POROUS STRUCTURES AS ACTIVE MICROFLUIDIC COMPONENTS

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SUMMARY

Active control of droplet mobility through low cost tools is highly desirable in applications entailing microfluidics, Lab-on-Chip devices and pertinent technologies. Here, we present the design concepts of a versatile, low cost tool for dynamic droplet mobility manipulation, employing a scheme with backpressure application. Initially sticky open- or closed-channel fluidics with hydrophobic, porous walls are rendered slippery with the application of backpressure through the porous walls. Deliberate control of backpressure directs the wetting phenomena to the desired state. Operation parameters, and control system considerations are presented. Ultra-low backpressure values, are needed for channels with small cross-sections, which in turn are compatible with ultra-low energy demands.

INTRODUCTION

Incorporation of materials and devices with controllable and active wetting properties is now emerging as a key issue towards high-performance microfuidics and embedded systems [1-4][1-5]. Droplet actuation and valving on such systems call for tools that deliver wetting and mobility switching on-demand, with high throughput, low cost and large production amenability. Desirable salient characteristics include also low energy demands, high adaptability, ultra-low actuation times and minimum interaction with the working liquid phase. Undesirable interactions may be chemical through incorporation of particles or any other third-party substances, or thermal through temperature increase.

Incorporation of simple porous surfaces on microfluidics is challenging alone [5]. Rendering them active increases complexity more.

In this work we present the design of an integrated tool, for controlling the mobility of plugs inside open- or closed-channel fluidics. The heart of the tool is a low-cost disposable fluidic with porous hydrophobic walls that may facilitate the application of backpressure [6-10]. The construction material is ceramic, exhibiting high robustness, chemical inactivity, mechanical stability and high temperature stability. With the application of backpressure, gas pockets evolve at the solid-liquid (S-L) interface, with tunable pressure and volume. With this the S-L surface area is decreasing, the receding contact line is partially detached, while additional, anisotropic Laplace pressures appear, along with asymmetric bubbles. The collapsing of the gas pockets introduce additional forward wave, assisting the liquid movement. Through deliberate backpressure control, the above mentioned phenomena, are tuned towards the desired direction. The design concepts and considerations are presented in this work.

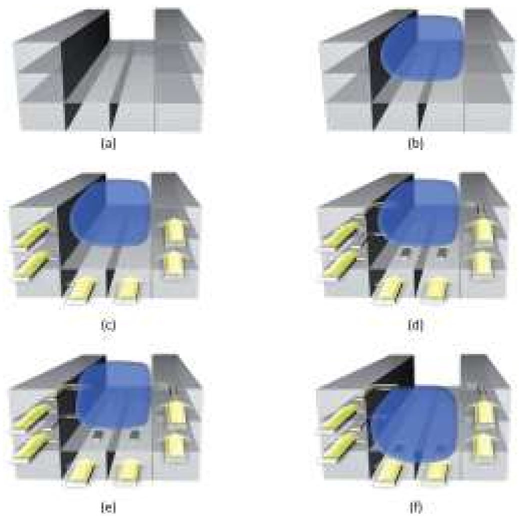

Figure 1. Schematic representation of the valve architecture and operation.

RESULTS

In Figure 1 we present the basic principle of the active valve developed. For the case depicted in Figure 1, the valve is rectangular and open from the top face only, however other geometries might be used as well. The central channel, acts as the microfluidic channel, while its adjacent channels serve for backpressure application; that is, they allow gas to feed through their porous walls to the microfluidic channel.

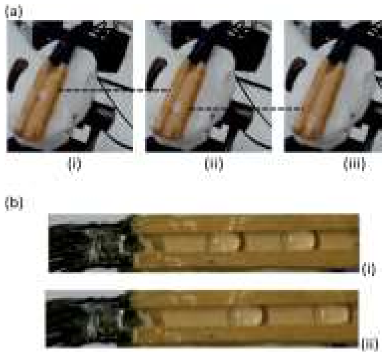

Figure 2. a) Snapshots from video showing a droplet moving inside the open-channel fluidic. (b) Manipulation of two plugs on the same fluidic simultaneously. The fluidic is tilted downwards on the right side.

In Figure 2 snapshots taken during actuation of a 30 ml plug are illustrated. Initially the plug sticks to the porous surface, because of the hydrophobic character of the walls and the high contact angle hysteresis. With the application of a backpressure, specific values of which are presented below, gas pockets appear at the liquid–solid interface with increasing volume and pressure, which render the walls slippery and triggering the droplet to low through and downwards due to the gravitational body forces acting on the plug.

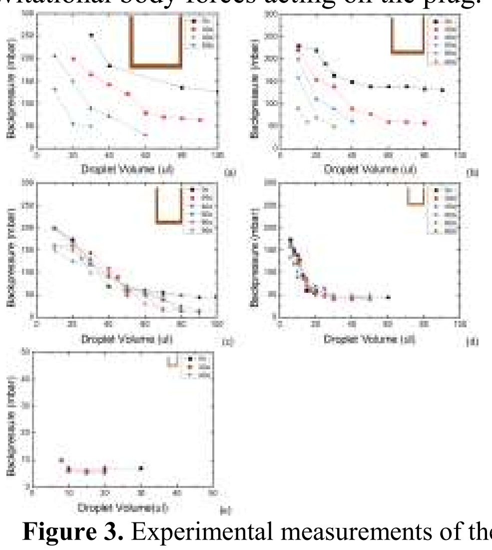

Figure 3. Experimental measurements of the minimum backpressure for actuation vs. droplet volume and tilt angle for valves with various cross sections

In Fig. 3 we present the experimental results for the minimum backpressure value needed to actuate a droplet, and hence set the valve-on, for various openings.

CONCLUSIONS

We presented the design concepts and fabrication of a versatile tool for dynamic droplet mobility manipulation. The tool is designed for both open- and closed channel fluidics. The heart of the tool is a ceramic, porous fluidic, enabling the application of backpressure through the fluidic walls. The inherently sticky walls are rendered slippery when backpressure is applied at the rear side of the channel walls. Depending on the porous characteristics and channel dimensions ultra-low backpressure values are needed to induce the transition from the sticky to a slippery state.

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