RAPID PROTOTYPING OF SELF ALIGNED 3D MICROFLUIDIC STRUCTURES

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ABSTRACT

This paper reports a cost effective and rapid prototyping technique to create self-aligned 3D microfluidic structures using polymeric thin films. The novelty stands in the fabrication of complex monolithic multilayered microstructures from a single polymeric sheet assembled by folding, and bonded by thermo-compression.

KEYWORDS: Rapid prototyping, self alignment, COP (cyclic olefin polymer)

INTRODUCTION

The use of a craft cutter for rapid prototyping has been reported before [1-4]. In this case we introduce a new and straightforward alignment method that eases the assembly, avoiding the use of alignment holes and pins [1]. Besides, bonding is performed by thermo-compression, which eliminates the necessity of adhesives, making the final device suitable for a wider range of applications, as it is composed of only one material.

The fabrication process workflow is shown in Figure 1. It starts slicing the 3D CAD of the microstructures into the number of layers needed to cover the total thickness of the device, taking into account that this number depends on the thickness of the chosen polymeric foil. These sliced layers are placed in the proper folding order creating a 2D CAD design where every other layer is mirrored to match the structures contained in its contiguous layers after the folding step. Each layer is separated from the next one by a dotted line frame indicating the folding path. In the second step, the entire microdevice is cut in the film accordingly to the 2D CAD design. In the third step, the cut film is folded and autoaligned and finally, stacked layers are bonded.

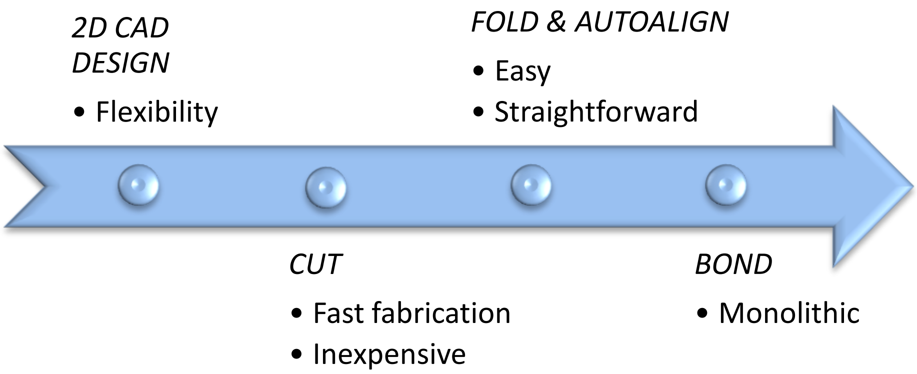


Figure 1: Workflow

Unlike other rapid prototyping techniques, e.g. hot embossing, lithography or casting; this one does not need clean room facilities reducing fabrication costs and times as it eliminates the necessity of a mould. This method allows multiple layer stacking keeping an excellent alignment level among them, thus enabling production of prototypes with excellent microfluidic functionalities such as valves, reaction chambers (PCR, chemical synthesis,...), mixers, inlets and channels...

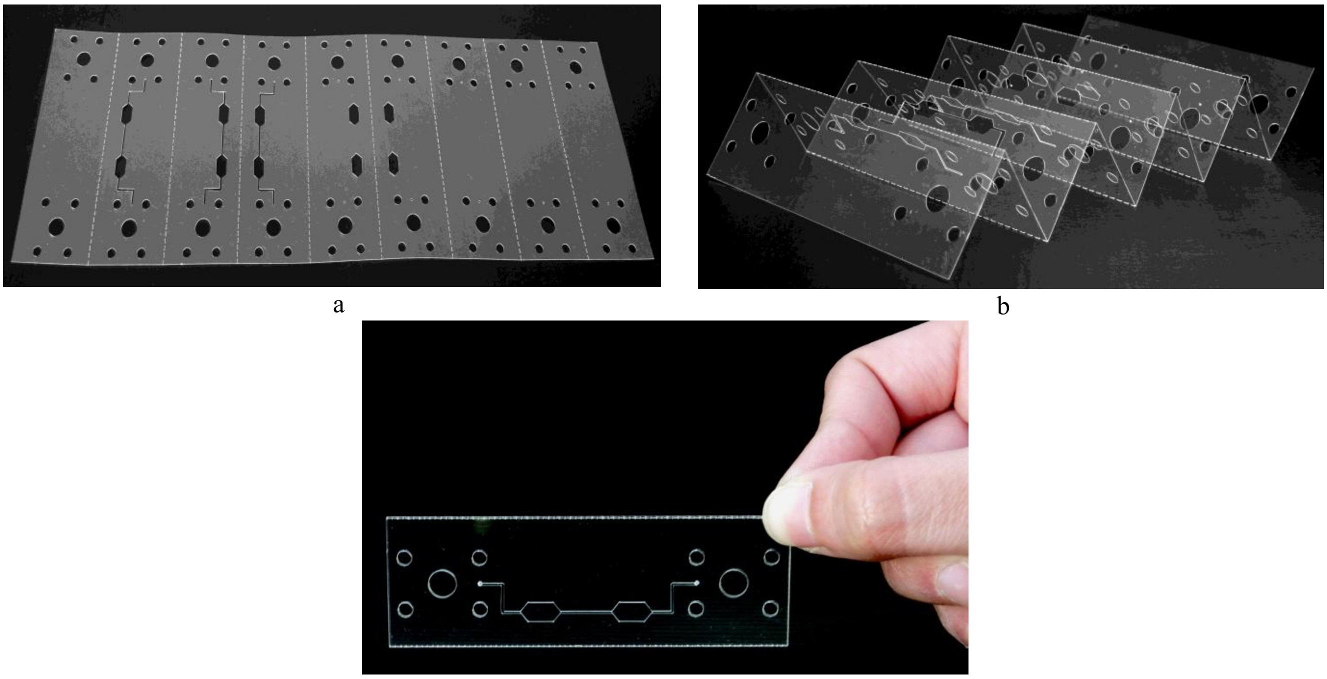
EXPERIMENTAL

In this work, the cutting process was performed using a cutting plotter (GRAPHTEC FC8000-60) that is traditionally utilised in the sign industry for cutting graphics in vinyl films. Here it is equipped with a CB09UA blade. The addressable resolution of this tool is 10µm, which fits the requirements for most applications in microfluidics.

COP (cyclic olefin polymer) is the chosen material to be cut, due to its good chemical, thermal and optical properties. In this particular case, a 100µm thick sheet of ZF-14-100 Zeonor® was used.

An adhesive carrier sheet is used as a support during the cutting process of the layout into the COP film, to prevent the film from bending or wrinkling and hence, to transfer the 2D CAD design as precisely as possible to the film.

After completion of the cutting process, unwanted material is weeded manually using a pair of tweezers (figure 2-a). The remaining impurities and dust are removed from the surface with the help of a deionizing air nozzle. In the next step layers are folded alternatively following the dotted lines written with the cutting plotter (figure 2-b). And finally, assembled polymeric foils are placed between two glass slides with the same area of the foils. These glass slides act as a solid substrate, confering stiffness to the stacking. Thermo-compression bonding takes place at 138ºC and 4kN for 80 minutes. In figure 2-c a monolithic labcard is shown after completion of the proposed workflow.



a b

c

Figure 2: (a) Structured COP slide (100µm thickness) including chambers, channels, folding frame and holes for microfluidic connections. (b) Folded layers that will build up the final 3D microfluidic stack. (c) Finished labcard fabricated from a single COP slide and assembled by folding using a self alignment frame

RESULTS AND DISCUSSION

First of all, a series of channels (rectangles) have been cut varying the step size down to 10 µm in order to evaluate the resolution obtained with the CB09UA blade, applied to a 100 µm thick COP film. The results, using 10 µm and 25 µm resolution, are shown in table 1 for channels between 500 and 600 µm wide. It can be seen that the X axis (film movement) produces features closer to the design size than the other one (blade movement), and in both cases the result is precise (reproducible).

Table 1. Deviation of the cut structures from the theoretical size (based on 5 measurements for each data)

CB09UA					
Resolution	**Theoretical Size (µm)**	**Y AXIS (blade)**		**X AXIS (film)**	
		Channel (µm)	St. deviation (µm)	Channel (µm)	St. deviation (µm)
10µm	500	479.75	1.50	511.75	0.96
	525	498.75	0.96	525.25	2.06
	550	523.80	2.59	552.50	0.58
	575	564.75	3.10	558.00	0.71
	600	580.25	0.96	592.25	2.22
25µm	500	598.00	7.49	499.20	4.49
	525	480.77	1.17	532.60	5.06
	550	503.40	2.71	551.20	2.70
	575	528.00	2.37	572.80	7.13
	600	561.60	3.82	583.70	23.82

Once the cutting plotter was tested, the following step was to obtain the alignment error depending on the resolution. For that purpose, a chamber structure was used. The results are shown in figure 3, where it can be seen the huge difference in the misalignment error depending on the resolution. In figure 3, enlarged views can be found in a, b, c and d, showing the misalignment between the stacked layers.

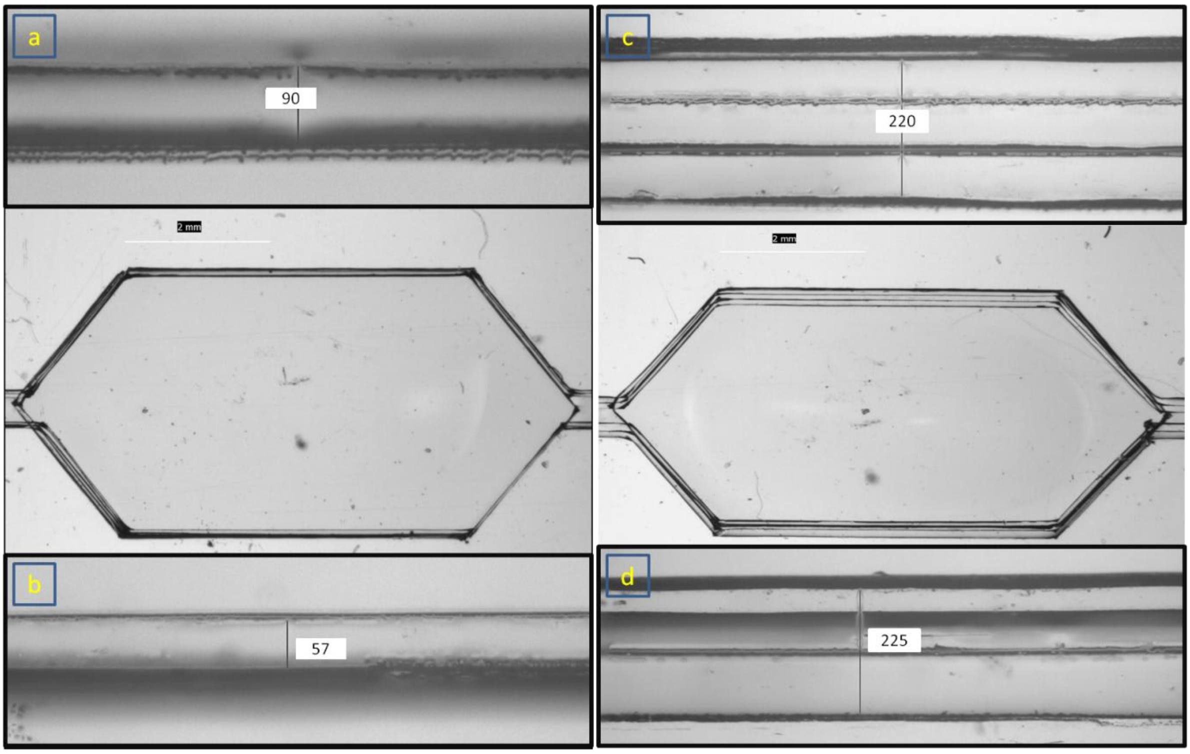


Figure 3: The chamber on the left was cut at an addressable resolution of 25 µm. The chamber on the reight was cut at 100 µm addressable resolution

A labcard was built based on the approach presented in this work. This labcard includes two chambers with a volume of 12µl each, and channels with a section of 300x500µm. It is composed of 9 layers of 100 µm each, producing a device with a total thickness of 900µm. This approach was also succesfully used to produce thermoreversible valves [5].

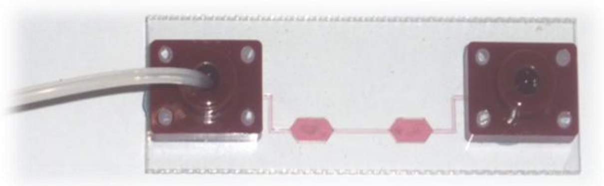


Figure 4: Labcard equipped with the needed adaptor for microfluidic tests

CONCLUSION

A self-alignment concept has been introduced for the assembly of polymeric thin films, which enables the fabrication of fully functional microfluidic prototypes (figure 4) within less than two hours.

ACKNOWLEDGEMENTS

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REFERENCES

[1] D. A. Bartholomeusz, R. W. Boutte and J. D. Andrade, "Xurography: rapid prototyping of microstructures using a cutting plotter", *J. Microelectromechanical Systems*, vol. 14, pp. 1364-1374, (2005).

[2] P. K. Yuen and V. N. Goral, "Low-cost rapid prototyping of flexible microfluidic devices using a desktop digital craft cutter", *Lab on a Chip*, vol. 10, pp. 384-387, (2010).

[3] W. Wang, S. Zhao and T. Pan, "Lab-on-a-print: from a single polymer film to three-dimensional integrated microfluidics", *Lab on a Chip*, vol. 9, pp. 1133-1137, (2009).

[4] J. Do, J. Y. Zhang and C. M. Klapperich, "Maskless writing of microfluidics: Rapid prototyping of 3D microfluidics using scratch on a polymer substrate", *Robotics and Computer-Integrated Manufacturing*, vol. 27, pp. 245-248, (2011).

[5] F. Benito-Lopez, M. Antoñana, D. Diamond, V. Castro-López, "Thermoreversible Modular Microfluidic Valves Using EMISE Ionogel", *Proc. MicroTAS 2013*, Freiburg, Germany, (2013).

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