ELECTRON TECHNOLOGY
Internet Journal
ISSN 1897-2381
http://www.ite.waw.pl/etij/

MIXER WITH MICROCHANNELS IN LTCC TECHNOLOGY

S. KAMIŃSKI, L. REBENKLAU, J. UHLEMANN, K.-J. WOLTER

Electronics Packaging Laboratory, Dresden University of Technology,
D-01062 Dresden, Germany

Received Oct. 23, 2006; revised Nov. 23, 2006; accepted Nov. 27, 2006; published Dec. 15, 2006

ABSTRACT

LTCC technology gives the possibility to form spatial structures and can be used to produce components, applied in analytical fluidic systems. This paper will discuss related construction of Y-shaped mixer with microchannels, including cutting process in two lamination layers of LTCC using CO_2 laser. The sample was fabricated by combination of LTCC structure with PMMA covers (polymethylmethacrylate). Mixer was designed for the fluid flow rate to 20 µl/min. The sample was examined for the two fluids: water and ethanol.

1. Introduction

Mixing two liquids at very small volumes is an important process often used in biomedical applications and chemical analysis. In general, micromixers can be categorized as active and passive devices [1]. An active mixer is achieved by additional pumping and moving elements. However, this type of process is complex and expensive. In comparison with an active mixer, a passive one doesn't need additional elements [2]. Fluidic mixing in microchannels is not as simply as it seems to be in view of occurrence the laminar flow. In this case, mixing relies mainly on diffusion, Reynolds number flow is smaller then $Re < 2320$ [3].The entire fluid mixing in this type of mixer is dependent on width, length, velocity of fluid flow and its diffusion. Accordingly, the channel should be long enough to provide absolute mixing. Applying the equations below, it is possible to determine entire channel length depending on its geometry and applied liquids [4]:

$$\tau = \frac{w^2}{2D}, \qquad (1)$$

$$u = \frac{Q_1 + Q_2}{A}, \qquad (2)$$

$$L = u \times \tau, \qquad (3)$$

where: τ – mixing time, w – the channel width, D – diffusion coefficients, Q_1, Q_2 – the flow rates, A – the channel cross-section area, u – the average velocity, L – the required length of the channel.

Liquid mixers are manufactured by special technologies, usually by bonding etched silicon wafer with microchannels and glasses, respectively. General requirements for the mixer with microchannels are: small device area, fast mixing time, mixing small volumes and integration ability in complex systems [4]. This paper describes design and construction of mixer with microchannels, using LTCC technology, screen printing and laser technique.

2. Test structure preparation

The structure has been designed for mixing two liquids such as ethanol and water. Figures 1 and 2 show design of mixer made of LTCC layer which is combined with PMMA material above and below LTCC material.

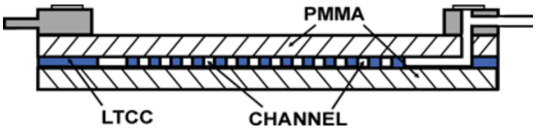

Fig. 1. Mixer cross-section.

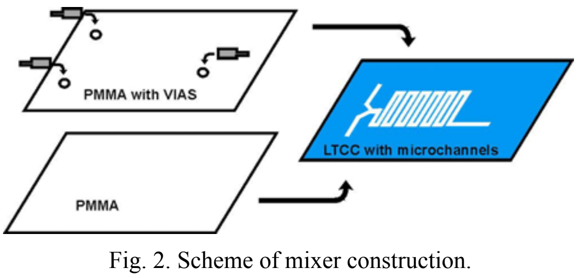

Fig. 2. Scheme of mixer construction.

Mixer was designed for liquid flowing up to 20 μl/min so that the water and ethanol are completely mixed. The channel in LTCC structure has width of 280 μm and 100 mm length. The height of channel depends on thickness of LTCC layer. After burning out the structure, made of 2 LTCC DuPont 941 foil layers, its height amounts to 460 μm (Fig. 3). In the first stage of the process, the two LTCC layers were laminated during an isostatical process at a temperature of 70ºC and pressure of 190 bars. In the second stage, the channels were cut out from green tape by CO_2 laser with power 8 W, a cutting speed of 10 mm/s and an air pressure of $1.4{\cdot}10^5$ Pa.

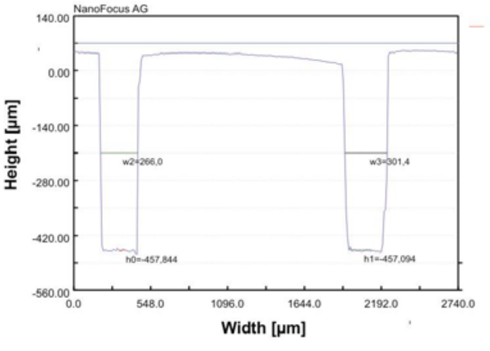

Fig. 3. Cross-section profile of channels in LTCC layer.

Because of the channel's considerable length, it is designed as a meander of 500 μm radius to decrease the area of entire mixer (Fig. 4a). The channel length between each meander is about 5 mm. In the standard technology, the distance length should not be longer than 5 mm because of the occurrence of strong deformation during the burning out process. Deformation is caused by a too-large ratio of length to area width between the channels. Therefore, the LTCC material becomes more elastic and flexible (Fig. 4b).

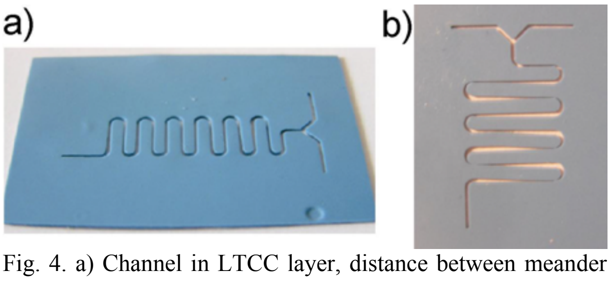

Fig. 4. a) Channel in LTCC layer, distance between meander 5 mm, b) channel deformation after burning out.

PMMA structures are prepared by a CO_2 laser with following parameters: power 40 W, air pressure $1{\cdot}10^5$ Pa, cutting speed 100 mm/s. The holes by which the liquid is flowing from pumps, flows in to the mixing channel, has 500 μm diameter.

Later PMMA covers and LTCC layers are connected to each other by Elastosil N199 silicon compound using screen printing technique. The fittings are mounted on the upper cover in order to connect mixer with pumps supplying the fluids. To compound them, Norland Optical Adhesive 68 Ultraviolet Curing adhesive was used. The entire mixer structure has dimension of $40{\times}25$ mm^2, as is shown in Fig. 5.

Fig. 5. Real appearance of mixer with microchannels made of LTCC and PMMA layers.

3. Mixing test

Mixer is connected to two medical syringe pumps (B. BRAUN Melsungen AG). Each pump supplies one kind of liquid – the first pump extracts water and the second ethanol. When water turns blue and ethanol turns yellow, thus the entire liquid mixed of two substances appears to green (Fig. 6). The system used for mixing observation, consisting of microscope, two syringes pumps and mixer, is shown in Fig. 7.

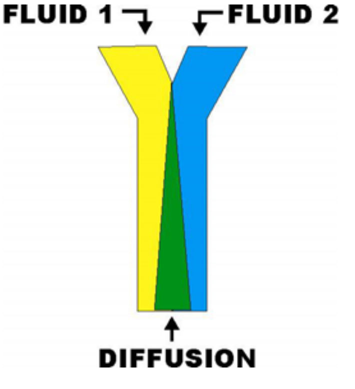

Fig. 6. Mixing by diffusion.

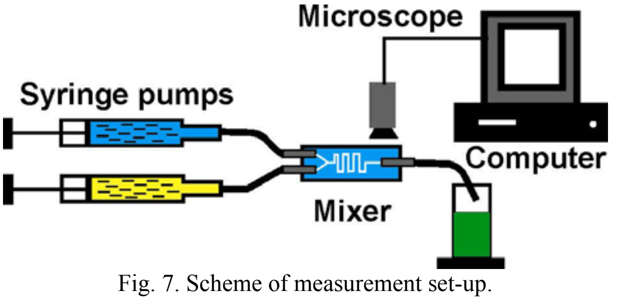

Fig. 7. Scheme of measurement set-up.

The tests of mixing are carrying out for flows in range from 3 μl/min to 33 μl/min. The entire liquid mixed for flow of 20 μl/min was assumed. The achieved result is smaller then assumed and amounts to 16 μl/min of maximal speed by which the two applied fluids were mixed. The results are shown in Fig. 8.

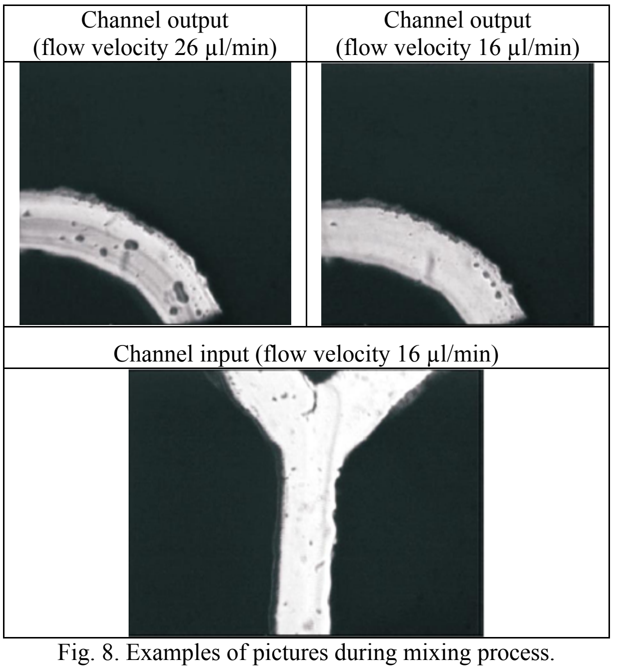

Fig. 8. Examples of pictures during mixing process.

The effect of mixing fluid after flowing out from a mixer for different types of flows is shown in Figs. 9 and 10.

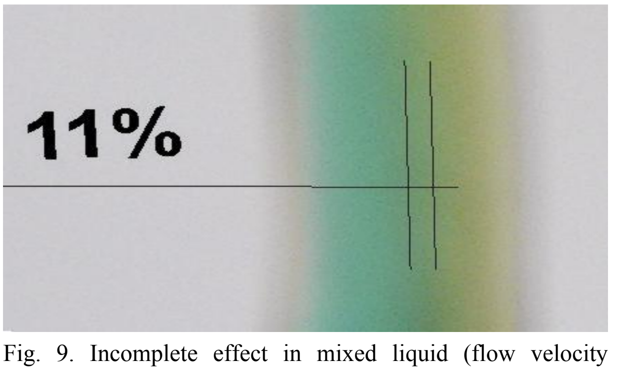

Fig. 9. Incomplete effect in mixed liquid (flow velocity 33 µl/min).

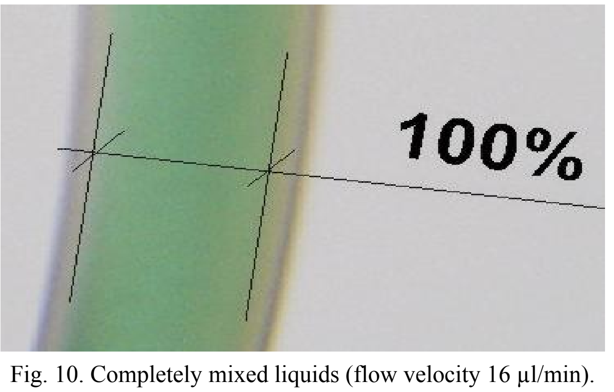

Fig. 10. Completely mixed liquids (flow velocity 16 µl/min).

The results of investigations are show in Fig. 11, depicting relationship of mixing effect with flow velocity.

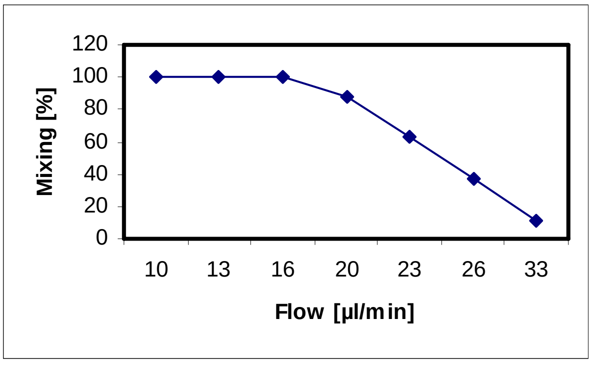

Fig. 11. Influence of flow velocity on the mixing effect.

4. Conclusion

The presented paper describes design and construction of Y-shape mixer with microchannels, which can be integrated with subcomponents and also with analytical devices. The LTCC technology, screen printing and laser technique are used for its fabrication. The process of ethanol and water mixing was observed under microscope and analyzed. In consequence, the effect of entire fluid mixing was obtained for smaller flows than assumed. Probably this is caused by using the coloring agent, which can influence on water diffusion process and ethanol.

References

1. Nam-Trung Nguyen, Zhigang Wu, *Micromixers – a Review*, J. Micromech. A. Microeng., 2005, **15**, R1–R16.
2. G. Ostromecki, T. Zawada, L. J. Golonka, *Fluidic Micro-Mixer Made in LTCC Technology – Preliminary Results*, Proc. 28th Int. Spring Sem. on Electronics Technology, ISSE 2005, 352–357.
3. L. Rebenklau, *Beiträge zum Aufbau und zur Technologie LTCC – basierter mikrofluidischer Bauelemente und Systeme*, Dissertation, Elektronik-Technologie in Forschung und Praxis, Band 11, Dresden University of Technology.
4. Nam-Trung Nguyen, S. T. Wereley, *Fundamentals and Applications of Microfluidics*, 2002 ARTECH HOUSE Microelectromechanical Systems Series).
5. M. Koch, H. Watt, A. G. R. Evants, A. Brunnschweiler, *Improved Characterization Technique for Micromixer*, J. Micromech. a. Microeng., 1999, **9**, 156–158.