Heater dedicated for Lab-on-a-chip systems

Karolina Maciejewska, Elzbieta Jastrzebska, Artur Dybko

Warsaw University of Technology, Department of Microbioanalytics, Warsaw 00-664, Poland
e-mail: kmaciejewska@ch.pw.edu.pl

The authors report a new construction of a heater, which can be applied in Lab-on-a-chip systems. The heater was fabricated on a ceramic plate as a solid support. A commercially available paste DuPont 5091D with positive temperature coefficient (PTC) was used as a resistive material. Next, metallic conductors were created using gold sputtering in argon enhanced plasma environment. Finally, the gold layers were bonded with connection wires. The developed heater can be integrated with microsystems dedicated for bioanalysis, enzymatic reactions and cell cultures.

Key words: heater, microsystem, Lab-on-a-chip, PTC

Introduction

Miniaturization of a device is a leading strategy in many researches (e.g. biological research or chemical analysis) [1,2]. The principal idea of lab-on-a-chip structures is the integration of the whole analysis steps (i.e. dispensing, mixing, reacting, temperature control, analyzing) in one chip. Their dynamic development is due to the series of advantages offered by the application of these systems in basic research. First of all, due to the small size of the internal microchannels (several tens of microns) using a microsystems can enable to reduce the volume of samples into micro-and nanoliters [3]. It allows to reduce quantity of reagents used in experiments, what in turn helps to lower the costs and shorten the time of analysis [4]. Nowadays, microfluidic systems are especially used in biological studies and biomedical applications. For many biological and chemical measurements, temperature is a crucial parameter to control. Therefore, *Lab-on-a-chip* systems have to be integrated with a heater. It is important, because many of analytical reactions and cell cultures should be carried out at defined temperature. There are many heaters developed in MEMS technology (Micro Electro-Mechanical Systems). Some of them are based on a metal layer deposited on a solid support or silicon doped with phosphorous [5-7]. Commercially available heaters such as Peltier element can also be used to construct microsystems [8]. In order to create a transparent heater an ITO (Indium Tin Oxide) layer can be deposited [9]. Such heaters are especially useful in experiments on living cells where a stabile temperature around 37°C is required. The heater has to be connected to a system with temperature feedback.

The aim of the work was to design a heater which can be integrated with *Lab-on-a-chip* systems dedicated for bioanalysis. The heater was based on the DuPont 5091D paste, which was spin coated on a ceramic plate. The 5091D paste has many advantages such as: a linear dependence of resistance with temperature, bendability and environmental stability. Moreover, it exhibits very high positive temperature coefficient of resistance (TCR) and this property of the material can be utilized in self-regulating temperature function.

Preparation of a heater

A commercially available DuPont 5091D paste (DU PONT, U.K.) with positive temperature coefficient (PTC) was used for fabrication of the heater. This is a screen printable paste usually used in electronic application *i.e* temperature sensors and temperature compensation elements. Since the paste was prepared for screen printing technology its viscosity was quite high, so we decided to modify the technology of its preparation. The heater was manufactured in the following way. The paste was diluted with isopropanol (pure for analysis, POCH S.A. Poland), in a ratio of 1:2. Then, a layer of the diluted paste was prepared using a spin-coater (WS-6505, Laurell Technologies, USA). 1 ml of the diluted paste was dropped onto the ceramic plate and then spin coater was turned on with 2000 rpm. Next, the plate with the coated paste was allowed to level at room temperature (for 10 min) and then dried for 15 min at 150°C. Finally, the paste layer was baked in an oven for 10 min at 850°C. Afterwards, a gold layers were created using a vacuum sputter (Desk V, Denton Vacuum, USA) to form a metallic conductors. A conducting glue (Conductive Epoxy - CW2400 from Chemtronics) was used to fix wires to the heater (Fig. 1).

Results

The heater dedicated for integration with *Lab-on-a-chip* systems was obtained according to the procedure described in the experimental section. The heater surface was analyzed using scanning electron microscope (Hitachi TM-

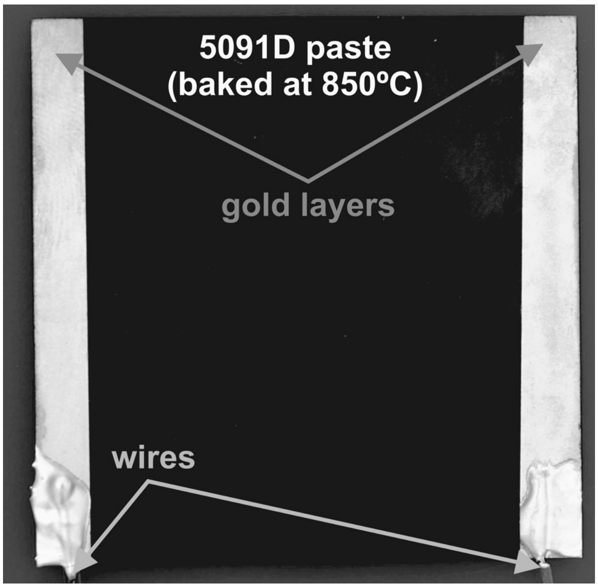

Fig. 1. The fabricated heater manufactured on a ceramic plate

1000). The layer of 5091D paste before (A) and after baking (B) is shown in Fig. 2. In addition, a thickness of layer was measured using a laser confocal microscope (LEXT, Olympus). As a result, a thin layer was obtained (Fig.2C) with the following parameters: a thickness of the 5091D paste layer approx. 50 μm, a thickness of the metallic conductors approx. 2 μm.

The characterization of the manufactured heater was also performed. In this purpose, the heater was placed in a drying oven with the regulated temperature and the resistance was recorded with the help of a ohmmeter. During this test, a linear dependence of resistance with temperature was observed (Fig. 3). Our results correspond to the results presented in the literature. A similar dependence between temperature and resistance has been obtained in other microheaters. For instance, J. Wu et al. presented the microheater for PCR reaction. This microheater was made of PDMS with injected silver paint [10]. In turn, Leo et al. presented another approach of a microheater fabrication. They developed platinum based heater, in which linear dependence between temperature and resistance was also observed [11]. Fabrication procedure of this examples is more

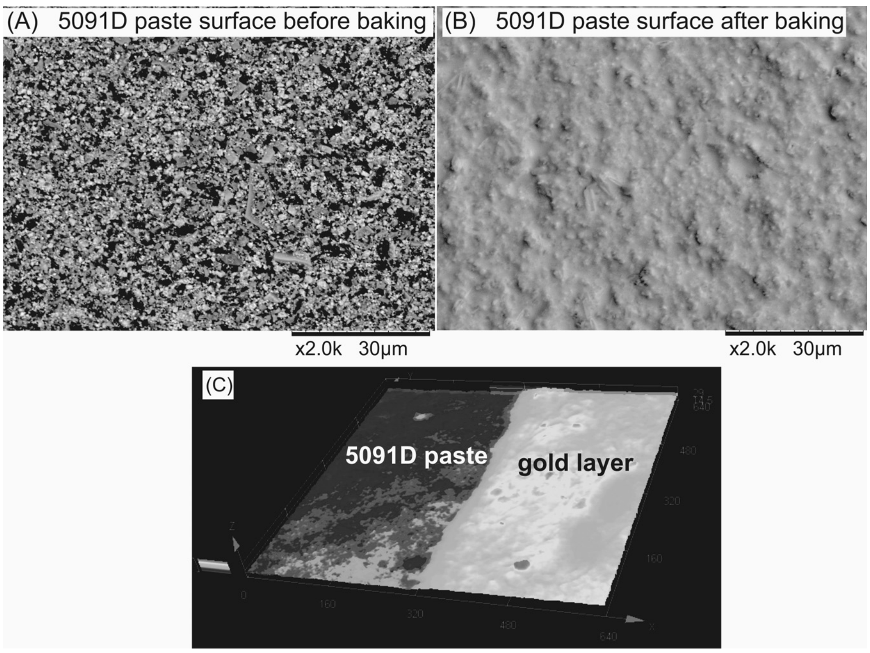

Fig. 2. The layer of 5091D paste before (A) and after baking (B) at 850°C (scanning electron microscope – Hitachi TM-1000). (C) The picture of the heater surface (laser confocal microscope – LEXT, Olympus).

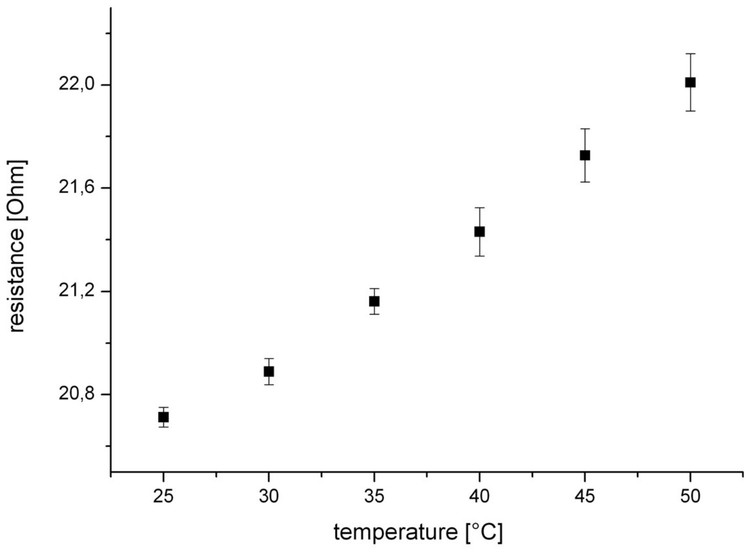

Fig. 3. The dependence of the heater's resistance to the temperature

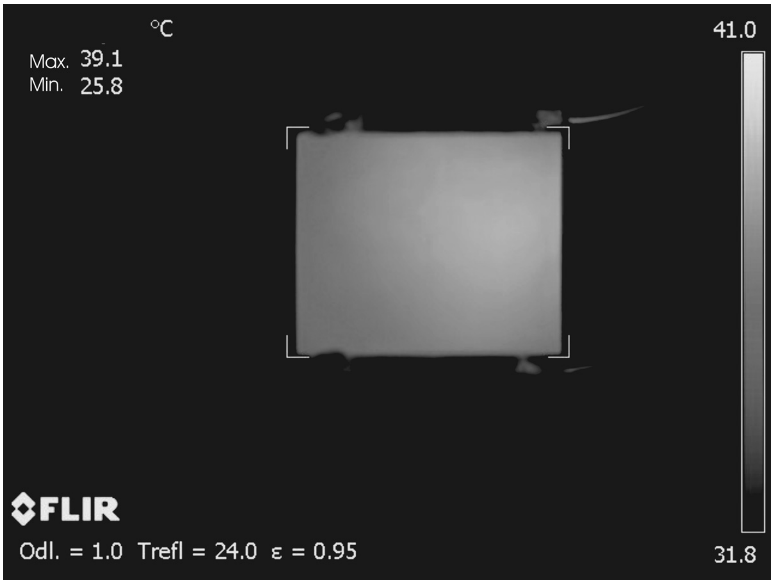

Fig. 4. Temperature distribution over the heater prepared on a ceramic plate

complicated then technology presents in this paper. Moreover, our microheater does not require an additional temperature control element.

The temperature distribution over the whole heater was evaluated with a help of a thermal camera (FLIR P620) (Fig. 4). The temperature distribution along the heater is quite uniform with the accuracy 4-5°. Moreover, it was analyzed that the heater works properly in a wide range of temperature. The highest recorded temperature equaled to 130°C. It confirms that the fabricated heater can be applied successfully in various experiments, *i.e.* analytical and enzymatic reactions, cell cultures, PCR reaction.

Conclusions

In this paper we present a fast procedure for fabrication of the heater dedicated for *Lab-on-a-chip* systems. DuPont 5091D paste with a positive temperature coefficient (PTC) was chosen for development of the heater based on a ceramic plate. This procedure provides the heater with stable and uniform temperature distribution. Therefore, it can be applied to set temperature in microfluidic systems dedicated for biomedical application. The proposed technology is quite simple and cost effective

This work was realized with a frame of project Iuventus Plus, which is financed by the Ministry of Science and Higher Education, contract No. 0205/IP2/2011/71.

References

[1] A. Manz, N. Graber, H.M. Widmer, Sens. Actuat. B 1990, 1, 244-248
[2] H. Andersson, A.B. van den Berg, Sens. Actuat. B 2003, 92, 315-325
[3] A.L. Paguirigan, D.J. Beebe, BioEssays 2008, 30, 811-821
[4] L.Y. Yeo, H.Ch. Chang, P.P.Y. Chan, J.R. Friend, Small 2011, 7, 12-48
[5] T. Chen, J. N. Chung, J. of Heat Transfer 125 (2003) 1074-1086
[6] Y. H. Choi, S. U. Son, S. S. Lee, Sens. Actuators A 111 (2004) 8-13
[7] J. Kita, A. Dziedzic, L. J. Golonka, A. Bochenek, Microelectronics Reliability 40 (2000) 1005-1010
[8] I. Wyzkiewicz, I. Grabowska, M. Chudy, Z. Brzozka, M. Jakubowska, T. Wisniewski, A. Dybko, Sens. Actuators B 114 (2006) 893-896
[9] J. Lin, M.Wu, Ch. Kuo, K.Lee, Y. Shen, Biomed. Microdevices 12 (2010) 389-398
[10] J. Wu, W. Cao, W. Wen, D. C. Chang, P. Sheng, Biomicrofluidics, 3, (2009) 012005
[11] A.I.K. Lao, T.M.H. Lee, I.-M. Hsing, N. Y. Ip, Sens. Actuators A 84 (2000) 11-17.