Femtosecond laser rapid prototyping and characterization of microfluidic device for particles sorting

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Abstract. Rapid prototyping methods for the fabrication of polymeric lab-on-a-chip (LoC) are on the rise, as they allow high degrees of precision and flexibility. In this contest, the flexibility of ultrafast laser technology enables the rapid prototyping and high-precision micromachining of 3D LoC devices with complex microfluidic channel networks. In this paper, we describe the realization process of a microfluidic tool for fully inertial particles sorting. The microfluidic network was realized in polymethyl methacrylate (PMMA), exploiting femtosecond laser technology. The multilayer device was assembled through a facile and low-cost solvent-assisted method. In particular, we studied the particle focusing in curved inertial microfluidic channel with trapezoidal cross section. A particles focusing along the walls of the device, sensitive to particle size and flow rate, was observed based on the principle of Dean-coupled inertial migration in spiral microchannel.

1 Introduction

Lab-on-a-Chip (LOC) are portable and compact microfluidic devices capable to process small amounts of biological samples with high precision and sensitivity. Potentially, such devices can integrate in small and compact platforms the capabilities of a standard biological laboratory. Polymeric materials, such as PMMA, are attracting growing interest because they are much cheaper although keeping good mechanical strength, optical transparency, chemical stability and biocompatibility. Various techniques can be employed to fabricate polymeric LOC devices. Among them, the fs laser technology can successfully be employed especially when customization or rapid design modifications are required. Here, we exploited the fs-laser 3D capabilities for fabricating a polymeric side-based cell sorter. The reliability of the LOC was tested through fluorescent polystyrene beads.

2 Materials and methods

The device was fabricated on PMMA substrate (Vistacryl CQ; Vista Optics, Ltd., UK) with optical surface quality (measured surface roughness $R_{RMS} < 2$ nm). The plates were square, with a length and width of 30 mm and a thickness of 5 mm for the upper layer and 1 mm for the bottom one. The fabrication setup is in Fig. 1 and is based on a 1030 nm ultrafast laser system (Pharos, Light Conversion) linearly polarized, with a pulse duration of 190 fs. The beam was focused and moved onto the polymeric surface through a galvo-scan head (IntelliSCANNse 14; SCAN-LAB Germany) equipped with a telecentric lens with a focal length of 100 mm, providing a spot diameter at the focusing point of about 25 µm. The device was quickly assembled following the procedure described in [1] and based on a solvent-assisted method. The microfluidic characterization was performed by injecting in the channel diluted fluorescence beads through a syringe pump system and viewing the fluorescence through a microscopy (LEICA DMI3000M)

Fig. 1. Sketch of the fs-laser fabrication setup.

3 Design of the microfluidic device

In Fig. 2 (a) the design of the cell sorter is reported. It is composed of a 6-loop Archimedean spiral microchannel

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with 1 inlet and 2 outlets. The bifurcation was designed for continuous filtration of two different particle sizes, namely 6 µm and 15 µm. To enhance the sorting efficiency, the channel has a trapezoidal shape [2], whose dimensions are in Fig 2 (b).

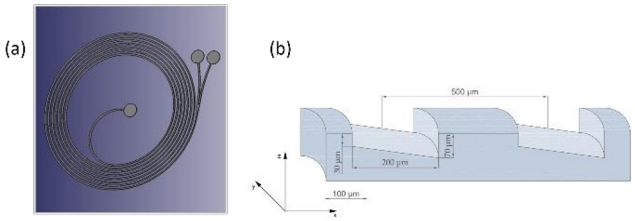

Fig. 2. Sketches of the (a) cell sorter device and of the (b) profile of the microchannel.

For continuous size-based cell extraction the inertial forces inside trapezoidal microchannels are exploited [3]. Spiral microchannels can introduce continuous and stable Dean vortices that apply drag force on microparticles leading to particle focusing along the channel profile depending on the particle size [4-6].

3 Results

A preliminary study of the laser parameters able to produce the layout and dimensions in Fig 2 (b) has been carried out. Particular attention was paid to the quality of the edges, which are required to be as smooth as possible to avoid problems when sealing the device.
The profile of the trapezoidal channel is reported in Fig 3.

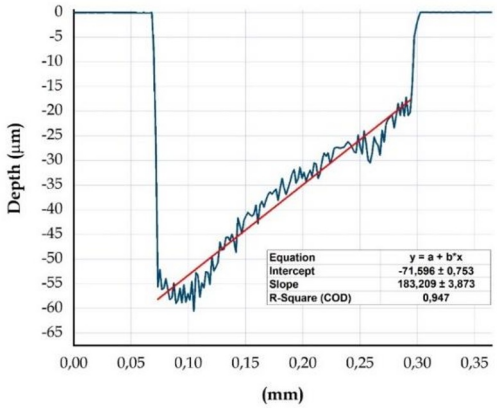

Fig. 3. Trapezoidal profile of the canal reconstructed using optical profiler.

The device was then assembled and connected to the microfluidic pump. The sealing was proved up to $320\ \mu L/min$. The focusing of particles with diameter of $6\ \mu m$ and $15\ \mu m$ was studied by varying the flow rate. Figure 4 shows the flow traces at $15\ \mu L/min$ acquired with 15 µm polystyrene beads. Here, the migration of the microspheres towards the external wall of the channel can be observed, as indicated by the small arrows, as the number of coils increases, proving the reliability of the fs laser fabricated LOC.

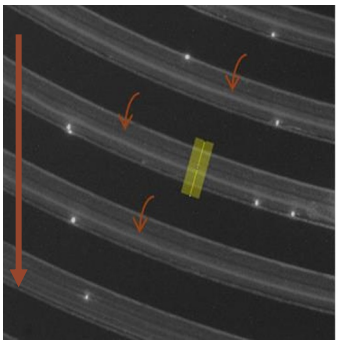

Fig. 4. Microscope image of the 15 µm beads flowing in the spiral microchannel (15 µL/min).

Acknowledgements

This research was funded by the Italian Ministry of Education, University and Research (MIUR) within the projects TIT-AN Nanotecnologie per l'immunoterapia dei tumori [PON ARS01_00906] and EXTREME [PON ARS01_00849].

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