

Lasers in Manufacturing Conference 2019

# Complete manufacturing of microfluidics chip with only one ultra-short pulsed laser

Marc Décultot<sup>a\*</sup>, Anne Henrotin<sup>a</sup>, Jérôme Patars<sup>a</sup>, Jose Antonio Ramos-de-Campos<sup>a</sup>

<sup>a</sup>Lasea S.A, Rue des Chasseurs Ardennais 10, Liège 4031, Belgium

---

## Abstract

The microfluidics field is knowing an important expansion and this is due mainly to its various possibilities in the study of chemical and biological reactions with only few consumables. To follow this growth, researchers and industrials need accurate manufacturing tools more flexible, and able to offer the best efficiency for microfluidics chips. In this study we have developed a new methodology based on an ultra-short pulsed laser in order to fulfil these objectives. Thanks to the accuracy of the laser machine and the physical properties of ultra-short pulsed laser, we have developed a flexible solution giving the opportunity to adapt the design for each chip, easily and in an unlimited way, while respecting the microfluidics expectations. Furthermore, to achieve a complete, hermetical, and resistant welding of microfluidics chips, this study presents a new methodology, based on the same ultra-short pulsed laser and machine combined with a new contact free clamping system.

Keywords: ultra-short pulsed laser; micro-machining; welding; transparent polymer; microfluidics

---

## 1. Introduction

The microfluidic field is an astonishing field of research, with his working close to biological system like blood vessel, the possibility to use mini reactor for chemical reaction and a lot of others applications. Polymers are interesting matters for microfluidics (Azouz et al, 2014) and two main steps are necessary to create a microchip.

The first step is the engraving of microchannels in the substrate. The most popular method to make them is by plastic injection, with a mould specially manufactured according to the microfluidic design. This method

---

\* Corresponding author. Tel.: +32 (0) 4 365 02 43; fax: +32 (0) 4 384 37 55.  
E-mail address: mdecultot@lasea.com .

is very efficient and cheap for large productions. But it's not appropriate to manufacture prototypes, because each design modification requires to manufacture a new expensive mould. In another hand, the laser processing of polymers (Klank et al, 2002, Cheng et al, 2004, Nayak et al, 2008) makes it suitable for manufacturing of prototypes, thanks to its high versatility to quickly modify the designs, combined with the accuracy and the power of the laser beam.

The second step is the sealing of these microchannels to ensure hermeticity. To seal the chip, a thin transparent film is welded without any additional substrate, as layer of absorption (Volpe et al, 2015 and Roth et al, 2017), on the transparent engraved substrate. The flexibility of laser tool is very suitable to adapt to each modification of the design, even if sometimes it's necessary some complex clamping tooling for ensuring a good result.

Generally, these two steps are manufactured with different tools, but this study presents the results of the achievement of these two steps on COP substrate with the same femtosecond laser. The engraving step shows microchannels with order of magnitude of hundred micrometres, and a roughness of 300 nm. For the sealing, a new clamping system using electrostatics forces is presented, which enables to make the welding. Combining these two steps, a microfluidic chip has been completely manufactured.

## 2. Industrial setup

To make the two steps of the microfluidic chip manufacturing with only one laser, a machine has been built by LASEA (Fig 1). The laser of 20 W at 1030 nm with a pulse duration of 300 fs has been used for the engraving and the welding of the microfluidic chip. To guide the laser beam, the machine has a LS-Scan® (galvo-scanner of LASEA) equipped with a F-theta objective of 100 mm, which gives a spot of 14  $\mu\text{m}$  diameter, and controlled by the LASEA's software called KYLA™. Finally, the machine is also equipped with a form recognition camera to ensure correct position of samples, and with an electrostatic charge generator for the clamping system.

This machine enables easy modifications of microchip design, and a free-contact manufacturing.



Fig.1. (a) Pictures of the outside of the machine; (b) and of the inside.

### 3. Micro-channel machining

Depending on the detection application in particular for which the microfluidic chip is required, we will have to use a microchannel design or another, with its length, section, roughness, etc. optimized to it, and usually with a high requirement of precision and detail.

During this study, the common microchannels size is 100  $\mu\text{m}$  depth and 200  $\mu\text{m}$  wide, but smaller microchannels could be achieved easily thanks to the small spot size of the beam (14 $\mu\text{m}$ ). The Fig 2 shows an example of a microchannel's dimensions.

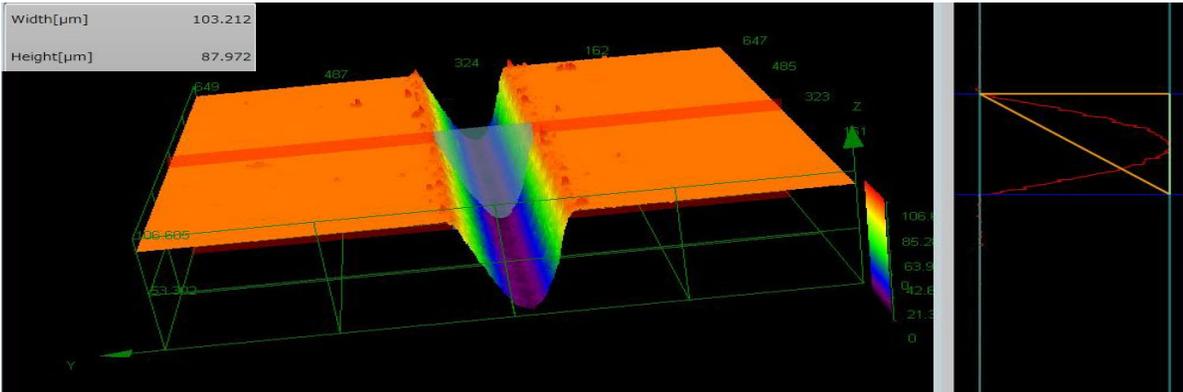


Fig. 2. Profile's view of a microchannel with its dimensions

The laser micromachining of polymers causes the appearance of bubbles beneath the surface engraved (Huang et al, 2010). When the bubbles growth and when they explode, this creates a succession of craters that degrades the microchannels roughness. This phenomenon is limited in the present study thanks to the femtosecond laser used. Actually, this short-pulsed duration allows low thermal diffusion in polymers and induces a roughness around 400 nm. To overtake this limit, new device has been added to the machine to reach value of roughness below the 300 nm. The Fig 3 shows the roughness analysis of the bottom of a microchannel of 100  $\mu\text{m}$  depth and 200  $\mu\text{m}$  wide, made with a confocal microscope.

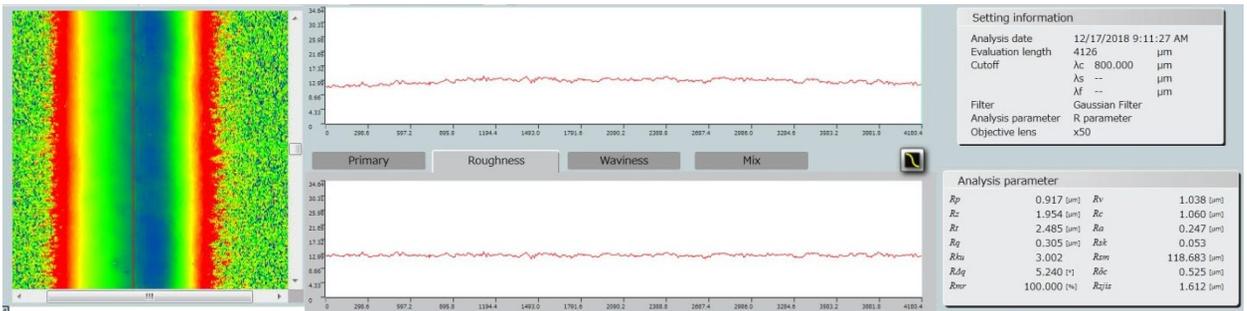


Fig. 3. Analysis of bottom's microchannel with roughness below the 300 nm

#### 4. Micro-channel welding

To ensure a good control on the fluid flux is needed to achieve a totally hermetical sealing of microchannels. The developed system enables a perfect enclosure without leakage.

##### 4.1. Clamping system

One of the most important aspects to obtain a good welded joining is the clamping system. If the gap between the two polymers is too high, the polymers can melt, but without mixing with each other. The joining will be at best, an adhesive joining, but not a cohesive joining. To control the dimensions of the gap, it's possible to take advantage of the transparency of the materials. Indeed, the thin air gap between the two parts, produces a pattern of coloured fringes when observed from the top in ambient light (Fig 4). This interferometric pattern is described thanks to the interference's theory, by the equation 1.

$$I(\lambda) = I_{R_1} + I_{R_2} + 2\sqrt{I_{R_1}I_{R_2}} \cos\left(\frac{4\pi l}{\lambda} + \pi\right) \quad (1)$$

According to this equation, it is possible to link the colour of each fringe to the thickness of the gap between the two polymers, which allows us to ensure the quality of the clamping.

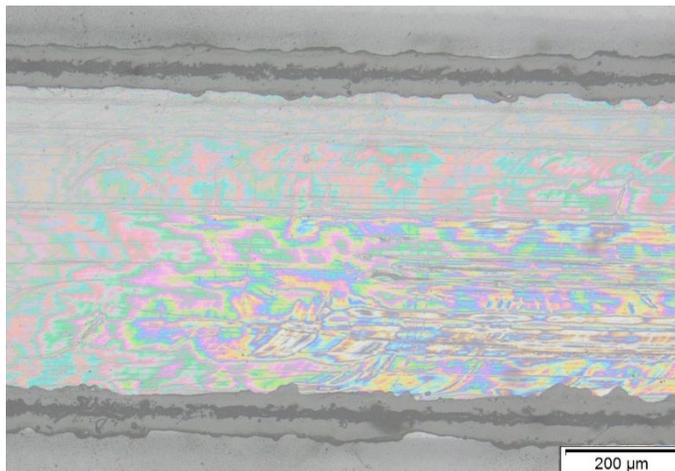


Fig. 4. Example of colored fringes on a chip sealed, between two microchannels.

A classical way to ensure a good clamping of the two polymers is based on a piston that will push together the two polymers against a transparent plate. The drawback of this method is that severe damages can be done to the samples and the transparent plate is affected by the heat during the joining process. Another problem is the lack of parallelism between the piston and the transparent plate which causes an inhomogeneous clamping. To avoid this, LASEA uses opposed electrostatic charges on the two polymers, which makes electrostatic attraction between them. Thanks to this invention (patent pending), a really good locking up is ensured without contact of external device, avoiding all the inconvenient of the classical clamping system, making the system more adapted for industrial production.

#### 4.2. Welding

After the lock up of the polymers together, laser parameters defined by LASEA are applied on the sample to make the welding. When materials melt, due to the energy of a laser beam, the heat diffusing around the irradiated zone causes a weld seam bigger than the spot size of laser. With a spot size of  $14\ \mu\text{m}$ , the low thermal diffusion of the femtosecond laser makes possible to have a weld seam of only  $100\ \mu\text{m}$  width. Due to the measure of the exact position of the sample with the form recognition camera, the weld seam is accurately positioned around the microchannel. This welding is strong enough to resist at a pression of 8 bars and no leak was observed on a microchannel of 30 cm length.

### 5. Complete manufacturing

Using the LASEA machine with only one ultrafast pulsed laser, microchannels have been engraved to draw the LASEA logo and the film have been welded on the chip, finalizing a complete manufacturing of a microfluidic chip, with a specific and complex design (Fig 5).

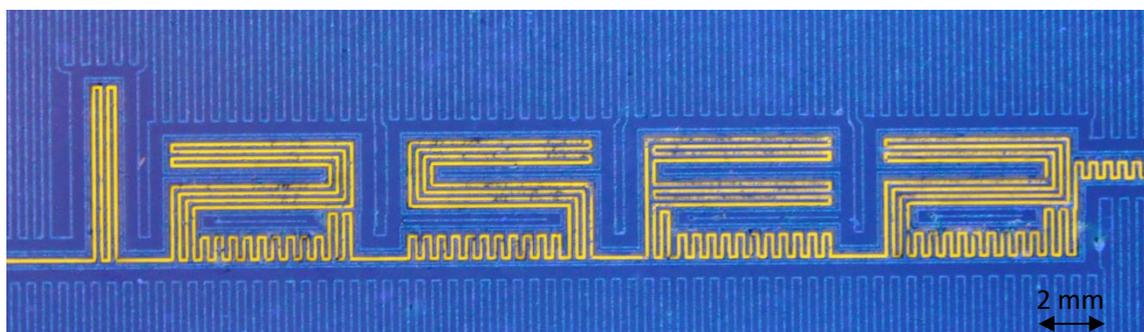


Fig. 5. Example of a microfluidic chip (width of  $120\ \mu\text{m}$  for microchannels) manufactured with the machine of LASEA.

### 6. Conclusion

This work proved that it's possible to process the two steps of microfluidics' chip manufacturing with only one ultra-short pulsed laser. For the engraving of microchannels in the polymer, a width of  $100\ \text{nm}$  and a depth of  $80\ \mu\text{m}$  are affordable, and a roughness below the  $300\ \text{nm}$  at the bottom of a channel of  $200\ \text{nm}$  wide have been demonstrated. In future, smaller microchannels with lower roughness will be investigated.

For the sealing of microchannel, a complete microchip has been welded, using the same laser than for the engraving and the new clamping system based on electrostatic charges.

## **Acknowledgements**

We would like to acknowledge the assistance of the Wallonia Region for its financial support, in the frame of the project 7512.

## **References**

- Azouz, A.B., Murphy, S., Karazi, S., Vásquez, M., Brabazon, D., 2014. Fast Fabrication Process of Microfluidic Devices Based on Cyclic Olefin Copolymer in *Materials and Manufacturing Processes*. 29, 93-99.
- Klank, H., Kutter, J.P., Geschke, O., 2002. CO<sub>2</sub>-laser micromachining and back-end processing for rapid production of PMMA-based microfluidic systems in *Lab Chip*, 2, 242-246.
- Cheng, J-Y., Wei, C-W., Hsu, K-H., Young, T-H., 2004. Direct-write laser micromachining and universal surface modification of PMMA for device development in *Sensors and Actuators B* 99 186-196.
- Nayak, N.C., Lam, Y.C., Yue, C.Y., Sinha, A.T., 2008. CO<sub>2</sub>-laser micromachining of PMMA: the effect of polymer molecular weight in *J. Micromech. Microeng.* 18 095020.
- Volpe, A., Di Niso, F., Gaudioso, C., De Rosa, A., 2015. Welding of transparent polymers using femtosecond laser in *Optics Express* 23, 4
- Roth, G.L., Rung, S., Hellmann R., 2017. Welding of transparent polymers using femtosecond laser in *Optics and Lasers in Engineering*, 178-181.
- Huang, Y., Liu, S., Yang, W., Yu, C., 2010. Surface roughness analysis and improvement of PMMA-based microfluidic chip chambers by CO<sub>2</sub> laser cutting in *Applied Surface Science* 256 1675-1678.