MICRO-CHANNEL IN LTCC

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The paper is focused on the micro-channel in LTCC (Low Temperature Co-fired Ceramics), which is one of the methods used for the creation of a fluid sensor. The sensor is composed of a mechanical and electrical part. The mechanical part is 3D structure, where are particular layers lamination on itself. There are many shapes, which creation results micro-channel after lamination and sintering. These shapes are fabricated by laser machine. The main aim of the work is to create the channel of a defined shape and size. It is very difficult because LTCC substrate change size during of sintering. This change can be up to 20 percent in all coordinate. The electrical part comprises electrochemical sensor which was created using thick-films sensors technology.

Keywords: channel, LTCC, thick film, Heraeus, CeramTec

1. INTRODUCTION

LTCC is a technology for multilayer electronic circuits fabricated by lamination of single tape upon itself [8]. Each layer can be a carrier for conductive layers which are produced using classical Thick Film Technology (TFT) process [7] concretely by screen and frame printing. Generally the TFT uses precious metals, such as Au, Ag, Pd, Pt, but other metals such as cooper or aluminium can be used [6]. LTCC technology allows the integration of passive elements like resistors, capacitors and inductors into the 3D structure. The LTCC tape can be used for different shapes which are usually cut by laser machine. The combination of electrical and mechanical components is suitable for construction of complex devices. In our case it is fluid sensor consisting of a mechanical part represented by micro-channel and electrical part represented by the TFT electrodes inserted inside the structure. The aim of this work is the design and fabrication of simple micro-channel to confirm the possibility of use of this technology for construction of more complicated microsystems. In the next part of this work all acquired knowledge is used for design and fabrication of channel electrode system (sensor) for trace determination of species in aqueous solutions.

2. MICRO-CHANNEL DESIGN AND FABRICATION

2.1 Design

The micro-channel was made of Low Temperature Co-fired Ceramics (LTCC) obtained from CeramTec and Heraeus Company. The structure is composed of four layers. The first layer is a base layer. On the base layer there is the second layer with the channel. The third layer is used for the channel as well, because the substrate is thin and it is necessary for the channel to be higher. There are two holes in the last layer which are used for fluid inlet and outlet. The holes and channels are cut into LTCC using laser (ALS 300, Aurel, Italy). The whole structure is shown in the figure 1.

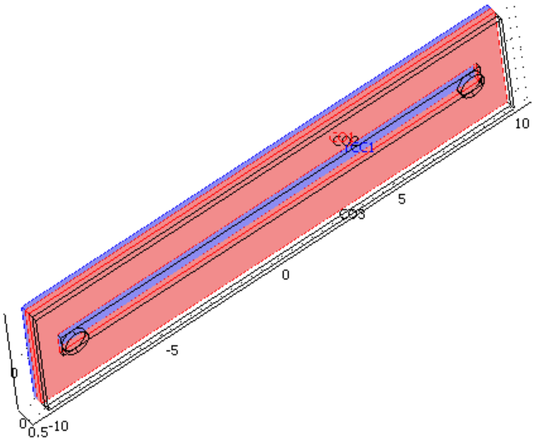

Fig.1.: Design of micro-channel structure

2.2 Fabrication

There are same problems reacted to the first part of the micro-channel fabrication, e.g. a flag of the substrate and poor adhesion of each layer. It is shown in the figure 2. Small (micro-porous) defects can also cause problems to sensors which are based on the fluid principle. The prototype of the channel is shown in the figure 3 and detail of channel in the figures 4 and 5. These problems can be cause bad temperature profile during sintering or sharp edges of structure. The temperature profile is shown in the figure 6.

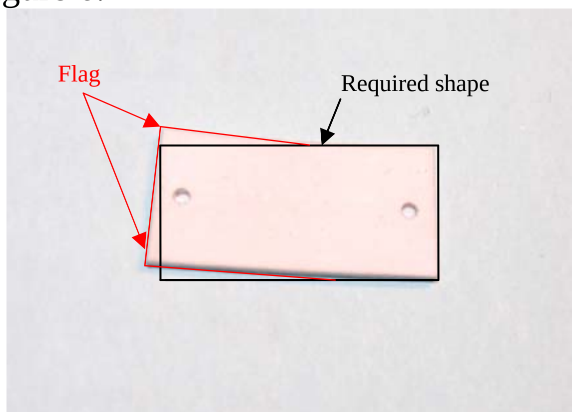

Fig.2: Micro-channel with flag defect

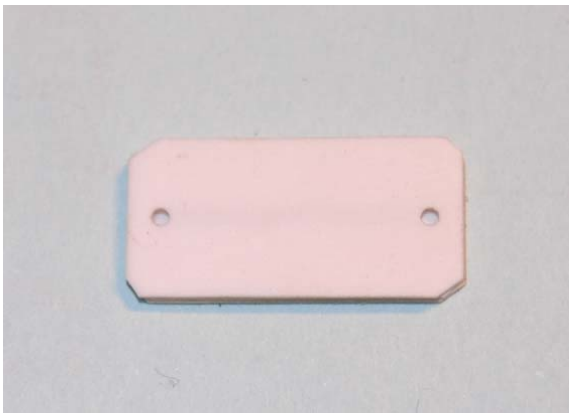

Fig.3.: Final micro-channel without defect

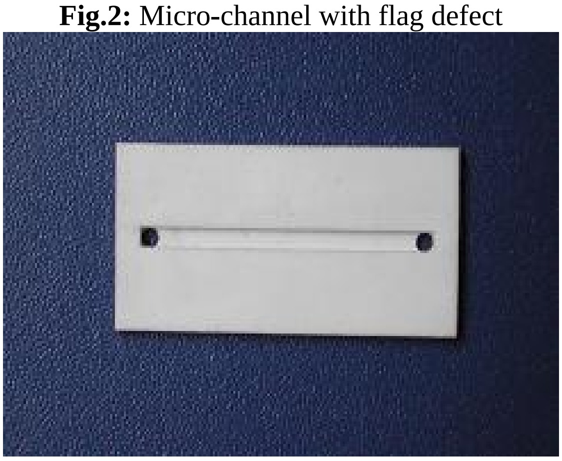

Fig.4.: Detail of micro-channel with holes

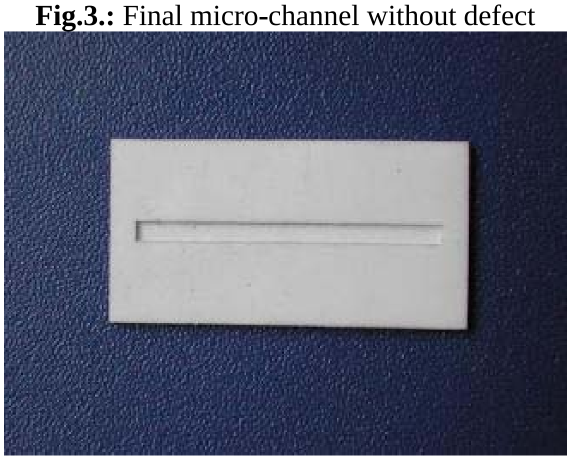

Fig.5.: Detail of micro-channel

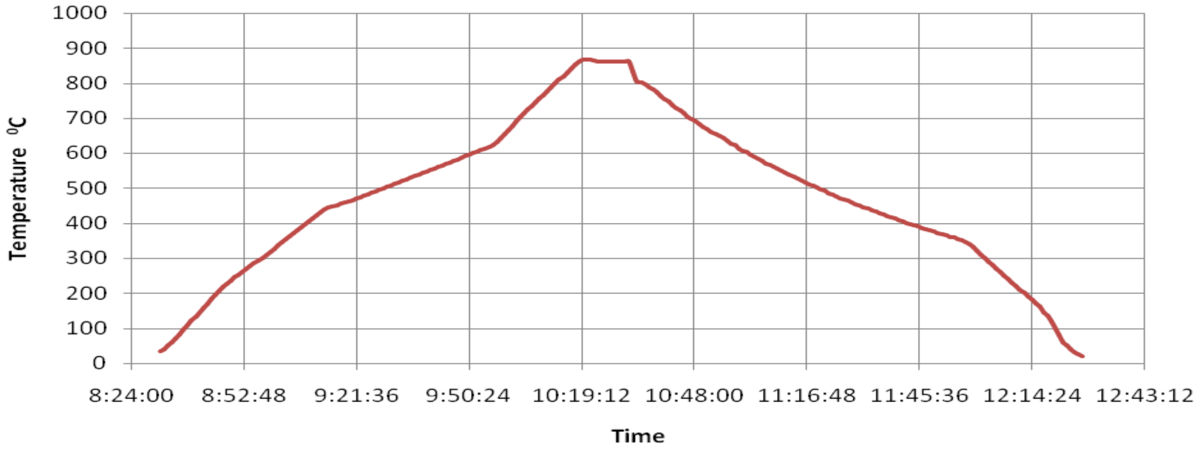

Fig.6.: Temperature profile during sintering

3. Microsystem Design

Another part of this work is focused to the creation of the final structure design with channel electrode system considering above mentioned problems with the micro-channel construction. The final structure consists of four layers as in the first case. The first layer is the base layer in which the electrodes for measurement are placed forming up the three-electrode system. The second and third layers are forming the micro-channel. The last layer covers the whole structure with two holes for fluid inlet and outlet. The design is shown in the figure 7.

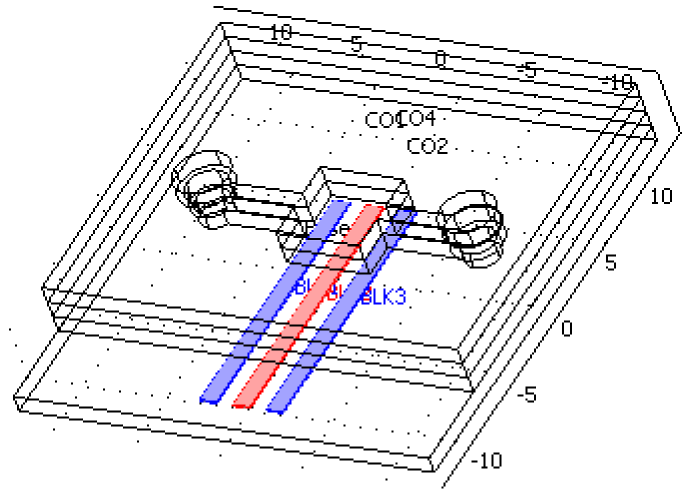

Fig.7.: The design of final micro-channel

4. Results and Discussion

The LTCC ceramics tape CT 700 type from Heraeus Company was used for fabrication. The electrodes were screen-printed using thick-film technology (TFT). Reference and auxiliary electrodes are made of using ESL 9912-K silver based paste and a working electrode is made of gold based paste ESL 8844-G. All used pastes were obtained from ESL Electroscience firm (UK).

Real sample of fabricated channel electrode system is shown in the figure 8. After the main fabrication process a small defect was observed. This defect is probably caused by the incompatibility of the paste and substrate. It means that the size of the substrate was reduced by 20% during the sintering, but the size of the pastes from ESL Company is reduced minimally. The defect was formed just in the place where is the free space above the paste (micro-channel and contacts part). It is shown in the figure 9. This defect decreased the channel profile, but it did not influence the channel patency. The small flag of the substrate is shown in the figure 9 too.

Fig.8.: The sensor top view

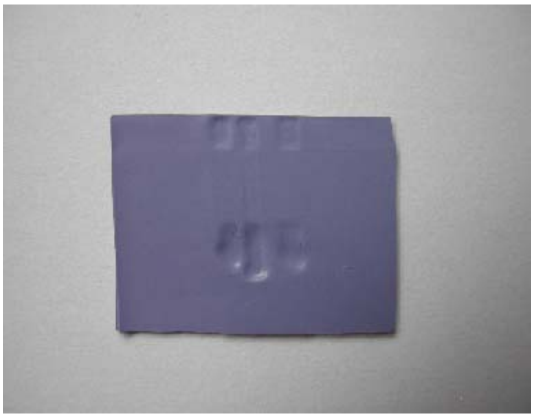

Fig.9: Sensor bottom view

The inlet of analyzed solution to the micro-channel is realized with pipeline. It could not be inserted into the hole, because the hole is very small so that the micro-channel could be chocked up. This problem could be solved by the contacting of pipeline directly on the substrate surface using epoxy resin. The generally suggested material for pipeline is some kind of metal. In our case it is not acceptable material, because various species or elements included in sample solution can react and influence or affect the measurement.

The ideal material for pipeline is the same as the material used for micro-channel. The pipeline made from LTCC is chemically unchangeable, but in contradiction it is fragile and the fabrication is very difficult. First the laser was used for cutting of hole. Then the square sheet of substrate was spooled on the round timber and inserted into the hole. In the next step the structure was sintered. The structure was not fixed during the sintering. The fabricated pipeline from LTCC after the sintering is shown in the figure 10.

There were found many problems during the fabrication of this type of pipeline. Problems came up with sintering, when the substrate change its character. The micro-porosity between substrates is caused by bad adhesion of substrate on the internal wall of the hole. The internal wall of the hole is not smooth enough. The cracks are the next problem. For example they can be caused by substrates pressure activities during the sintering process. The unattachment of the pipeline's walls is probably caused by small pressure in the place where the wall should be joined together. The defects were discovered using the microscopy view. All kinds of defects are shown in the figures 11, 12 and 13.

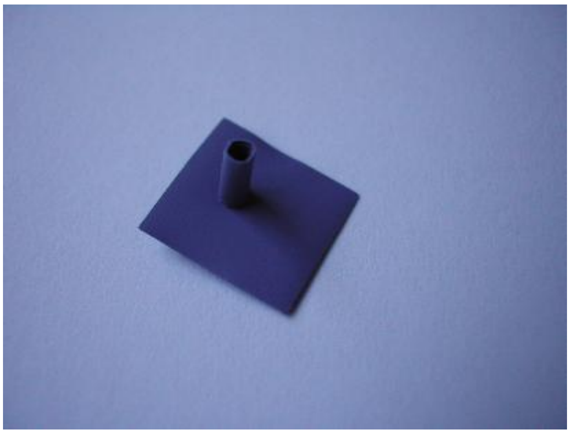

Fig.10: Pipeline from LTCC

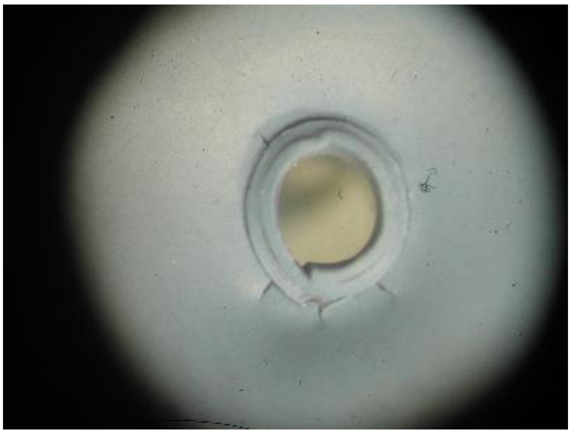

Fig.11: Defect pipeline – cracks

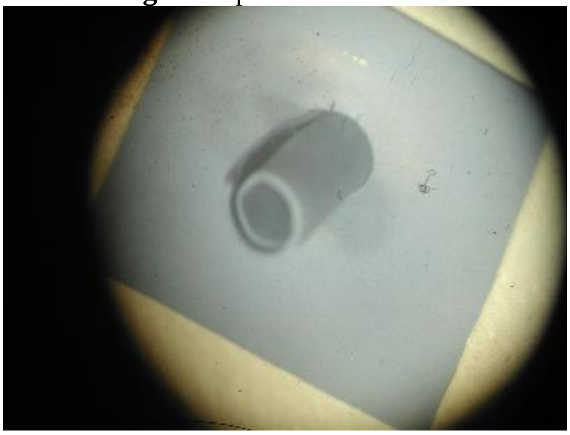

Fig.12: Defect pipeline – unattached substrate

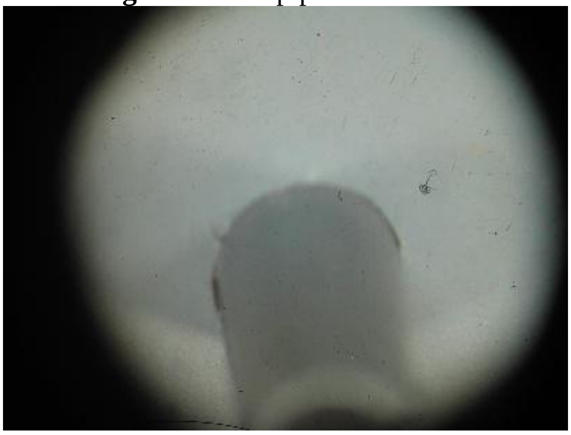

Fig.13: Defect pipeline – micro-porosity between substrates

5. CONCLUSION

In this paper there was shown the possibility of use of LTCC technology for fabrication of small electrode microsystem for trace determination of species or elements in aqueous solutions. Using the obtained experience with basic LTCC micro-channel construction, there was designed and fabricated LTCC based sensor microsystem for trace analyses in aqueous solutions in this work. Observed fabrication problems are described and discussed above.

The next work will be focused on connection of the pipeline to the inlet and outlet and elimination of the flag defect and bulging defect of the substrate. The optimized sensor will be electrochemically tested and evaluated using various voltammetric methods.

6. ACKNOWLEDGEMENT

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