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LTCC Microfluidic Systems for Biochemical Diagnosis

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This paper presents design, fabrication and testing of three LTCC (Low Temperature Co-fired Ceramics) based microfluidic systems. These microdevices are: enzymatic microreactor for urea determination, potentiometric sensor with ion selective electrodes (ISE) based array sensitive to potassium ions and amperometric glucose sensor. Performance of the presented LTCC-based microfluidic systems has been tested. All ceramic microdevices have revealed high output signal and large detection range. The properties of the presented LTCC-based microfluidic systems are comparable with similar ones made of silicon. Obtained results has shown that presented ceramic microsystems can work as a stand-alone device or can be integrated into a more sophisticated micro analysis system for *in vivo* or *in vitro* monitoring of various (bio)chemical compounds.

K e y w o r d s: LTCC (Low Temperature Co-fired Ceramics), thick-film, numerical modelling, microreactor, sensor

1. Introduction

Modern analytical procedures which are applied in chemistry, biology or medicine consist of several steps: sample collection, carrying out appropriate (bio)chemical reaction, product separation and detection of the analyte. Classical instrumental analysis is characterized by relatively long time of detection, considerable reagents consumption and large amount of wastes. All these disadvantages seem to be eliminated by use of micro-total analysis systems (μTAS) or lab-on-chip (LOC) devices [1]. These miniature devices work with liquid samples in the micro- or even nanoliter

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scale [2]. Thanks to this, they are characterized by small size, short response time, high sensitivity and good selectivity. Moreover, they produce less wastes in comparison with classical laboratory equipment used in analytical chemistry. Therefore, microfluidic systems finds practical applications in analytical diagnosis and continuous monitoring of various biochemical parameters. Quite recently, LOC and μTAS devices were manufactured mainly using silicon micromachining technology. However, in accordance with the newest trends, cheaper technologies and materials are applied. Modern microfluidic systems are quite often manufactured using relatively cheap polymers [3, 4], PCB (Printed Circuit Board) [5, 6] and LTCC (Low Temperature Co-fired Ceramics) [7, 8] technologies. In comparison with the PCB technology, the advantages of the LTCC technique, are the following: chemical inactivity, chemical resistance, good thermal conductivity, high temperature stability. Moreover, the LTCC tapes can easily be cut into desired form in the way to accomplish both mechanical and electrical functions under a single ceramic module. The main profit of the LTCC technique is possibility of integration of fluidic structures, passive components, sensors, actuators, electronics and package into a multilayer module. The LTC ceramic can be easily bonded to other materials e.g. silicon [9], glass [10] or polymers [11]. Thanks to these advantages, the LTCC has found practical application as flow sensors, electrochemical biosensors, microanalyzers, micromixers, microreactors and polymerase chain reaction (PCR) devices [12–15].

This paper presents design, fabrication and measurements of three ceramic-based microfluidic systems for in vivo monitoring of various chemical compounds. The enzymatic microreactor for urea determination, potentiometric sensor with ion selective electrode (ISE) based array sensitive to potassium and ammonium ions and amperometric glucose sensor were fabricated using the LTCC microelectronic technology, which has a few advantages over other microfabrication processes. The ceramic microfluidic systems performance was evaluated experimentally. All presented LTCC-based devices revealed high output signal and large detection range comparable with similar ones made of silicon.

2. LTCC Technology

The LTCC (Low Temperature Co-fired Ceramics) microelectronic technology is commonly used for hybrid circuits fabrication. In the past it was used to produce multilayer devices for telecommunication, automotive and aerospace application. Recently, this technique is also applied for production of sensors, actuators and microsystems. The LTCC was developed in the end of 1980s. A traditional structure consists of several dielectric tapes (alumina filled glasses), connecting vias, surface and buried conducting lines and passive components (resistors, capacitors, inductors). A flow-chart of the LTCC multilayer module fabrication process is presented in Fig. 1.