ULTRA LOW COST MICROFLUIDIC DEVICES FABRICATION AND ITS APPLICATION IN ELECTROPHORESIS

S. K. Chhina, M. Rahbar, A. A. Kaleibar, P. C. H. Li[1] and M. Parameswaran
School of Engineering Science, Simon Fraser University, 8888 University Drive, Burnaby, B.C., Canada (V5A 1S6)
[1]Department of Chemistry, Simon Fraser University

INTRODUCTION

Microfluidic devices and electrophoresis separation of bio-molecules has been established to be a dominant diagnostic tool for clinical diagnosis, rapid screening for health conditions and diseases. Moreover, it has proven to be an invaluable tool for forensic and paleontological studies. Conventional microfluidic devices are prepared from glass and silicon [1] and electrophoretic separation of samples employ comparatively pricey high voltage power supplies. Though microfluidic devices have turned out to be an indispensible part of many research and diagnostic areas, the cost is still relatively on the higher side. To address this concern, a low cost micofluidics device fabrication using Plexiglas as material in combination with an electrophoretic bio-molecule separation using low-cost high-voltage dc-to-dc converters such as those used in disposable camera flash units is presented.

PMMA MICROFLUIDICS

The Lab-on-chip microfluidics technology is the key to powerful new diagnostic instruments. Polymers such as Polymethylmethacrylate (PMMA or Plexiglas) have several advantages over traditional materials, such as lower fabrication costs and complexity [2]. In addition, a lower cost of the raw material these plastic substrates can be patterned using a wide variety of methods, including laser ablation, hot embossing, reactive ion etching and deep UV lithography [3]. Therefore, there is a great demand to develop plastic diagnostics devices that would allow early diagnosis of disease. In keeping with our philosophy of developing low-cost, simple microfluidics, we are working on different ways of producing the microfluidic devices. These techniques include 254 nm deep UV, silk screen printing technique. The PMMA microfluidics utilize the property of PMMA that it breaks down into smaller polymeric chains on exposure to 254 nm radiation and then PMMA dissolves conveniently in isopropyl alcohol (IPA) [3,7]. The 254 nm deep-UV radiation sources are inexpensive and are commercially employed for water disinfection and DNA cross-linking. We are utilizing the methodology in which an UV opaque material is used to mask the PMMA sample to define the microfluidic channels and reservoirs; then the sample is exposed to 254 nm radiation. The exposed samples are developed using an IPA-water mixture which rapidly define the microfluidic pattern. The sample is then drilled with port holes to provide inlet/outlet access. Finally, the patterned sample piece is bonded to another blank piece of Plexiglas using microwave bonding that utilizes a commercial microwave oven to provide the heat required for the bonding process [2]. The 254 nm exposure fabrication techniques accomplish 50 micrometer wide channels on the PMMA samples in the order of few square centimeters can be easily created using this technique. For microfluidic channel width greater than 150 micrometers CO_2 laser cutting process is used.

SILK SCREEN PRINTING

There are few techniques that are reported for masking the PMMA during the 254 nm deep UV exposure. Use of gold (Au) as the masking material has been reported [3]. This method utilizes a bilayer of chrome-gold (Cr-Au) deposited on PMMA. The micro-channel design is transferred onto Cr-Au by photolithography and etching. Further, Cr-Au acts as a shadow mask for exposing PMMA. Though this technique is reasonably inexpensive, it requires high-cost processing equipment as the technique involves metal deposition and metal etching. To overcome this problem, a very cost-effective method using silk screen printing to produce the mask has been reported [4]. In this method, the microfluidic channels are designed using a CAD program such as L-Edit, Cadence, etc. The channel design is

used to obtain a Mylar mask. The Mylar mask is then used to produce a silk screen. The image on the silk screen is then transferred to the PMMA by a pushing the UV Opaque ink (Inktech Screen printing ink) [5] using a squeegee. Figure 1, illustrates the various items utilized in the silk screen printing process.

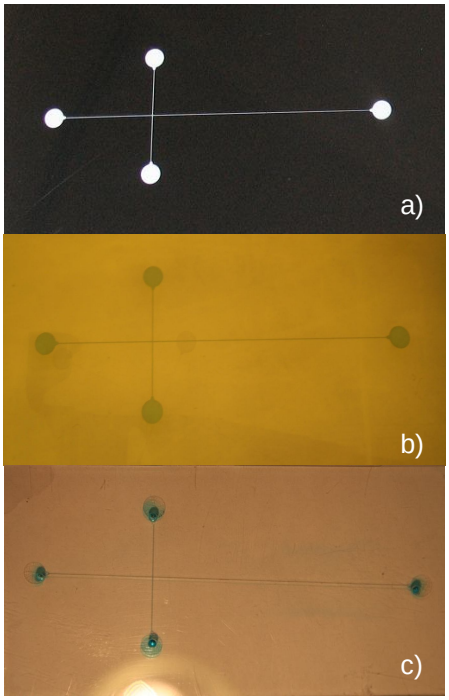


Figure 1: a) the Mylar mask, b) The silk screen and c) The final bonded microfluidic chip

ELECTROPHORETIC PINCH INJECTION

Electrophoresis is an electric field-aided technique to separate bio-molecules. Generally, most of the bio-molecules intrinsically have an electric charge; therefore, a particular species can be isolated from a given sample based on the charge difference. This technique can be used to separate proteins, DNA fragments, etc. Traditionally, electrophoresis is carried out on sieving matrices provided by gels like polyacrylamide and agarose. Due to the advancement of microfluidics, the technique can be implemented in compact microfluidic units and can be potentially developed into hand-held portable devices. Besides the microfluidic unit, a precision high voltage power supply is essential to execute the electrophoretic separation. We have constructed a high voltage power supply using disposable camera flash units to generate the required high voltage potentials to perform, what is called, pinch injection. In pinch injection a sample is taken and a known amount of sample volume can be introduced into a micro channel and the sample can be electrophoretically separated.

PINCHED INJECTION IN PMMA CHIP

We have performed and compared pinch injection on channels fabricated by two different fabrication methods - the CO_2 laser ablated channels (Versa Laser 3.60 CO_2 laser cutter [6]) and the channels produced by 254 nm exposure using silk screen technique to create the mask. The Figure 2 shows the cross-section of the channels fabricated by laser ablated and the UV exposure.

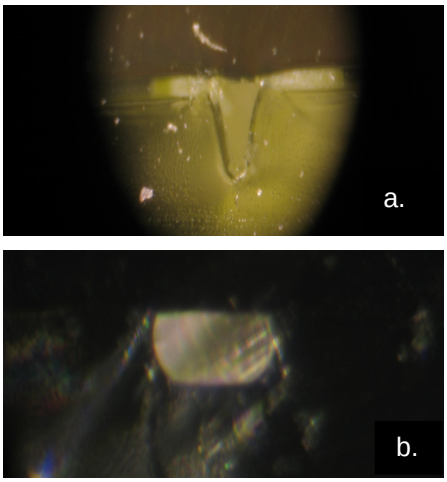


Figure 2: Cross-section of the bonded microfluidic channel made by a. Laser ablation, b. by 254 nm UV exposure using gold as the masking material and subsequent IPA treatment. (Note that different scales are used to reveal the 100 and 50-micron wide channels in figure a. and b.)

It was observed that the laser ablated channels are rough at the bottom; cracks appear after bonding; whereas the channels produced by the 254 nm exposure have relatively smooth bottom surface because low stress levels, thus lesser cracks, appear after the microwave bonding.

PINCH INJECTION ON CHANNELS FABRICATED BY CO_2 LASER ABLATION

A 5.00 cm long horizontal and 1.25 cm vertical channel was constructed on PMMA (OPTIX® from Plaskolite) substrate was constructed by using Laser Cutting. Figure 3 shows the T-section microfluidic unit.

Reservoirs made out of thick PMMA are then glued by Locatite crazy glue onto the bonded microfluidic unit. The sample (a fluorescent dye in sodium borate solution) and buffer (sodium borate pH 9.5 solution) are used for the pinch injection. Fluid flows within the channels are controlled through the applied potentials to the reservoirs. The required electric potentials are provided by five disposable camera flashes.

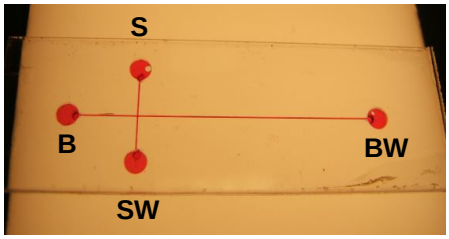


Figure 3: Microfluidic unit fabricated by laser ablation and microwave bonding. (*Red dye introduced into the channels for visual clarity.*)

A single camera flash unit is utilized to provide the loading voltage between the sample (S) and sample waste (SW) reservoirs. Two camera flash units are used to supply the dispensing voltage between buffer (B) and buffer waste (BW) reservoirs. Another two flash units provide the intermediate voltages during the loading and dispensing step.

Results

A pinched injection of the sample fluid is achieved by switching the voltages between the loading and the dispensing step. During the loading step, the fluid is moved from S (0 V) to SW (300 V) in the loading channel while the B and BW are held at the ground potential to confine the sample plug in the cross section. In the dispensing step, the sample plug is introduced into the horizontal channel and the sample is moved from B (0 V) to BW (692 V). The S (477 V) and SW (477 V) are guarded to insure the backup of the sample fluid (hence no leakage) in the loading channel and a sharply defined plug.

PINCH INJECTION ON CHANNELS FABRICATED BY SILK SCREEN PRINTING & 254 nm UV EXPOSURE

A T-section of the same dimensions and material is made by using silk screen printing and 254 nm exposure. The pinch injection was performed by following the same procedure and use of chemicals as mentioned in the above section. Figure 4 demonstrates the pinch injection in the microfluidic unit.

The voltages applied for the pinch injection in laser ablated and 254 nm exposed microfluidic units are almost similar to those mentioned above except that the voltages of S and SW in the loading step differ considerably (see Chart 1). Also, the dispensing voltage (B and BW) required to dispense the confined plug into the horizontal channel on the channels fabricated by silk screen and 254nm exposure is lower than those fabricated with the laser ablation (see Chart 1). This may be due to difference of channel characteristics in both the methods. Chart 1 compares the results in both the cases.

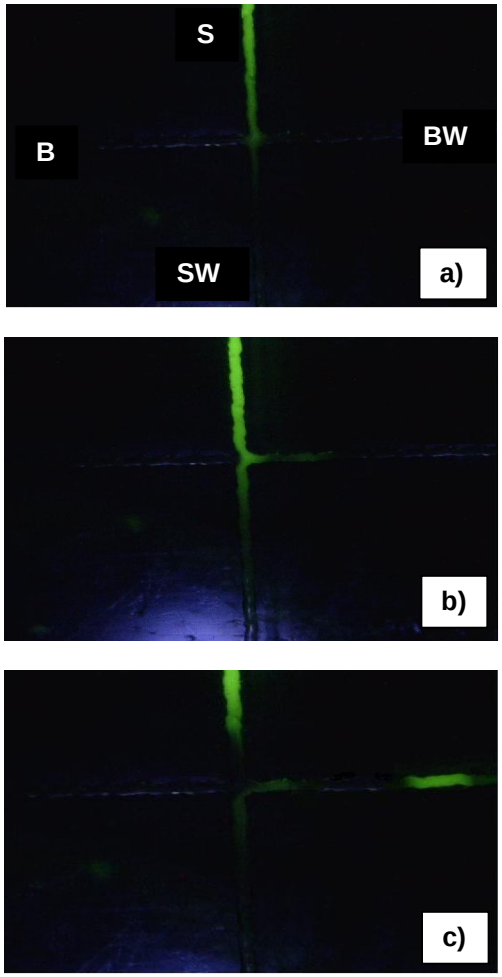
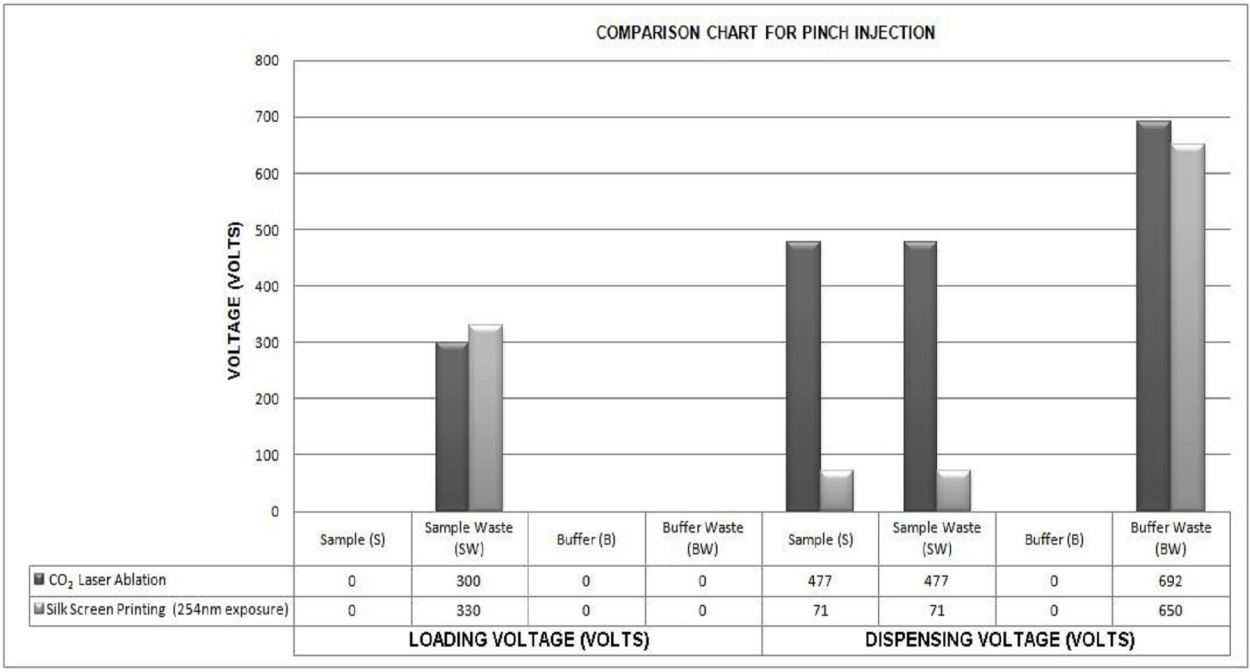


Figure 4: a) The sample is loaded into the loading channel; b) The sample plug is confined into the channel intersection; c) The sample plug is dispensed into the horizontal channel. (*The microfluidic unit used in this demonstration is fabricated by using silk screen mask-printing and 254nm exposure*)

Chart 1: Comparison of the voltages used for pinch injection in the channels fabricated by laser ablation and silk screen printing (254 nm UV exposure)



	Sample (S)	Sample Waste (SW)	Buffer (B)	Buffer Waste (BW)	Sample (S)	Sample Waste (SW)	Buffer (B)	Buffer Waste (BW)
CO_2 Laser Ablation	0	300	0	0	477	477	0	692
Silk Screen Printing (254nm exposure)	0	330	0	0	71	71	0	650
	LOADING VOLTAGE (VOLTS)				DISPENSING VOLTAGE (VOLTS)			

APPLICATION AND CONCLUSION

We have presented an ultra economical method of manufacturing microfluidic components on PMMA substrates using Silk Screen Printing process / 254nm UV exposure. In combination with the microwave assisted bonding process we can produce fully functional microfluidic components that can be easily reproduced. Further, we have successfully demonstrated the pinch injection using the PMMA microfluidics and the inexpensive power supply recovered from the disposable camera flashes. Our future work will focus on carrying out capillary gel electrophoresis in these microchannels and to configure a low cost electrophoretic cancer marker (protein) separation device from easy-to-collect body fluid samples.

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REFERENCES

[1] George M. Whitesides, “The origins and the future of microfluidics,” *Nature*, Vol 442, doi: 10.1038/nature05058, 2006.

[2] M. Rahbar, S. Chhina, D. Sameoto, and M. Parameswaran, “Microwave-induced, thermal-assisted solvent bonding for low-cost PMMA microfluidic devices,*" J. Micromech. Microeng*., Vol 20: 015026, 2010.

[3] M. Haiducu, M. Rahbar, I. G. Foulds, R. W. Johnstone, D. Sameoto, and M. Parameswaran, “Deep UV patterning of commercial grade PMMA for low cost, large scale microfluidics,*" J. Micromech. Microeng*., vol. 18, pp. 115029, 2008.

[4] Aminreza Ahari Kaleibar, Mona Rahbar, Marius Haiducu, Ash M. Parameswaran, “Patterning of PMMA microfluidic parts using screen printing process,” *SPIE*., vol. 7593,DOI: 10.1117/12.841345,2010.

[5] Inktech Corporation, 160 Fenmar Drive, Toronto, Ontario M9L 1M6

[6] "http://www.ulsinc.com/versalaser/english/PDFs/VLS_Platform_0608.pdf," Universal Laser Systems, 2009.

[7] Johnstone R.W., Foulds I.G., and Parameswaran M., “Deep-UV exposure of poly (methyl methacrylate) at 254 nm using low-pressure mercury vapour lamps,” *Journal of Vacuum Science and Technology* B. vol. 26, no. 2, pp. 682-685, 2008