2017-12-06

OPTIMIZATION OF MICROCHANNEL FABRICATION USING XUROGRAPHIC TECHNIQUE FOR MICROFLUDIC CHIPS

Somyot Chirasatitsin, Sanja Kojić, Goran Stojanović

Somyot Chirasatitsin, Sanja Kojić, and Goran Stojanović. 2017. OPTIMIZATION OF MICROCHANNEL FABRICATION USING XUROGRAPHIC TECHNIQUE FOR MICROFLUDIC CHIPS. (Novi Sad, Serbia, December 6-8, 2017.): 1–4. https://open.uns.ac.rs/handle/123456789/9652 (accessed 15 May 2024).

https://open.uns.ac.rs/handle/123456789/9652

ETIKUM 2017

Scientific Conference With International Participation
Novi Sad, Serbia, December 6-8, 2017

Chirasatitsin, S., Kojić, S., Stojanović, G.

OPTIMIZATION OF MICROCHANNEL FABRICATION USING XUROGRAPHIC TECHNIQUE FOR MICROFLUDIC CHIPS

Abstract: *This paper presents the optimisation process of parameters needed for xerographic technique. This is technique for microfabrication of microfluidic channels in thermoplastic material using plotter cutter as device for making the pattern of microchannels, inlets and outlets and lamination process for bonding the microfluidic chip. Used materials, methods and measurements are explicated. Optimisation of parameters for with, angle, step and curvature are varied and discussed.*

Key words: *xurogfaphy, micromachining, microfluidics, thermoplastic, microchannel*

1. INTRODUCTION

Constant improvement of accuracy and precision in scientific research techniques and permanent battlefield for low-priced research has always been drifted side by side. Therefore, an accuracy of one low-cost fabrication technique determinates the application and usability of that technique. Moreover, optimization of fabrication technique determinates the edge of its performance.

Trying to reach the highest performance, lowest price or balance both, numerous techniques for microfabrication of microfluidic devices are established [1]. Main directions of development are: silicon-based microfabrication [2] (mainly based on MEMS microfabrication techniques, alternatively in glass [3]), rapid prototyping in polymers (covering elastomers: polydimethylsiloxane, poly(methyl methacrylate), etc. and thermoplastics like 3D printing and microcutting techniques) [4,5] and paper based techniques [6,7].

The choice of the fabrication method depends on its capability to generate the part with the desired features [1]. Xurographic technique is polymer rapid prototyping technique which uses polymer materials such as vinyl, polyvinyl chloride, polyethylene terephthalate, polyester, polyimide, etc. like substrate, cutting plotter as a channel making device and lamination as bonding procedure [1,3].

In this paper optimization of micromachining process of cutting the channel was performed. More precisely: width, angle, step, and curvature of the cut were tested in the available ranges and dimensions of the channels were measured (using SEM), compared and discussed. Furthermore, future usage of limitation was commented for this type of micromachining technique.

2. MATERIALS AND METHODS

2.1 Microchannel fabrication

The equipment and materials are shown in **Error! Reference source not found.**. The cutting plotter (CE6000-60 PLUS, Graphtec America, Inc., USA) with the 45° cutting blade (CB09U) were used to engrave microchannels in the plastic laminating films (MBL® 80MIC A4 hot lamination foil, Minoan Binding Laminating d.o.o, Serbia) supported on the cutting mat (12" Silhouette Cameo Cutting Mat). The hot laminator FG320 were employed to bond the xurographic microchannels.

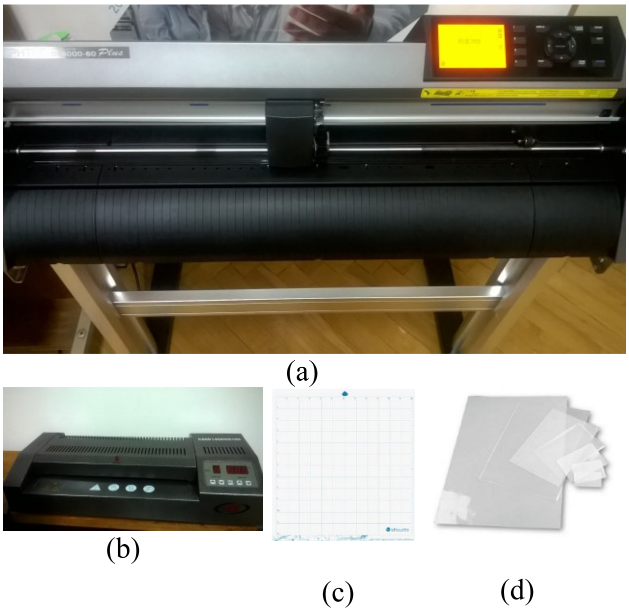
(a)
(b)
(c)
(d)

Fig. 1 Xurographic equipment and materials: (a) Cutter, (b) Laminator, (c) Mat, (d) Foils

Additionally, the channel drawing of the dxf format was produced by an open source 2D-CAD software (LibreCAD, v.2.1.3), then imported to the cutting controller software (Graphtec Pro Studio). Moreover, the command set of the cutting plotter was set to GP-GL with 0.01 mm resolution.

2.2 Microchannel investigation

The carved microchannels were observed by the tabletop scanning electron microscope (TM3030, HITACHI, Japan - courtesy of the BioSense Institute, University of Novi Sad). The SEM micrographs were employed at 5kV with TOPO and Shadow1 modes. The ImageJ software (NIH, USA) was applied for evaluating dimension of microchannel micrographs.

2.3 Microfluidic chip fabrication

The microchannel drawing files were imported to the Graphtec Pro Studio software. Before cutting, the cutting conditions were set such as cutting speed, acceleration and force. This research used the speed of 1 cm/s, the acceleration level 1 and the force of level #1 to #15.

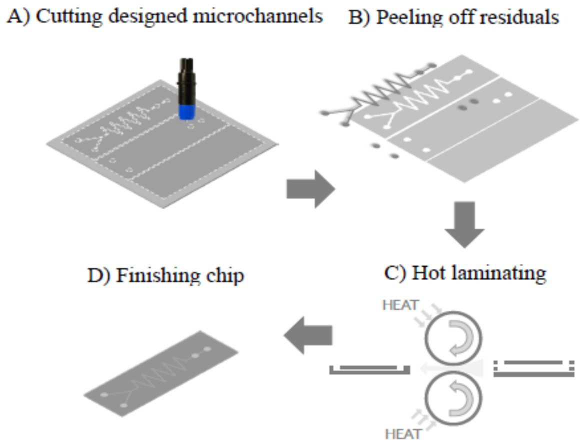

Fig. 2 Fabrication of microfluidic microchannel

The procedure for manufacturing microfluidic microchannels is shown in Fig. 2. Briefly, the channels were carved on the laminating foils supported by adhesive cutting mat. After that the cut foils were peeled off from the mat and the residuals were removed. Basically, to fabricate a microfluidic chip, there are at least three layers of cut foils (i.e. top inlet, core pattern, and bottom supporter layers) are assembled. However, in this research, only two layers were used: the core and the bottom layers, in order to be able to observe the channels via SEM microscopy. Those two layers were laminated through hot rollers at 130°C to bond layers and form the final microfluidic microchannels.

3. RESULTS AND DISCUSSION

3.1 Width of the cut

The microchannels were carved into the laminating foils with different cutting forces from level 1 – 15 (0.12 N – 1.74 N). The shape of the cutting blade is shown in Fig. 3A. The wedge and relief angles were 30° and 45° respectively, therefore the cross section of microchannel was triangular or trapezoidal. The width measured at the ridge of the engrave line were shown in Fig. 3C – D and Fig. 4. The higher force, the wider channel; e.g. at 0.35 N the wide was about 21 µm, whereas at 1.74 N was about 63 µm.

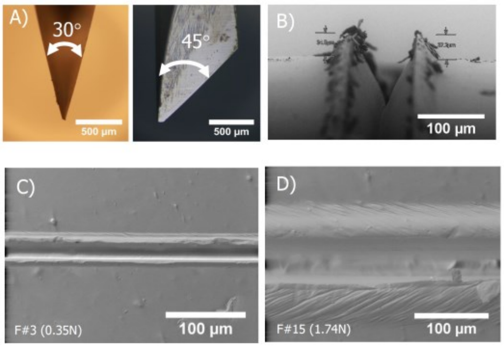

Fig. 3 Cutting blade and engraved microchannels

It was found that the width of cut was proportional to the cutting force from 14 µm width at 0.12 N, then plateaued out at 63 µm width at 1.27 N (to 1.74 N), as can be seen in Fig. 4, called the critical force, according to the thickness of the foils of 80 µm and the wedge angle of the blade. As a result, the foils were cut through. This implies that the thicker are the foils, the wider are the channels. If the desired width is higher than 60 µm, the foil thicker than 80 µm should be used.

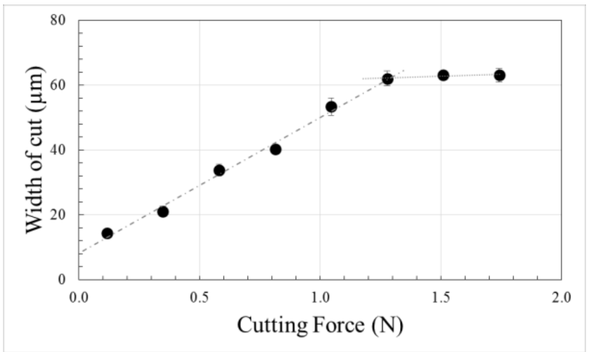

Fig. 4 Graph of the width of cut and cutting forces

The cutting whose force is lower than the critical force was typically called half-cutting, meanwhile one of higher than that was defined as die-cutting. The critical force is influenced by the thickness of the material, the elastic modulus and the ultimate strength of material as well as the relief angle of cutting blade. Therefore, cutting force should be optimized before microchannel manufacturing.

3.2 Step of the cut

The resolution of blade movement was investigated at the cutting force of level 1 (0.12 N) and varied distance of two parallel lines from 25 µm - 200 µm as shown in Fig. 5. The accuracy of the step motor was very high from 200 µm to 100 µm. However due to the plotter's mechanical resolution of 25 µm, the highest error observed was the same number at drawing distance of 50 µm. Nevertheless, the identification between two lines with 25 µm distance could not be observed.

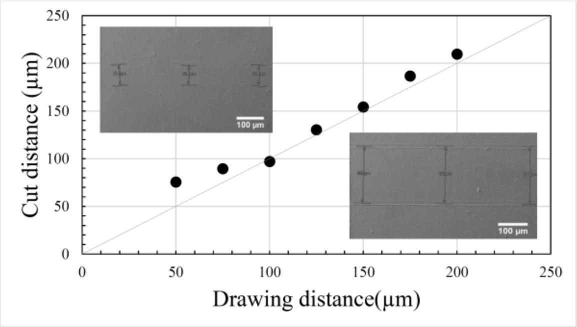

Fig. 5 Graph of designed and cut distances

According to the results of the width of the cut and the step of the cut, the channel width lower than 100 µm could be fabricated by only one pass of engraving with half-cutting. Likewise, the channel wider than 100 µm theoretically could be done by carving two parallel lines with die-cutting. It should be pointed out that the cross section area was always triangular or trapezoidal.

3.3 Angle of the cut

The ability to cut at desired angle was investigated as shown in Fig. 6. The cutting force was set at level 15 (1.74 N) during this experiment. The average error was 4.8° ± 0.8° showing that the angle of the cut was very accurate. However, the overcut at the angle was observed resulting in non-smooth connection line as shown in the inset.

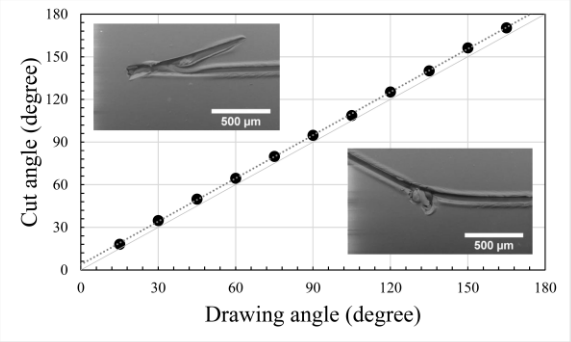

Fig. 6 Angle of the cut

3.4 Curvatures of the cut

The foils were cut in circle and measured in both horizontal and vertical axes as shown in Fig. 7. The length in vertical was slightly longer than in horizontal, so that the vertical's error was higher. This could be the mechanical resolution difference between the motors of the blade and the media movement of the plotter. Even though the step of the cut was very accurate, the combination of vertical (media) and horizontal (blade) motor movement could cause the resolution error as high as 66% at the cut of lower than 100 µm in diameter.

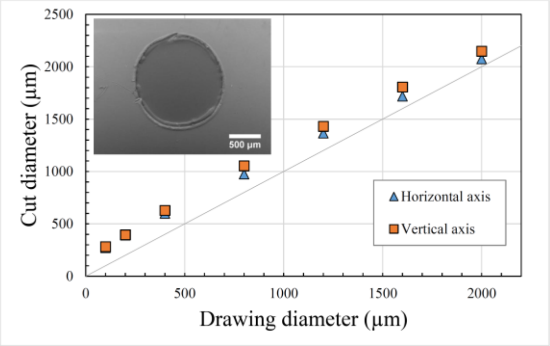

Fig. 7 Curvature of the cut

3.5 Dimension of actual microchannels

The microfluidic microchannel was designed and composed of the two inlets of 2 mm diameter joined with Y-junction, the zigzag micromixing path of 200 µm width, and the detection zone of 2 mm diameter. The SEM micrographs were shown in Fig. 8.

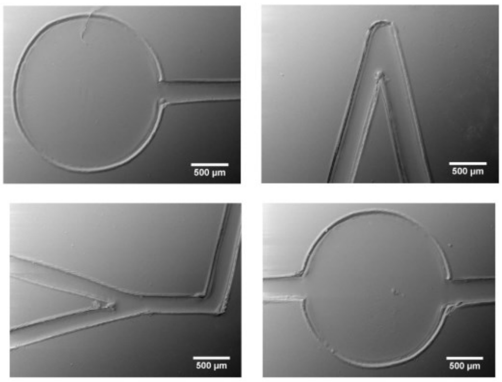

Fig. 8 Dimension of zigzag channel

The diameters of cut circles of inlet and detection zone were, as expected from the previous experimental results, that the vertical axis was slightly longer than the horizontal one. Interestingly, the connection between the circles and straight channels revealed the undercut as the cut direction was changed. Also, the straight channels were wider as the channels were closer to the circles. This could be caused by the unstuck foils to the cutting mat before being carved. Therefore, choosing a higher adhesive force of the mat would solve this.

Unusually, the width of straight channels at the zigzag line at the angle of 75° to the longitudinal axis was about 320 μm on average which was about 60% wider than which of design. This error again could be the influence of the combination of the vertical and horizontal movement of the plotter's motors. However the angle was as designed as 75°. Therefore, the design drawing should be compensated before cutting to obtain the desired dimension.

4. CONCLUSION

When establishing new equipment, it is important to define and optimise all needed parameters for determination of fabrication technique performance, limits and accuracy. This paper presents optimisation procedure for plotter cutter and lamination processes. Results shows that channel width of 63 μm, on the 80 μm foil, can be reached using cutting force higher than 1.27 N. Moreover, results of the width of the cut and the step of the cut implies that the channel width lower than 100 μm could be fabricated by only one pass of engraving with half-cutting. While, the channel wider than 100 μm could be made by carving two parallel lines with die-cutting. Measured width of the channel in the chip was 60% wider then on the drawing design. This ratio should be calculated in the measure in the drawing design.

5. REFERENCES

[1] Galindo-Rosales, F. J., Silverio, V., Cardoso de Freitas, S.: *Complex Fluid-Flows in Microfluidics*, Springer International Publishing AG, 2018.

[2] Leester-Schadel, M., Lorenz, T., Jurgens, F., Richter, C.: *Microsystems for Pharmatechnology*, Springer International Publishing Switzerland, 2016.

[3] Silverio,V., Cardoso, S., Gaspar, J., Freitas, P. P.,&Moreira,A.L.N.: *Design, fabrication and test of an integrated multi-microchannel heatsink for electronics cooling,* Sensors and Actuators A: Physical, 235, 14–27, 2015.

[4] Voicu, D., Lestari, G., Wang, Y., DeBono, M., Seo, M., Cho, S., et al.: *Thermoplastic microfluidic devices for targeted chemical and biological applications*, RSC Advances, 7, 2884–2889, 2017.

[5] Konstantinou, D., Shirazi, A., Sadri, A., & Young, E. W. K.: *Combined hot embossing and milling for medium volume production of thermoplastic microfluidic devices,* Sensors and Actuators B: Chemical, 234, 209–221, 2016.

[6] Fu, E., & Downs, C.: *Progress in the development and integration of fluid flow control tools in paper microfluidics*, Lab on a Chip, 2017.

[7] Posthuma-Trumpie, G. A.,Korf, J., van Amerongen, A.: *Lateral flow (immuno)assay: its strengths, weaknesses, opportunities and threats,* A literature survey. Analytical Bioanalytical Chemistry, 393, 569–582, 2009.

Authors: **Dr Somyot Chirasatitsin,** University of Prince of Songkla University, Faculty of Medicine, Institute of Biomedical Engineering, 15 Karnjanavanich Rd. Hat Yai, Songkhla 90110, Phone: +66 7445 1743, Fax: +66 7445 1744.
E-mail: somjot.c@psu.ac.th

M.Sc. Sanja Kojić, Prof. Dr. Goran Stojanović, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovica 6, 21000 Novi Sad, Serbia, Phone.: +381 21 485 2553, Fax: +381 21 4750572.
E-mail: sanjakojic@uns.ac.rs
sgoran@uns.ac.rs

ACKNOWLEDGEMENT: This work is supported by the H2020 project MEDLEM no. 690876 and partly financed by Provincial Secretariat for Higher Education and Scientific Research project no. 142-451-2508/2016-01.