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Effect of surface modification on parallel flow in microchannel with guideline structure

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HIGHLIGHTS

- The organic-aqueous parallel flow in a microchannel with guideline structure was studied using computational fluid dynamics.
- The surface modification by silanization was proposed to improve the flow in the microchannel.
- The slug-parallel flow pattern transition could take place at a lower flow rate for the surface modified microchannel.

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ABSTRACT

A parallel multiphase flow provides simple phase separation of product mixture at the end of a microreactor and hence, reduces the requirements for post-treatment unit operations. Surface modification by silanization was introduced to improve organic-aqueous two phase parallel flow in a microchannel made of glass with guideline structure. The effect of surface modification on water-toluene flow pattern in the microchannel was investigated using computational fluid dynamics (CFD). With the modified surface, the interface was fixed near the centerline of the microchannel. In addition, the fluids were kept in their own lines since feeding and needed less time to stabilize. The flow pattern transition between slug and parallel flow could take place at a lower flow rate for the microchannel with modified surface. By varying the flow rate ratio, the interface position could be adjusted. Finally, the effect of channel width on the interface position was demonstrated.

1. Introduction

Microreactor which offers potential advantages over conventional reactors such as intensified mass and heat transport is an important technique of process intensification. It has been developed to improve various reaction systems [1–5]. Over the past decade, many reactions involving immiscible systems such as organic-aqueous systems have been studied in microreactors [6–9]. Due to high surface to volume ratios, microreactor can reduce the mass transfer limitations in these systems which usually involve low solubility and very low rates of reaction.

For the multiphase liquid–liquid flow in microchannels, droplet, slug, parallel and annular flows have been reported in many works [10–12]. Among these flow patterns, the parallel flow can provide a phase separation of the product mixture at the exit and thus reduces the requirements of post-treatment unit operation. A stable parallel flow with each phase in their own lanes was expected to improve the separation performance. The phase separation is important in the design of the continuous microsystem which is the combination of microunits. A guideline structure has been applied in microchannels to stabilize the parallel flow pattern [13–16]. The effect of the guideline on the flow pattern and stability was investigated in our previous work [17]. The interface became more curved and stable with the presence of the guideline structure. Besides the use of guideline structure, surface modification is another proposed method [18–21]. Hydrophilic nature of glass surface of organic phase part could be changed to be hydrophobic by silanization.

Computational fluid dynamics (CFD) which is a powerful technique applying numerical methods for analyzing flow and performance of process equipment provides many advantages over experimental approaches. It can reduce cost as well as time in engineering design. A number of works on microchannels have been studied using this CFD method. Harries et al. [22] investigated

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