Microchemical Journal 144 (2019) 339–344

Contents lists available at ScienceDirect

Microchemical Journal

journal homepage: www.elsevier.com/locate/microc

Secondary bonding of PMMA micromixer with high-pressure

Shuai Zhang, Xueye Chen*

Faculty of Mechanical Engineer and Automation, Liaoning University of Technology, Jinzhou 121001, China

ARTICLE INFO

Keywords:
PMMA sheet
High-pressure
Multi-layer
Bonding strength

ABSTRACT

This paper studies the process to fabricate a micromixer by bonding the PMMA sheets after CO2 laser processing microchannel. It has been widely used in analysis chemical and detection as its low cost. Chemical analysis chips are commonly produced using low-pressure bonding. The bonding strength of the micromixer is improved by secondary bonding with high-pressure, which can meet the requirements of the chemical analysis with higher flowing rate and higher pressure. The effects on the single-layer and multi-layer microchannels are compared with high-pressure and low-pressure bonding. The deformation of the width and height at low pressure and high pressure of the single-layer channel are 12.4 μm, 23.5 μm and 17.1 μm, 54.1 μm, respectively. The multi-layer channels are 43.44 μm, 23.7 μm and 78.1 μm, 27.7 μm. The influence on the height of the V-shaped microchannel is greater when the single-layer micromixer is performed with high-pressure bonding, and when multi-layer bonding with high-pressure, the effect on the width of the rectangular microchannel is obvious. In the process of secondary bonding and pressurization, the chip position can be appropriately adjusted to avoid deformation caused by uneven force on the chip during manual operation. Since high-pressure bonding has an effect on the shape of the microchannel, different bonding methods can be selected according to different requirements of the chemical analysis chips on microchannel quality and bonding strength.

1. Introduction

Microfluidic chip is a functional unit applied in the field of analytical chemistry that integrates mixing, chemical reaction, detection and analysis [1,2], it has the characteristics of miniaturization, integration, and controllability [3]. Because of these advantages, it has been widely used in medical analysis [4], bioengineering [5], microreaction engineering [6] and other fields. Compared to traditional equipment, microfluidic chip has lower manufacturing cost [7], simple equipment requirements [8] and less analytical reagent usage [9] which significantly reduce the costs of application. Microfluidic chips are developed in the field of analytical chemistry, it is based on analytical chemistry and micromachining technology with microchannel. With this chip, fast and high-precision chemical analysis can be achieved. The implementation of lab-on-chip has become possible. As a key component of microfluidic chip, the research and application of micromixers have attracted the attention of scholars at home and abroad [10,11].

The materials currently used to fabricate micromixer chips are mainly silicon [12], glass quartz [13] and polymer [14]. According to different materials used in the production of chips, the processing technology can be divided into photolithography [15], corrosion [16], hot pressing [17], injection molding [18], laser ablation and other processes. High molecular polymer materials have many advantages, such as convenient processing, low cost, good transparency, suitable for mass production, etc. It has become the main material for making microfluidic chips, and has broad application in chemical analysis since these advantages [19]. Especially PMMA, it has been widely application for its excellent performance [20]. Hot pressing is one of the main methods which is used in the production of PMMA microfluidic chips. Zhang et al. has proposed a thermal assisted ultrasonic bonding method for polymer (PMMA) microfluidic devices [21]. Two different methods which be named nanoprecipitation and nanoemulsification evaporation were carried to produce SPIONs-loaded PMMA NPs whose size could be tuned from 100 to 200 nm [22]. A novel and rapid method has been presented for the sealing of PMMA-based microfluidic chips utilizing a low azeotropic solvent composed [23].

In our preliminary work, the design [24], simulation [25], optimization [26] and fabrication [27] of micromixer have been done. In particular, a large number of studies have been carried out on the parameters of processing microchannels on polymer sheets, and did a lot of experiments on the bonding of the micromixer. Based on these studies, this paper mainly focuses on the method to make a PMMA-based micromixer with secondary high-pressure bonding for chemical

* Corresponding author.
E-mail address: xueye_chen@126.com (X. Chen).

https://doi.org/10.1016/j.microc.2018.09.026
Received 3 September 2018; Received in revised form 20 September 2018; Accepted 24 September 2018
Available online 24 September 2018

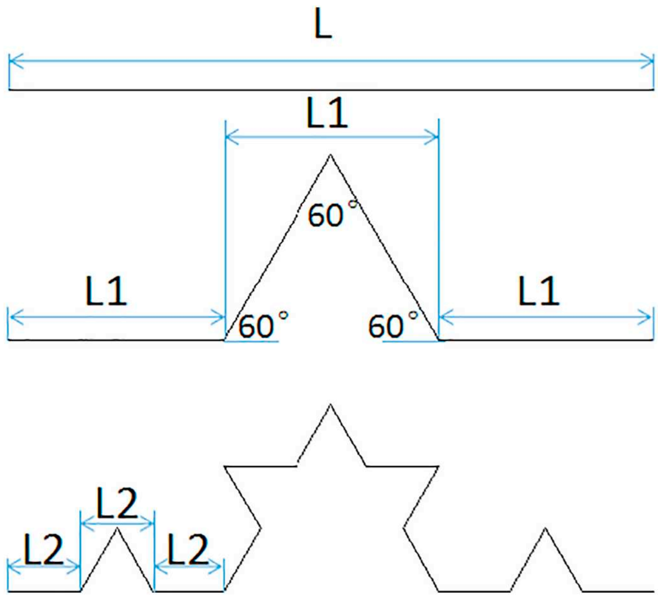

Fig. 1. Koch fractal principle.

analysis. The micromixer is not only sturdy, easy to operate, but also low in cost, it can be used in toxicology identification, DNA analysis, cell analysis, drug preparation, etc.

2. Micromixer model

Fig. 1 shows the design process of the microchannel based on the Koch fractal principle. "L = 9 mm" is a straight line, L1 = L/3 = 3 mm, L2 = L1/3 = 1 mm. the angle between the two sides is 60° degrees.

Fig. 2 shows the planar dimensions of the micromixer. The total length of the microchannel is 25 mm, the length of the inlets is 15 mm, the outlet is 7 mm, and the width of the microchannel is 0.3 mm. The mixing area of the micromixer consists of two Koch fractal units of length 9 mm. Optimized radius of the micromixer is R = 0.2 mm and r = 0.1 mm.

3. Materials and set up

3.1. Micromixer manufacturing materials

PMMA is currently the most excellent transparent material of the polymer with a visible light transmission rate of 92%. It has the advantages of light weight, low cost and easy molding. The refractive index is 1.482–1.521, the glass temperature is 105 °C, and it remains in the solid glassy state at about 115 °C. With temperatures higher than the glass temperature, PMMA has better plasticity and reinforcement, this feature has an important implication in the thermal bonding process of micromixer.

3.2. Experimental set up

The air-cooling CO_2 laser system is used to process microchannels on PMMA surfaces, it is a commercial laser system from Laichuang, Nanjing, PRC. The laser wavelength is 10.6 μm, and the maximum output power is 50w with a frequency of 5KHz. Compressed nitrogen at 0.45 bar of pressure is used as the assistance gas for CO_2 laser cutting of PMMA.

The thermal bonding machine is used to complete the production of the chip. In our laboratory, the thermal bonding machine (WH-2000, Suzhou Wenhao Chip Technology Co, Ltd, Suzhou, PRC) is very convenient and practical. Hot-pressing temperature time and bonding pressure are main control parameters, which are conveniently adjusted by setting buttons of the machine. The structure of the single-layer micromixer is shown in Fig. 2. Fig. 3a shows the distribution of the microchannels of the multi-layer micromixer at each layer based on the single-layer structure. Fig. 3b is a schematic diagram of the multilayer micro-mixer for bonding, PMMA sheets are bonded together under the heating and pressing of the hot plates.

4. Results and discussion

The parameters of CO_2 laser processing PMMA sheet have a great influence on the quality of microchannels. Based on the previous research, laser processing parameters are shown in Table 1. The Single-layer microchannels are processed with lower power, two passes and larger focal length to improve machining quality. Two passes help to reduce the roughness of the microchannel surface and larger focal length increases the width of the microchannel. Fig. 4 shows the cross-sectional shape of single-layer and multi-layer microchannels. Influenced by the Gaussian pulse intensity distribution of the laser beam, microchannel cross-section is V-shape, and the aspect ratio of single-layer microchannels is relatively close. The processing power of multi-layer channel is high, and PMMA sheet is completely cutting, the cross-section of microchannel exhibits a rectangular-shape.

The channels of the micromixer are processed according to the parameters of Table 1 with CO_2 laser system. All chips are cleaned in a

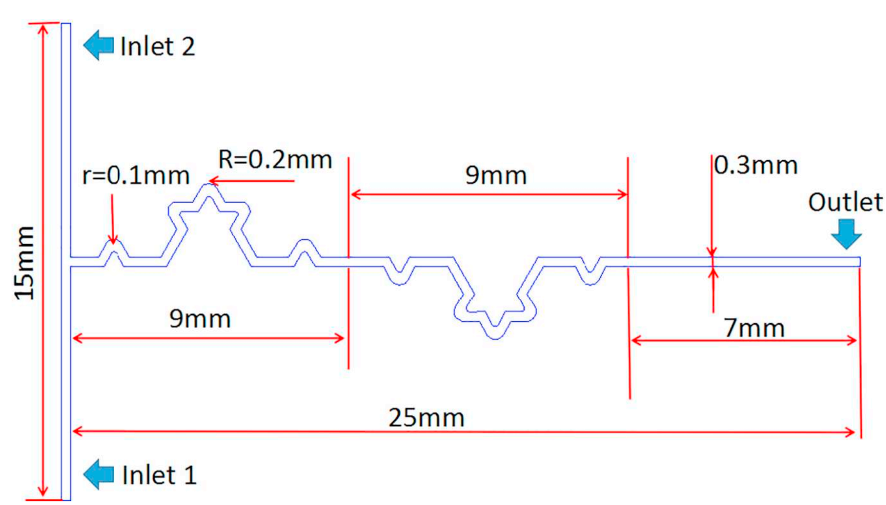

Fig. 2. The planar dimensions of the micromixer.