Simulation of Constant-Volume Droplet Generators for Parallelization Purposes

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Abstract

INTRODUCTION:
Droplet microfluidics is a fast growing research area that deals with the formation and break-up of micro-droplets using two immiscible fluids. This field is already revolutionizing the chemical and biological labs due to the enhanced characteristics offered by assays with greater surface area to volume ratio as compared to conventional methods [1-3]

A set of microfluidic channels is used to flow a continuous phase (CP) and a disperse phase (DP) into a point where droplet formation occurs. The balance between the shear stresses and the interfacial tension results in droplet break-off. There are several geometries capable of producing these micro-droplets, however most of them have shown that the droplet size is highly dependent on the flow rates [2,3]. Whereas this characteristic could be advantageous in a single device [3], it also makes their parallelization and consequent scale up a very challenging process [4,5], since small pressure or flow fluctuations can result in large variations in droplet size. New geometrically set droplet generators are currently being explored because in these devices, droplet volume is rather dependent on the generator's geometry. For this reason, these geometries are more appropriate for highly parallelizable systems [6].

In this abstract, we want to expand the understanding of some previously reported geometries [6], by means of CFD simulation and proposed a new mirrored geometry.

USE OF COMSOL MULTIPHYSICS®:
To model this phenomenon, we use the CFD module to simulate the laminar two-phase flow using the phase field method [7, 8]. In it, a continuous phase variable describes and tracks the interphase between both fluids in a time dependent study. The droplet formation was studied at different total flow rates and flow rate ratios in order to evaluate the robustness of the geometrically set generator.

RESULTS:
Our simulation matches the behavior of devices fabricated using soft-lithography (Figure1). The devices showed to be independent of the flowing rates within a wide range of values (Figure2). This characteristic shows their usefulness for parallelization purposes. We have also proposed another mirrored geometry (Figure3) that has the extra advantage of reducing the likelihood of

channel wetting.

CONCLUSION:
Simulations of geometrically set microfluidic droplet generators were done successfully and our model was validated with experimental results. We have then proposed a new geometry to avoid undesirable wetting and failure of such devices.

Reference

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Figures used in the abstract

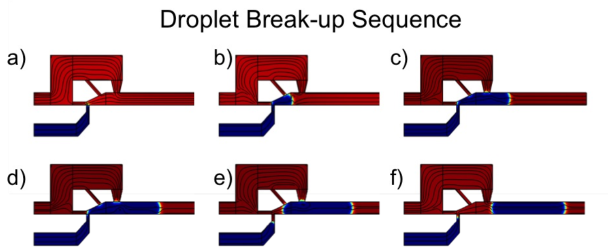

Figure 1: Droplet break-up sequence of a geometrically fixed droplet generator. The disperse phase (blue) grows gradually inside the cavity (a-b) until both bypasses are closed (c) and the built up pressure of the continuous phase (red) induces droplet formation (d-f).

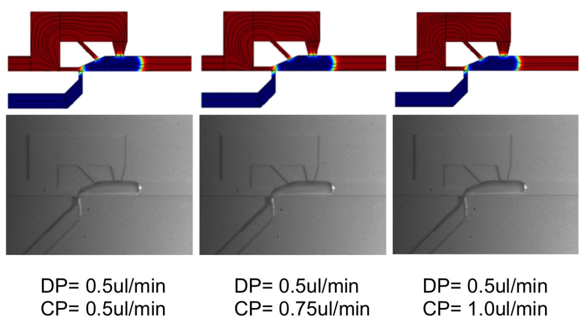

Figure 2: Simulation results vs. Experiments. This figure shows that even at different flow conditions the volume of the produced droplet remains constant, depending only on the size and geometry of the generator.

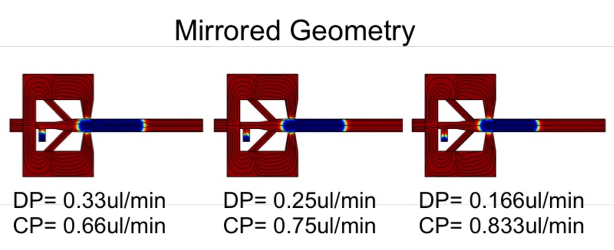

Figure 3: Proposed Mirrored Geometry. After validation of the model through experiments, we proposed a new mirrored-geometry that is less likely to wet the channels walls due to the inherited symmetry.

Figure 4