase flow. And the result of computing this multiphase flow model is corresponding to the experiment well, so the development of the unit chemistry operation model will become possible with the simulation in the future.**

Keywords—**Simulation, Multilayer flow, Liquid-Liquid Interface, Micro channel, Micro fluidics**

I. INTRODUCTION

The formation of steady oil/water flow in a micro channel is indispensable to achieve the solvent extraction that is one of the chemical operations in the micro chemical system. In order to build a solvent extraction simulation model, it is required to establish the model of the oil/water flow in a micro channel. We previously reported on the fluid simulation model of the interfacial formation evaluation by used the oil/water flow in Y-shaped channel [1]. As there are also reports using the multi-phases as solvent extraction [2], we simulated water/oil/water flow model in this paper.

II. EXPERIMENTAL

A. Multi-Phase Flow Tests

Figure 1 shows the experiment system. We used the three confluence channel which were 70μm wide and 30μm deep in the glass chip. Water was poured on both sides of the channel with the syringe pump, and the ethyl acetate was made to flow in from the center channel. The interface in the confluence part at that time was observed with the microscope. The observation began from the state that the three-phase flow was not formed. The flow rate of water was decreased, and the flow rate was measured when the interface formed again.

Table 1 shows physical properties of the solvent. Moreover, the contact angles between oil/water interface and channel wall for the calculation was estimated from the experiment result. The contact angles of the channel wall became about 10° from the meniscas when the interface vibrated as shown in Figure 2. And this value was used as a calculation parameter.

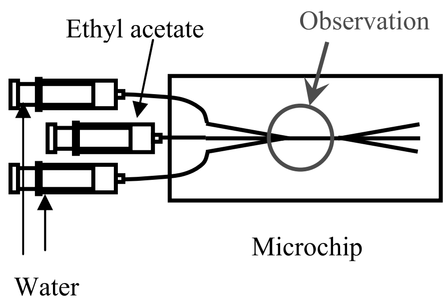


Fig. 1 Eperiment system

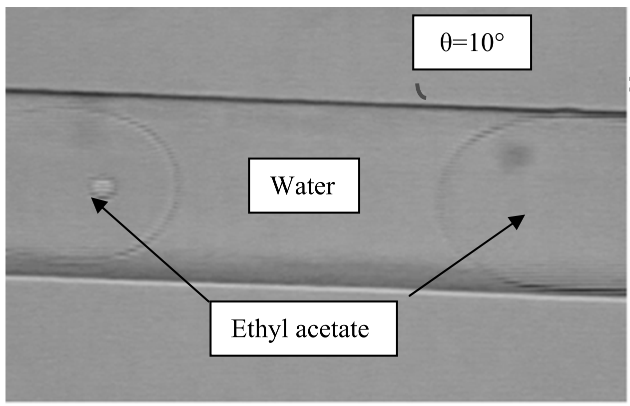


Fig. 2 Measurement of contact angles

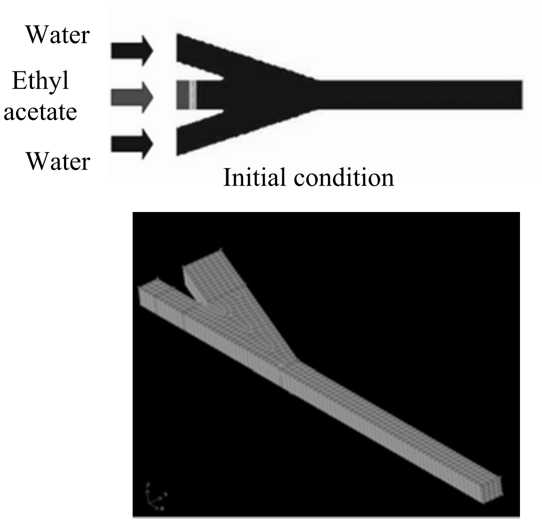
Table 1 Physical properties

	Density [g/cm^3]	Viscosity [poise]	Surface tension [dyn/cm]
Water	1.0	1.00×10^{-2}	-
Ethyl acetate	0.9	0.45×10^{-2}	6.8

B. Simulations

Behavior in micro channel on water/oil interface was requested by the numerical analysis by using the model of Figure 3. The same inflow condition as the experiment was used about this model. To confirm the interface was formed, the confluence part neighborhood was modeled. A commercial CDF code (FLUENT6.2) solved the full Navier-Stokes equations using a Finite volume method approach. To reproduce the three-phase flow as consist of the three-phase of water and oil, we used The Volume of Fluid (VOF) that was able to treat a complex transformation.

The free surface was analyzed in consideration of surface tension and the contact angle. The width of channel is 70μm and depth is 30μm, and we changed each flow rate of the water and ethyl acetate.



1/2 symmetry model

Fig. 3 Simulation model

III. RESULTS AND DISCUSSION

A. Comparison between experiment and calculation

When the three-phase flow forms the interface doesn't return and advanced while making droplet because there are a lot of flow of the ethyl acetate at the center channel. Therefore, the appearance that finally separated to the three-phase flow was confirmed from the experiment and the calculation result. An organic phase has been divided by narrowing of the width of this phase, and the contact of the interface when the three-phase flow was not formed. Therefore, the interface vibrated by droplet being made at almost the same position. Figure 4 shows the calculation result of interfacial behavior in the interfacial formation and non-formation.

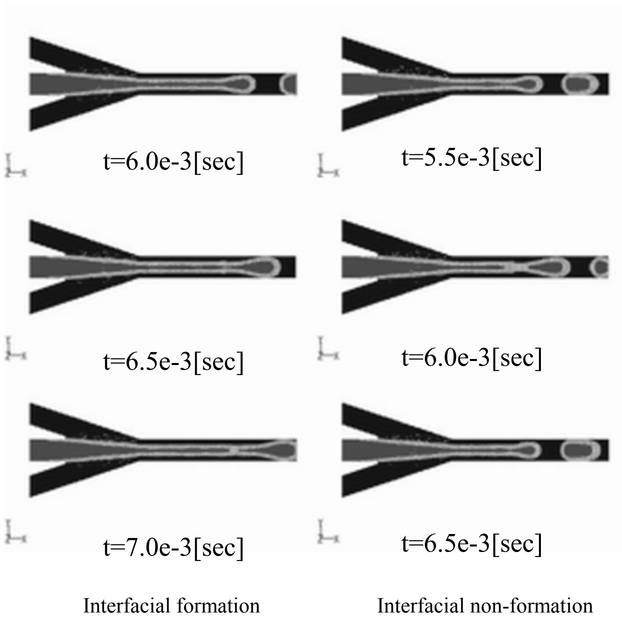


Fig. 4 Interfacial position at each time

When the flow rate of each phase is changed, the one that right or wrong of the three-phase flow formation was plotted is shown in Figure 5. The flow rate ratio of each phase (water phase/oil phase) influence was large in the formation on the three-phase flow. And it had changed from the state of the three-phase flow non-formation into the formation when the ratio was 0.35-0.45 or less.

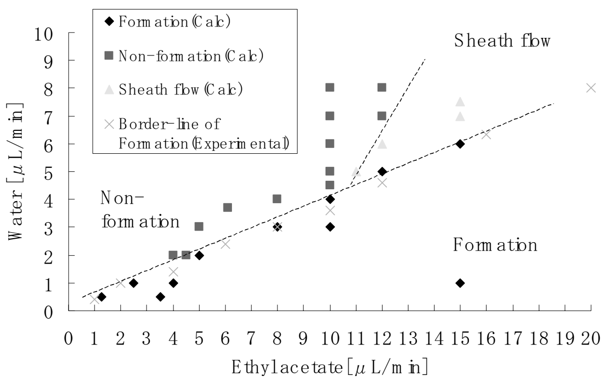


Fig. 5 Relation between interfacial formation and flow rate

Moreover, when having compared it with the calculation result, the borderline of an interfacial formation and non-formation is almost corresponding to the experiment result.

The sheath flow that was not contact with the channel wall was formed when the flow rate of oil phase was 11μL/min or more in the calculation, and the interface did not vibrate. However, this result was not confirmed by the experiment. As the reason, flow rate slightly changes actually while it is constant in the calculation. It was thought that the state that the interface has not come in contact with the channel wall was unstable, and the interface vibrated by the flow rate change.

IV. Conclusions

Consequently, the flow rate ratio of water/oil has influenced interface formation greatly. The stable interface was formed in below a certain ratio. The result of computing this multiphase flow model is corresponding to the experiment well, so the development of the unit chemistry operation model will become possible with the simulation in the future.

References

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