# Low Cost and Rapid Fabrication of Microfluidic Channels

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## INTRODUCTION

The manipulation of fluids in channels with dimensions of tens of micrometres- microfluidics- has emerged as a distinct new field. It is the science and technology of systems that process or manipulate small ($10^{-9}$ to $10^{-18}$ litres) amounts of fluids, using channels with dimensions of tens to hundreds of micrometres. The first applications of microfluidic technologies have been in analysis, for which they offer a number of useful capabilities: the ability to use very small quantities of samples and reagents, and to carry out separations and detections with high resolution and sensitivity; low cost; short times for analysis; and small footprints for the analytical devices. Microfluidics exploits both its most obvious characteristic — small size — and less obvious characteristics of fluids in microchannels, such as laminar flow. It offers fundamentally new capabilities in the control of concentrations of molecules in space and time. Microfluidics has the potential to influence subject areas from chemical synthesis and biological analysis to optics and information technology. But the field is still at an early stage of development [1].

Microfluidics has seen the rapid development of new methods of fabrication, and of the components — the microchannels that serve as pipes, and other structures that form valves, mixers and pumps — that are essential elements of microchemical 'factories' on a chip. Traditional microfluidic devices are fabricated by etching or molding channels into glass, silicone, PDMS, or other polymers or plastics.

Microfluidics must be able to solve problems for users who are not experts in fluid physics or nanolithography, such as clinicians, cell biologists, police officers or public health officials. For these applications, the total cost and time to be invested into fabrication facilities and materials should be brought down substantially [2]. Various paper based microfluidics fabrication techniques exit. These include photolithography, polydimethylsiloxane (PDMS) plotting, wax printing, laser cutting, and plasma and inkjet etching. All of these techniques, while using paper as the substrate requires expensive machinery and materials such as LASERs, photoresists, wax printers, positioning equipment, etc. [3]

## METHOD

The current method is the direct cutting of microchannels on polymer sheets using a craft cutter machine. The layer with the channels is sandwiched between two transparent plastic sheets. No 'inverse' or 'negative' structures of the shape to be fabricated is made unlike conventional lithography methods.

## EQUIPMENT

The Silhouette CAMEO digital craft cutter was used. The machine is similar to a desktop printer, it cuts paper and other materials like vinyl with a blade instead of printing on it. This craft cutter is designed for personal use for making vinyl decor, scrapbooking, card making and paper crafting, etc. With its own interactive computer software, Silhouette Studio, customized designs can be drawn and cut. Alternatively, customized designs can be generated in any CAD software and saved as DXF file format. The DXF file is then loaded onto the cutter software for direct cutting without the need for additional editing and is positioned adequately. Since the cutter software is not intended for designing microfluidic devices, it is more convenient and flexible to use a CAD package to generate designs.

*Figure 1: Silhouette CAMEO digital craft cutter machine. The cutting mat, tool, and the accompanying device software, Silhouette Studio ® in which a microchannel geometry has been loaded can be seen.*

The craft cutter comes with a rugged positioning mat with square grids. The accompanying software displays an equivalent grid on- screen. The mat is loaded into the machine with its edge aligned with a marking since no digital image feedback exists to ensure correct positioning of the cutting tool. Each grid cell is named alpha numerically and the image to be cut on the substrate is dragged and dropped into the position in the software.

The cutting tool is a V- tipped carbon steel piece assembled into a plastic casing. The length of the tool tip protruding out of the casing is controlled by a screw mechanism. The protrusion is graduated from 1 to 10 and its effect is to increase the depth of cut. The speed and number of repetitions of cut can be controlled directly from the interactive software. A ‘double cut’ could also be specified along a line in the software, and two cuts will be made along parallel lines 100 microns apart, on both sides of the input line.

## FABRICATION

The final microfluidic device is intended to have a layer of transparent double sided tape with microchannels cut on it using the craft cutter and sandwiched between two Oddy ® Polyester transparency films. The transparent double sided tape used for testing was a 150 micron thick Nitto tape. A full sheet (A4) of transparency film was anchored to the cutting mat, with its edges aligned with the outermost grid lines, using short strips of double sided tape. Strips of Nitto double sided tape of dimensions 5 cm x 2 cm were cut out. The protective coating on one side of each strip was removed and were pasted on to the transparent sheet on the mat at distinct grid positions. Care was taken to prevent air trapping under the tape and forming blisters.

The required channel geometry drawn in a CAD package was loaded into Silhouette Studio software. The two types of geometry tested were, one, a straight channel and two, a Y channel. Several test runs were made using different combinations of tool depth, speed and number of cuts. The best configuration for the specific tape used was found and imposed for all future tests using the same tape. Both single cut and double cut methods were explored. Single cut channels were satisfactorily produced using high depth of cut and slow speed, with multiple runs at the same location. During a single cut, the plastic layer is seen to shear first and deform to the sides and separate only with multiple cut over the same line. For double cut channels tweezers were used to remove the material cut from the channel. Multiple runs, though fewer than for single cut ones, were observed to be necessary for a clean cut and easy removal of centre material.

The tool tip, with a V geometry, produced a different channel shape for horizontal and vertical cuts when the tool was positioned in alignment with these directions. As a trade-off, the tool was always fixed at approximately 45$^{o}$ to the horizontal/ vertical prior to machine operation.

Holes were punched manually at the inlet and outlet positions- the two ends for straight channels and the three ends for Y channels. Finally the top protective coating of the tape was removed and was pasted to a transparent laser print sheet. Care was taken to prevent trapping of air and not to apply too high a pressure at the channel, lest it be closed by the polymer sheet side walls closing in on each other, especially on single cut channels.

Some of the devices were fabricated with round inlets cut using the craft cutter itself at the tips. These were later tested and characterised using the capillary rise in the channel. Other devices, with punched in/ outlets, were tested using a syringe to pump a dye into the channels.

TESTING

The micro channels were observed under a microscope with digital output and were inspected throughout the channel length. The channel width at various locations were measured and the general form and shape of the channels were studied.

Dyed water was used to check flow through the channels. The only key objective and concern was to obtain unobstructed, confined, continuous flow- without sideways leaks. For channels with punched inlets a syringe was used to inject the fluid while a droplet of fluid was left over the inlet on channels with circular- cut inlets. The latter depended on capillary effects for fluid flow.

RESULTS

Several microfluidic chips with straight and Y channels were produced using the above method. Average time required for the complete fabrication of a single chip was around three minutes. Channel widths as low as 150 microns were observed on visually unobstructed channels. However continuous flow could not be obtained in most of these channels. This may be due to obstructions in the channels in planes different from the one focused using the microscope. The criteria used in choosing the plane of focus on the microscope was the observation of maximum channel width. Continuous flow could be consistently obtained in channels with width greater than 400 microns. These were produced using manually drawn double cut channels.

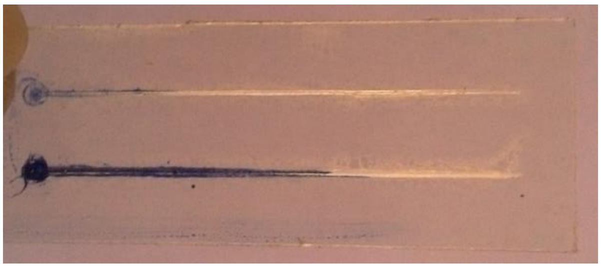

*Figure 2: Two straight channels- top: 200µm, bottom: 400µm. Capillary induced flow is observed in the wider channel up to more than half the length (total 6 cm) where flow stops due to an obstruction*

None of the Y channels produced could sustain continuous flow beyond the junction. This may be due to deformations of the thin sharp material at the Y junction due to hydrodynamic forces, closing the channel branches randomly.

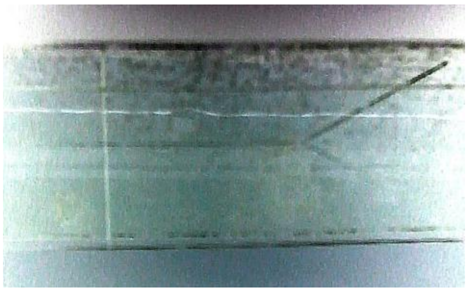

*Figure 3: Photographic negative of Y channel chip. The Y channel is seen as thin black lines*

All channels were seen to have random widths at different positions. This depended on the width of the input drawing, the orientation of the cutting tip at the position and the pressure applied while pasting the upper and lower anchor films. Thus a flow situation in these channels could not be predicted accurately mathematically at present. Moreover fluid always leaked sideways into blisters formed on the flanks of the channel, especially when a syringe was used. In many cases the chips were destroyed as sideways leakage increased as a high inlet pressure was applied. The amount of pressure and flow rate were not quantified since a normal syringe was used.

FUTURE STUDIES

Methods such as hot-tips (for inward and easy shearing), round tips (for uniform shearing of channel walls), and top PDMS layer (to avoid post-cut application of pressure and for proper inlet and outlet harness) should be tested to obtain consistently smaller and uniform channel dimensions. Other materials should be tested in place of the plastic double sided tape, preferably ones that can be made in situ, so that blisters formed by air and presence of dust can be eliminated completely.

## CONCLUSION

Every mainstream microfluidic chip fabrication technology or method comes with a penalty of time or cost of machinery and material. The current method presented here showcases a very low cost and rapid fabrication method which uses commonly available, non-hazardous chemicals/ materials. The process being a direct fabrication method requires the production of the final geometry directly rather than 'inverse' or 'negative' images of the final channel geometry. Hence this rapid method may be developed and used for testing and validating researches, produce lab-on-a-chip devices or point-of-care disposable medical devices.

## REFERENCES


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