

3D Printed Microfluidic Lab-on-a-Disk for Centrifugal Droplet Generation

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Summary:

A 3D printed microfluidic lab-on-a-disk (LOAD) for generation of oil-in-water droplets is presented. The device is the first solution combining droplet microfluidics, centrifugal technique, and additive manufacturing technology. Compared to standard LOADs, which are fabricated using subtractive methods, additive manufacturing technology has enabled development of a new research tool that can be easily and quickly replicated or redesigned for versatile microfluidic lab processes, e.g. sample preparation, biochemical reactions, or biomarker detection, with high potential for point-of-care applications.

Keywords: lab-on-a-disk, 3D printing, droplet generation, centrifugal technique, microfluidics

Introduction

Droplet microfluidics enable repeatable generation and precise control of discrete volumes of fluids in the nano- and picolitre range. Droplets of water-in-oil or oil-in-water can be used as individual microreactors, cell incubators, or drug delivery systems [1]. Unlike pressure-driven or electrokinetic fluid propulsion methods, the implementation of the centrifugal technique, also called as laboratory-on-a-disk, is one of the prospective improvements towards a real point-of-care application of droplet-based devices [2]. However, until now most lab-disks have been made of poly(methyl methacrylate) (PMMA) using only subtractive manufacturing methods, that require multistep patterning and lamination of polymer layers, which has challenged the spread of LOAD devices [3]. In this work, a monolithic lab-on-a-disk for centrifugal droplet generation, which was fabricated in a single additive manufacturing process, is presented.

Methods

The dimensions of the device are 120 mm in diameter, 15 mm central mounting hole, and a thickness of 1.4 mm, similar to a standard CD. The structure contains 4 radial microfluidic units for the generation of various droplet volumes according to the centrifugal profile (Fig. 1a). Each unit consists of an input chamber for a dispersed phase, a microchannel with a nozzle, and an output chamber for a continuous phase.

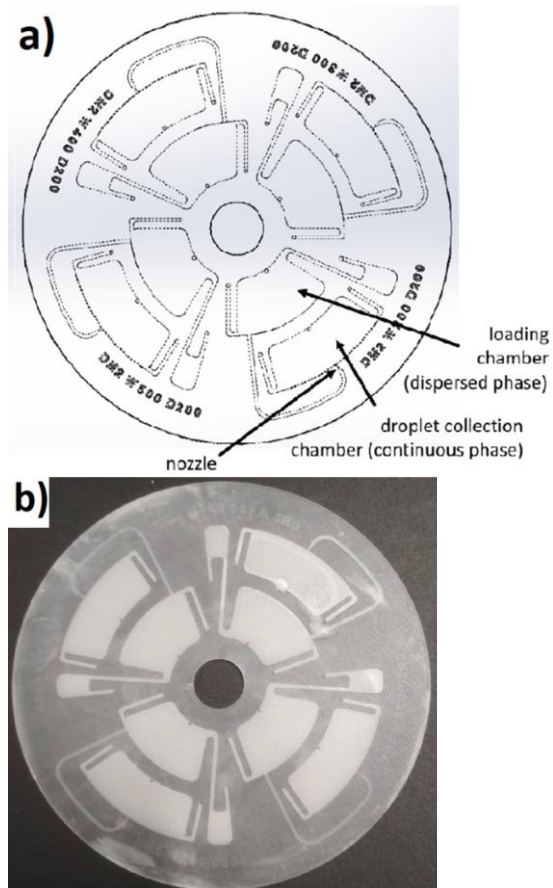


Fig. 1. A developed microfluidic lab-on-a-disk for droplet generation: a) model of the device, b) ready-to-use device (diameter of a standard compact disk).

The lab-disk was fabricated using multi-jet 3D printing technology from a semitransparent and biodegradable polymer (VisiJet M3 Crystal) and wax-like support material (Fig. 1b). Compared to subtractive technology used to manufacture PMMA LOADs, the additive manufacturing process allows for faster and simpler fabrication of the device with a minimum staff engagement and required high-tech equipment. Moreover, the monolithic structure provides homogeneous surface properties of the microfluidic units.

The spinning experiments were performed using laboratory setup for centrifugal analysis, comprising: BLDC motor, tachometer, illuminator, high speed camera, data acquisition card, and computer with dedicated control software. The microscopic images of the droplets were processed using a developed graphical application (LabVIEW), which enabled detection of spherical objects, calculation of their dimensions based on the scale pattern, and visualization of the statistical data.

Results

The monolithic lab-disk was characterized, including mechanical properties (e.g. deflection during spinning), impact of the chemical pretreatment (contact angle measurement for various organic solvents applied), and determination of the burst speed of oil and water. The device allowed the production of repeatable volumes of oil-in-water microdroplets without any additives, and with the use of the centrifugal force only (Fig. 2). Various spin profiles and nozzle widths were investigated to produce microdroplets in an approx. volume range from 5 to 270 nL. It was also noted that the influence of droplet generation speed on the average droplet volume is negligible below the value of the burst speed of water or oil, providing the emulsion with almost constant dispersion.

Conclusions

The first 3D printed lab-disk microfluidic device enabled the generation of oil-water emulsions with precisely controlled volumes. The software developed allowed for automatic image analysis and visualization of the results. Obtained diluted emulsions of essential oils in water can be used e.g. in intraoral microfluidic dispensers for therapeutic applications (as it is being investigated in other works). Applied here centrifugal technique combined with additive manufacturing technology can be implemented to develop novel portable instruments (similar to CD players) equipped with monolithic lab-disks, which could be easily adapted to other applications.

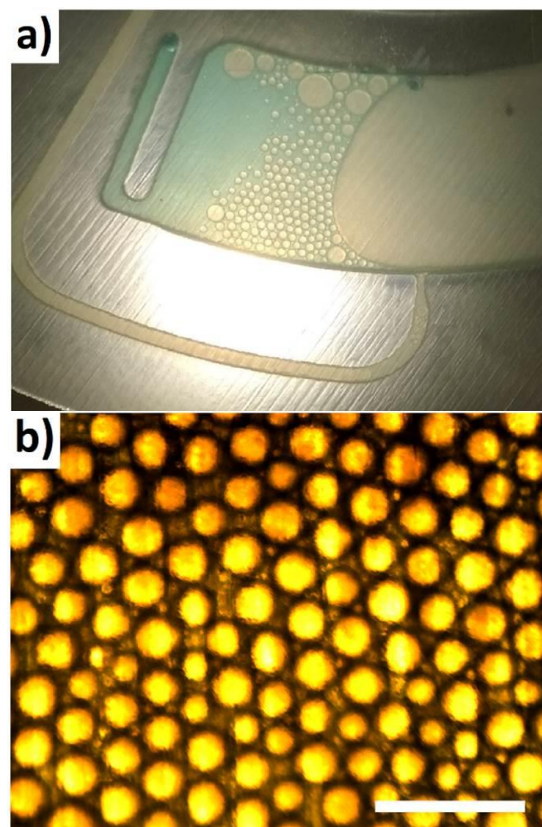


Fig. 2. The results of centrifugal droplet generation in the lab-on-a-disk: a) close-up of the output chamber after the emulsification process (some droplets merged after the device had been dismantled), b) magnified view of oil-in-water droplets generated in the output chamber (the bar indicates 1 mm).

References

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