Programmable delay in paper-based devices using laser direct writing

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Abstract

Demand for low-cost alternatives to conventional medical diagnostic tools has been the driving force that has spurred significant developments in the diagnostics field. Paper-based fluidics, proposed by the Whitesides' group in 2007 has been regarded as one such alternative, and consequently, this field has been progressing rapidly and a range of paper-based fluidic devices that implement different assays have since been demonstrated. Research into the development of methodologies that control, and in particular delay the flow of fluids in these devices is an urgently needed requirement that would enable greater functionalities in such paper-based devices.

In this work, to control fluid-flow, we report the use of a new approach that is based on the laser-based photo-polymerisation technique that we have reported earlier for the creation of fluidic patterns (channels/wells) in paper. The delay or slowing down, of the fluid-flow in a fluidic channel is achieved via the introduction of barriers aligned across the direction of the fluid-flow – in a fashion similar to how speed-bumps enable traffic-calming control on a road. The schematic in Figure 1a shows how the delay can be introduced via the creation/insertion of barriers which are solid and impermeable and by controlling the 'depth' of the solid/impregnable barriers (Figure 1) to allow for controlled leakage of the fluids under the barriers. The control over the depth of the barriers is obtained by simply adjusting the laser-writing parameters such as the output power and writing/scanning speed. We observe that solid/impregnable barriers of various depths decrease the fluid flow by a rate that is proportional to their depth.

Having patterned these barriers at pre-defined locations in the fluidic channel, using a pulsed laser operating at 266nm (20Hz, 10ns) we have achieved flow-delays with a time span ranging from few minutes to over an hour. We have also performed a study to understand the influence of the number of barriers and their position on the flow-delay, and this is shown in Figure 2.

Since the channels and flow-delay barriers can be written via a common laser-writing procedure, this technique has a distinct advantage over certain other methods that require specialist operating environments, or custom-designed equipment to enable both these aspects. We believe this rapid and versatile technique is therefore suited for fabrication of 'sample-in-read-out' type automated paper-based microfluidic devices that can implement single/multistep analytical assays.

Word Count: 385

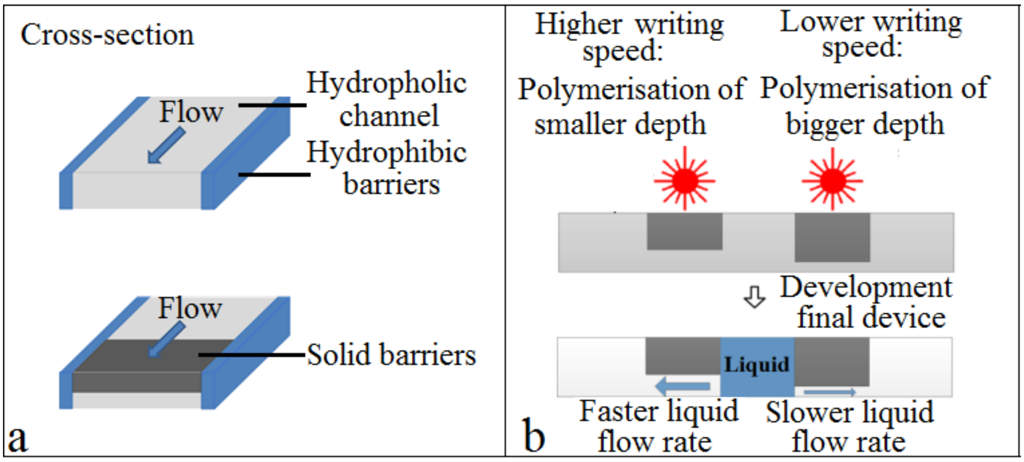

Figure 1: a) Schematic representation of a cross-section of a fluidic channel with a single solid/impregnable barrier; b) Schematics showing the creation of solid/impregnable barriers of variable depths inside the paper substrate.

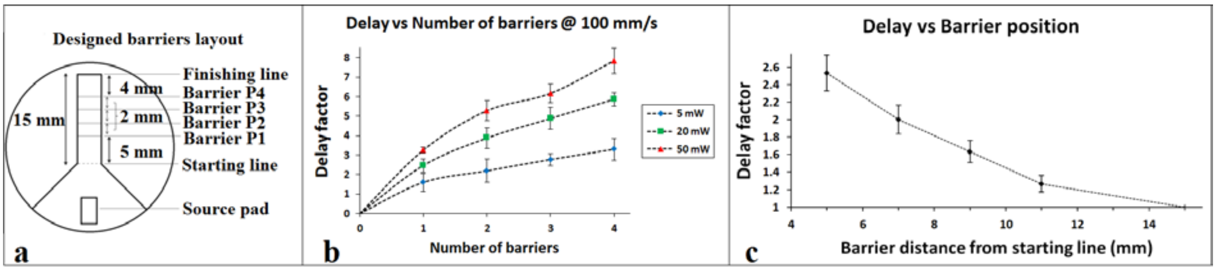

Figure 2: a) Schematic representation of the tested fluidic channel-barrier layout showing the position of the delay barriers (P1, P2, P3 and P4). Plots showing the relationship between the fluid delay and the b) number and c) position of the barriers (as a distance from the starting line). Error bars indicate the standard deviation for 3 measurements, and the line is a guide for the eye.