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Geometric optimization of liquid–liquid slug flow in a flow-focusing millifluidic device for synthesis of nanomaterials

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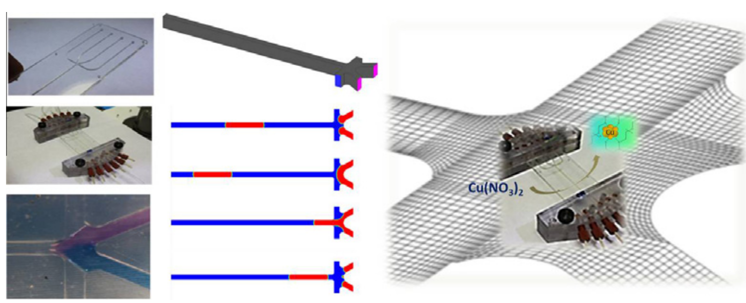
HIGHLIGHTS

- ▶ A numerical model was developed to capture slug formation hydrodynamics within millifluidic channels.
- ▶ A polymer-based flow focusing millifluidic chip was fabricated.
- ▶ The slug flow millifluidic reactor was utilized for size-controlled synthesis of copper nanoparticles.

GRAPHICAL ABSTRACT



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ABSTRACT

With recent increasing trend towards development of "easy to fabricate" and simple millifluidic systems that could provide required control as well as high throughput, we present here a demonstration of potential opportunities for controlled droplet/slug formation within a flow-focusing millifluidic chip. Numerical simulations supported by experimental evidence show that the millifluidic device provides similar control in slug formation as in the case of microfluidic devices. More specifically, our investigations reveal that the acquired slug volume depends on the squeezing volume ($V_{squeeze}$) and blockage volume (V_{block}) in the squeezing regime. While the squeezing volume ($V_{squeeze}$) can be tuned by manipulating the flow rate of the continuous phase, the blockage volume (V_{block}) depended only on the geometry of the focusing region. Based on numerical simulations, two millifluidic flow focusing channel designs to produce small slugs were suggested. The slugs were utilized for the synthesis of uniform copper nanoparticles. The findings are anticipated to have implications for a number fields ranging from fluid dynamics, lab-on-a-chip devices, chemical engineering, nanomaterials synthesis, protein crystallization to advanced drug delivery as well as chip fabrication.

1. Introduction

In the last few decades, major efforts by researchers have been directed towards the development of miniaturized fluidic devices, especially micro-scale systems, for a large number of applications [1]. Due to their large surface-to-volume ratio, micro-scale devices continue to offer several advantages. For example, minimal reagent consumption, better reaction controls (i.e., efficient heat and mass

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