A MICROFLUIDIC SYSTEM FOR INTEGRATION ON LAB-ON-A-CHIP DEVICES

A. A. Gomes[1], P. C. Morim[2], P. M. Oliveira[2], C. M. Marques[2], G. Minas[2], A. J. Pontes[1*]
[1]IPC- Institute for Polymers and Composites, Department of Polymers Engineering
[2]Department of Industrial Electronics
University of Minho, 4800-058 Guimarães, Portugal
***corresponding author: pontes@dep.uminho.pt**

Abstract *— One of the main potentialities of a Lab-on-a-chip is the control of the processes in chemical analyses and the accomplishment of biochemical experiences, with application in medicine and biotechnology. The integration of microfluidic biochip in mass production is one of the objectives of this work. Unlike other cases of microfuidic systems which microchannels layout are a "serpentine", the proposed one has the particularity that the microchannels have a layout similar to "ladders". The main advantage associated to this solution is that it can be obtained a complete mixing or reaction with smaller channels lengths, smaller sample volumes, short response times and with a fabrication cost reduction. Moreover, it can be easily integrated in Lab-on-a-chip device.*

Key Words: *microfluidic, Lab-on-a-chip, microinjection, micro part design*

I INTRODUCTION

The micro level analysis is a reality that brings enormous advantages when compared to traditional methods. The decreasing of fluids volume, the reduction of costs in the process, the control improvement and the quickness in obtaining results are some of the advantages [1].

The healthcare sector is nowadays one of the most dynamic and where the novelty is a strategic and operational imperative. The possibility of perform clinical analyses with instantaneous results and outside the clinical laboratories has led to the development of microfluidic devices with the fluidic, detection and readout systems integrated in a single-chip [2].

The research field and technological development of microfluidics has been developing quickly. This induces the attention of the industry and scientific community in all over the world.
One of its main potentialities is the control of the processes in chemical analyses and an achievement of biochemical analysis, with wide application in medicine, pharmaceutical industry and biotechnology, among others.
In microfluidic component several materials have been used, such as glass, plastic, resin or metal.
In this paper a description of the polymeric component (microfluidic system) focusing on the geometry, the materials selection and process viability is presented.

II MICROFLUIDIC SYSTEM

II.1 ANALYSES OF FLUIDS CONCENTRATION

The proposed microfluidic system should be an integrated part of a Lab-on-a-chip device that measure the concentration of biochemical parameters in biological fluids by spectrophotometry. This analytical technique is based on colorimetric detection and it is a very convenient and often used analytical technique in clinical laboratories for routine tests analyses [3]. The measurement is based on optical absorption in a part of the visible spectrum defined by the reaction of the specific biomolecule with a specific reagent. In addition, the biomolecule concentration is measured by using a mixture of a reagent with a sample [3]. Therefore, a complete mixture must be assured before the detection. Moreover, the microfluidic system that comprises the microchannels and detection chambers must comply with the requirements of that analytical method.

II.2 MICROINJECTION

Microinjection molding is one of the key technologies for micromanufacturing and it is widely used as a cost effective replication method for mass production [4].

Components manufactured by microinjection molding fall into one of the following two categories [4]:

- Type A - are components with overall sizes of less than 1 mm.
- Type B - have large overall dimensions but incorporate micro features with sizes typically smaller than 200 μm.

For a mass production of the integrated microfluidic system, which is one of the main objective of this work, the microinjection moulding process will be used. This process is one of the most promising mass production methods for polymer materials.

II.3 GEOMETRY OF THE MICROFLUIDIC

The outside dimensions of the microfluidic component are 26x11x1,3 mm (Figure 1). The component to be produced by microinjection is constituted by 2 parts: the "cover" and the “micromixer”.

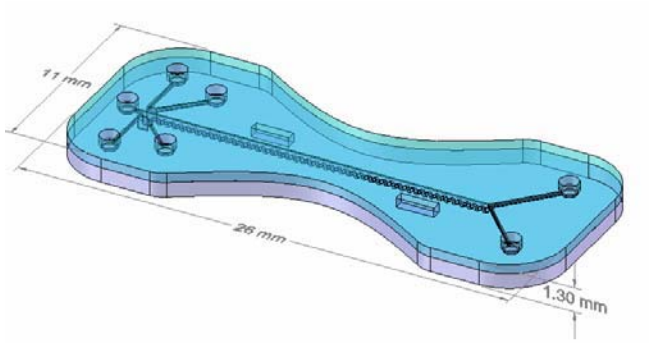

Figure 1. Nominal dimensions of the microfluidic.

This geometry falls in category B, since the micro channel has about 100 μm width and the distance between the steps is less than 200 μm. The angle of the steps is 45º and they are strategically positioned to promote a good mixture between the biological fluid and the reagent. The length of the micro channel is 20 mm, to ensure that fluids are mixed, even when large molecules with small diffusion coefficients are used in the mixing process (Figure 2).
On the micromixer part the holes diameter is 0.8 mm. This lower diameter is necessary to ensure that the tubs of the micro pumps don’t touch the bottom of the hole, allowing that the fluid flows without restrictions.

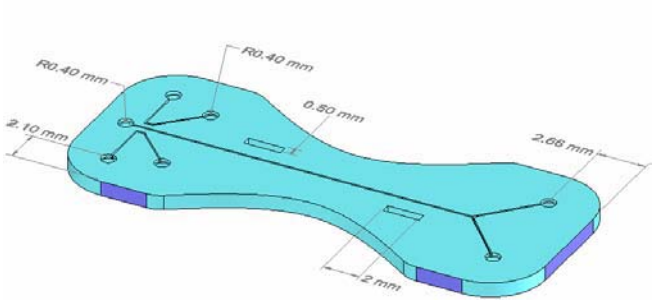

Figure 2. Nominal dimensions of the micromixer.

The cover will be placed above the micromixer in order to perform a micro channel impeding that the inserted liquids comes out of the channel. The micromixer has three blind holes for measurement purposes – the measurement area (Figure 3).

All of the holes on the cover have 1 mm of diameter. These dimensions are in accordance of the characteristics of the micro pumps tubs.

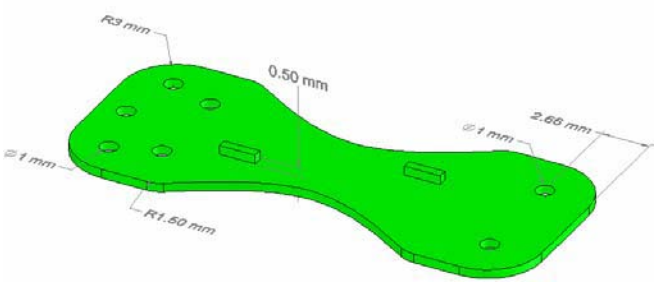

Figure 3. Nominal dimensions of the cover.

To obtain a perfect union between the two parts of the microfluidic, two tears in the micromixer and two saliencies in the cover were created.

The product has the function to mix two fluids: the biological fluid and the reagent and also to allow the color detection of the mixture by optical absorption. The mixer's body has three holes in the measurement area, with a minimum depth of 500 μm and the same geometry (Figure 4). This depth is crucial when it is used spectrophotometry by optical absorption.

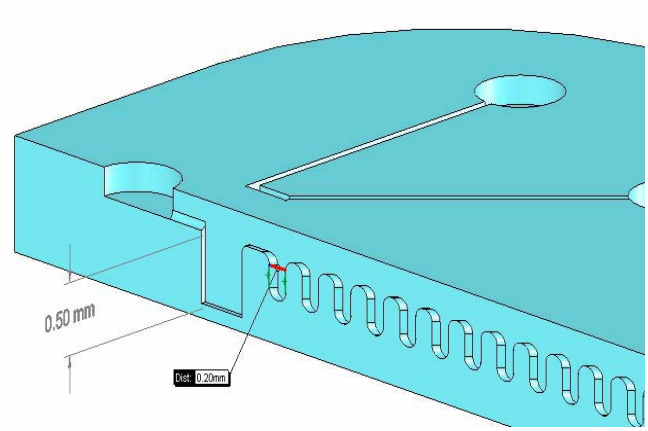

Figure 4. Section of micromixer.

The microfluidic device will use three micropumps to suck the fluids that are directly related with the three existent holes: one will suck the mixture of the biological fluid with the reagent, the other the reagent and the other the standard, e.g., a known concentration of the biochemical parameter in analysis.

Unlike other cases of Lab-on-a-chip which has a "serpentine" [5] as micro channel geometry the purpose micromixer has the particularity to consider the design of a “ladder” [6]. The advantages associated to this geometry are the small sample volume, small channels length, high degree of system integration, short response time and reduced cost [7].

II.4 MATERIAL SELECTION

For the material selection it is necessary that the material satisfies the following characteristics:

- ⇒ the material should be able to be processed by microinjection,
- ⇒ should be transparent,
- ⇒ recyclable,
- ⇒ low cost,
- ⇒ could not interact with the reagent, nor biologic fluid, or with the mixture.

The materials that better confine with this specification are the PDMS (polydimethilsiloxane) and PMMA (polymethylmethacrylate).
Cost, chemical resistance, heat resistance and the accuracy of chip processing are dominant factors on material selection, so PMMA was the chosen one.

II.5 SIMULATION OF THE PROCESSABILITY

In order to assess the processability by microinjection process several 3D simulation of the flow were done using Moldflow software.

The most important conditions of the injection process used in the MoldFlow software are described in next table.

Table 1. Simulation MoldFlow Conditions

Material	PMMA
Temperature mold	60 ºC
Melt temperature	250 ºC
Cooling time	20 s

In Figure 5 it is possible to observe that the filling of the steps is done perfectly without gaps or voids.

The same observation of the uniformity of the filling could done in Figure 6, now for the entire parts.

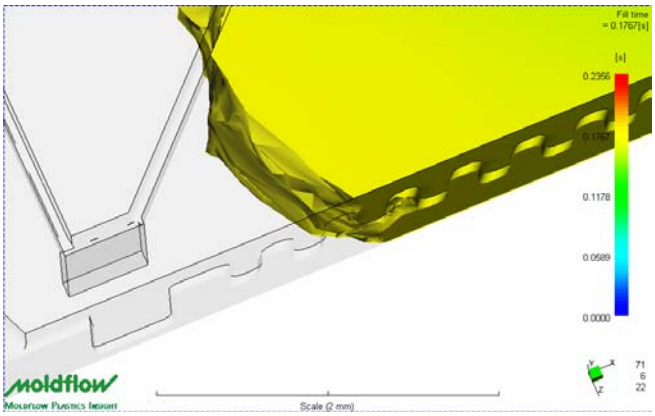

Figure 5. Detail of the steps filling.

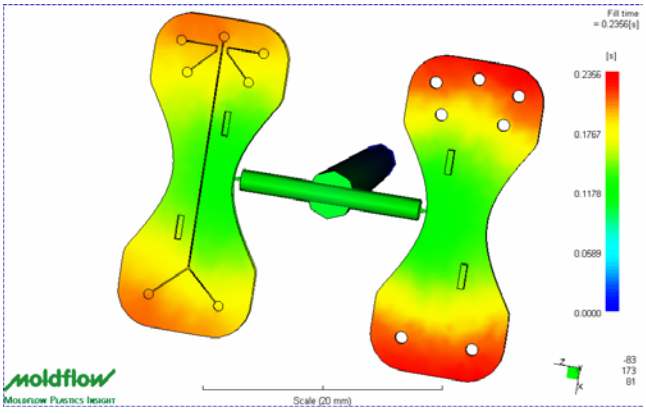

Figure 6. Fill time.

Regarding to the predicted temperature at the end of the fill (see Figure 7) it is possible to observe that the melt increase its temperature in about 9ºC. This temperature rise is due to the high shear rate applied to the polymer melt. However, this will not affect the final quality of the parts.

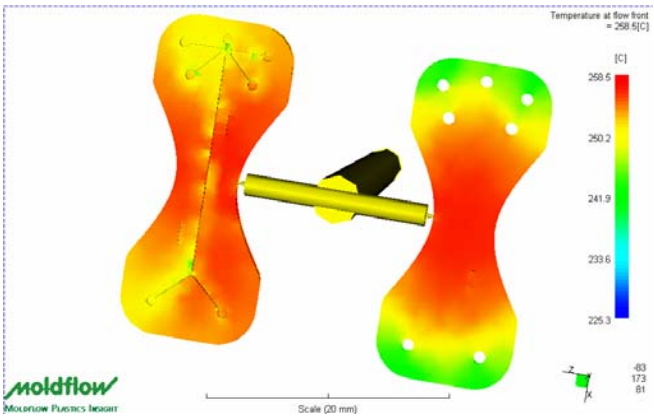

Figure 7. Temperature at end of fill.

In the simulation work a warpage analysis was also done. The prediction results show that the parts will deflect in maximum 0.13 mm in the opposite side of the measurement region, not compromising the measurement analysis (Figure 8).

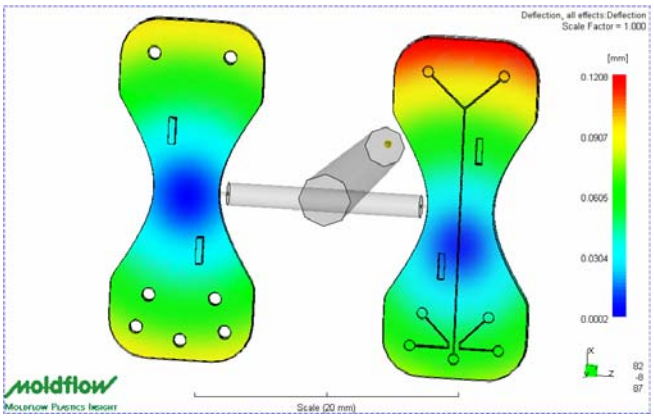

Figure 8. Warpage analysis: deflection results.

III CONCLUSIONS

A new innovative microfluidic device was designed and proposed. This device has the advantage to use small sample volume, high degree of system integration, short response time and cost reduction. Moreover, the mixer can be a disposable die, which minimize the cost associated with cleaning of the microchannels and avoids the contamination between analyses

REFERENCES

[1] R. Tanaka, *Microfluidic Chip Technology in Japan*, March 2006.

[2] Connolly, *Biosensors & Bioelectronics*, 10 (1995), pp. 1-6.

[3] Biochemistry and Organic Reagents: for bioscience investigation. Sigma-Aldrich Diagnostics®, 2002.

[4] C.A. Griffiths, S.S. Dimov, D.T. Pham, Microinjection moulding: the effects of tool surface finish on melt flow behaviour, Elsevier, 2006.

[5] G. Minas, R. F. Wolffenbuttel, J. H. Correia, *A Lab-on-a-Chip for Spectrophotometric Analysis of Biological Fluids*. In Lab-on-a-Chip, 5, (2005), pp. 1303-1309

[6] D.S. Kim, S.H. Lee, C.H. Ahn, J.Y. Lee, T.H. Kwon, Disposable integrated microfluidic biochip for blood typing by plastic microinjection moulding, *The Royal Society of Chemistry*, Lab Chip, no. 6, pp 794-802, 2006.

[7] S. C. Jakeway, A. J. de Mello and E. Russell, *Fres. J. Anal. Chem.*, 266 (2000), pp. 525-539.