Dropbox : an "off-the-shelf" microfluidic device for monodisperse emulsification based on a 3D-printed nozzle injector

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Droplet generator is an important tool in many different fields, including complex emulsion and particle generation, drug delivery, protein dynamics, particle sorting and single cell analysis [1]. All the commercially available and most of lab-made droplet generators are based on a flow-focusing technology implemented in rectangular microchannels fabricated by lithography, and made in polydimethylsiloxane (PDMS), polymers or glass. This planar configuration has many limitations, mostly due to the contact between the walls of the chip and both phases at the junction, making an hydrophobic or hydrophilic coating necessary for water-in-oil or oil-in-water droplet generation, respectively.

Due to their axisymmetric flow, glass capillary devices on the other hand possess advantages for microfluidic applications, yet their widespread use is limited by the difficulty to implement this technology in an easy-to-use device. Co-flow systems have been set up using commercially available components, but these devices produce large droplets (>100 μm) at low flow rate and lack the ability to generate small and monodisperse droplets (<100 μm) at high flow rate that can be produced using a flow-focusing device. Furthermore, the centering of the capillary into an outer flow channel is challenging [2].

Glass capillary device for flow-focusing microfluidics droplet generation developed by Utada uses two circular capillaries inserted into a square outer flow channel, which greatly simplifies alignment and centering of the device. However, the restrictions necessary to obtain a focusing effect at the outlet of the inner capillary is obtained by pulling and breaking a glass capillary, a very "art-dependent" and not reproducible technique limiting the use of this design in microfluidic applications. Furthermore, the small space for the continuous phase between the glass capillary and the square channel limits the flow-rate, hence the high-throughput, in the droplet generation process.

Here we present a flow-focusing glass capillary device based on the alignment of two capillaries in a metallic chamber and the use of a 3D-printed nozzle injector. This configuration of the Utada design is fabricated using techniques that allow an industrial production of the device and a very easy-to-use experience for the end-user, while keeping all the advantages of the glass capillary flow focusing on the commercially available glass, polymer or PDMS chips.

We will present experimental results in various configurations (water/oil, oil/water, bubble/water, double emulsion) demonstrating the versatility of the device, and compare them to a force balance model developed to predict the size of the droplets.

References

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