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Cost-effective microfluidic device for detection of psychoactive substances

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***Abstract*—This paper presents design and fabrication of cost-effective microfluidic chip using xurographic technique. Seven layers of PVC foils and gold electrodes as a plane of microfluidic device were laminated in order to obtain a compact chip. Syringe pump was used for introducing fluid in one inlet and when fluid went through the microchannel the electrical parameters of capacitive structure has been changed which was measured by means of impedance analyser. Using this method, it is possible to detect concentration of psychoactive substances in low volume in aqueous or biological media (such as saliva), very efficiently.**

***Keywords*—PVC foils, microfluidic chip, impedance spectroscopy, psychoactive substances**

I. Introduction

According to the United Nations drug report [1], around 25 million people are addict on different illicit drugs or psychoactive substances. Microfluidics represents a spectrum of powerful tools for analysis of different fluids and it is especially useful for drug analysis and detection in micro scale. The advantages of microfluidic devices for detection of psychoactive substances are [2]: (a) low fluid volume, (b) fast analysis; (c) safe and low-cost platform and (d) open format devices. Due to the above-mentioned advantages of microfluidic devices, comparing to other costly and robust techniques such as mass spectrometry, NMR spectroscopy or UV spectroscopy [3], they are widespread for applications in point-of-care testing or for sensing [4] or wearable sensors applications [5]. In recent period, it has been reported application of microfluidic devices in different drug based studies [6] or forensic drug analysis [7]. Moreover, the application of microelectrodes for the detection of illegal drugs has been investigated [8]. Different technologies and materials can be used for fabrication of microfluidic devices [9]: polydimethylsiloxane (PDMS) [10]-[12], glass [13], other polymers [14] or paper [15], [16]. The combination of impedance-based detection techniques with microfluidic systems has been already published [17], [18]. The measured impedance depends on the geometry of the electrodes, which has been analysed in the paper [19]. Interdigitated electrodes system with fluids going through the space between the electrodes ensures the change of electrical characteristics [20]. However, there has been very little studies reporting application of microfluidic devices as point-of-care tests for the detection of various opiates or psychoactive substances.

This paper describes a new design of microfluidic chip combining gold electrode structures and meander microchannel in order to detect different concentration of opiates through variation of electrical parameters such as impedance, phase angle, capacitance, etc. Compactness of the microfluidic device has been achieved using cost-effective xurographic technique, based on lamination of PVC foils. Fabricated structure enables fast analysis and quick response time due to the short overall length of the microchannel from one inlet to one outlet for fluid (with different concentration of psychoactive substances) which can be detected and monitored using the proposed device. In this way, we have developed a less subjective method for detecting illicit drugs than the laboratory analysis or colour change-based methods.

II. Design and Manufacturing of Microfluidic chip

A. *Design of microfluidic device*

Design of microfluidic chip consisting of one inlet and one outlet, plane gold electrodes in different layers as well as meander microchannel between them is depicted in Figure 1.

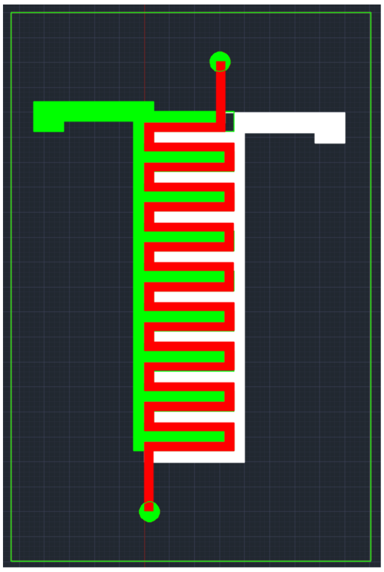


Fig. 1. Compact design of microfluidic chip (top and bottom electrodes are continual plane)

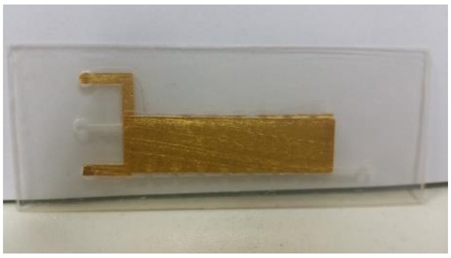
Dimensions of this structure were: 3.29 cm × 0.9 cm.

B. *Fabrication of microfluidic device*

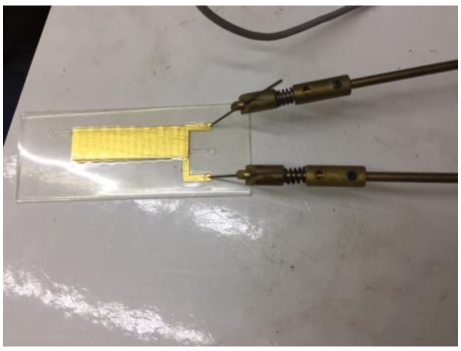
The microfluidic chip was composed of 7 layers. The first layer is PVC foil as a substrate. The thickness of the foil (used for all PVC layers) was 80 µm. We used PVC laminating films (MBL® 80MIC A4 hot lamination foil, Minoan Binding Laminating d.o.o, Serbia) supported on the cutting mat (12” Silhouette Cameo Cutting Mat). The second layer is gold capacitive electrode which has been cut in desirable shape using the cutting plotter (CE6000-60 PLUS, Graphtec America, Inc., USA), Figure 2, with the 45° cutting blade (CB09U). The third layer was PVC foil with engraved microchannel for the fluid flow in the shape of meander. In order to obtain higher thickness of the channel, the fourth and fifth layers were the same. The sixth layer was second part of gold electrode structure. Finally, seventh layer contains inlet and outlet in the PVC foil for testing of this chip.

Fig. 2. Cutter for Xurographic techniques.

The above mentioned layers were laminated using the hot laminator FG320 on 130 °C, previously stacked one by one. The fabricated microfluidic chip, after successful lamination, can be seen in Figure 3, whereas Figure 4 depicts magnified view on some parts of the manufactured microfluidic chip.



(a)



(b)

Fig. 3. Microfluidic chip with (a) one inlet and one outlet; (b) contacts for conducting electrical measurements.

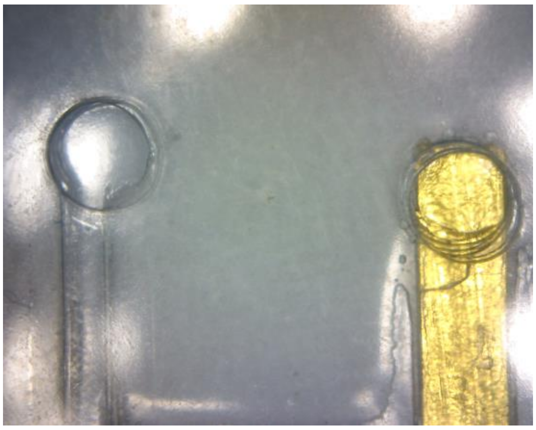


Fig. 4. Magnified view of the inlets and contacts of the chip

III. RESULTS AND DISCUSSION

The experimental set-up can be seen in Figure 5.

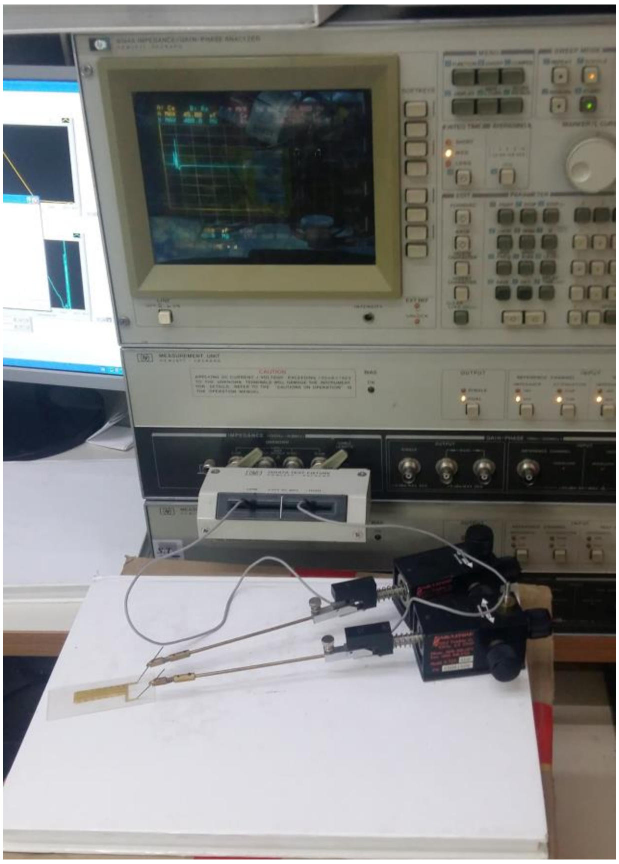


Fig. 5. Experimental set-up for measuring different concentration of psychoactive substances.

For electrical characterization Impedance Analyzer HP4194A has been used whereas syringe pump was used for entering fluid (artificial saliva with two concentrations o Trodon drug solution) into microchannel. When the fluid went through the channel the medium between capacitive electrodes has been changed. The variation in fluid concentration changes dielectric constant of the medium of capacitor (composed of gold electrodes on foils), which provide variation in impedance or capacitance measured by means of the Impedance analyser. The measured results are shown in Figure 6 for impedance and in Figure 7 for phase angle.

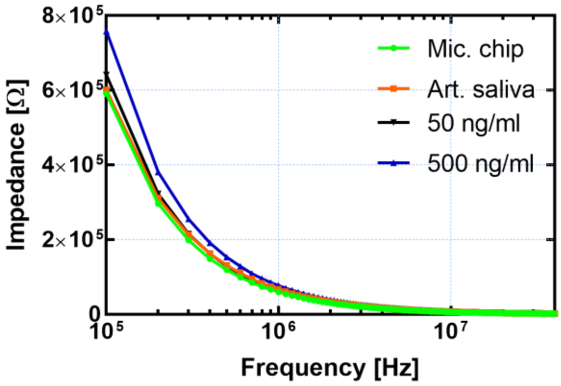


Fig. 6. Impedance as a function of frequency.

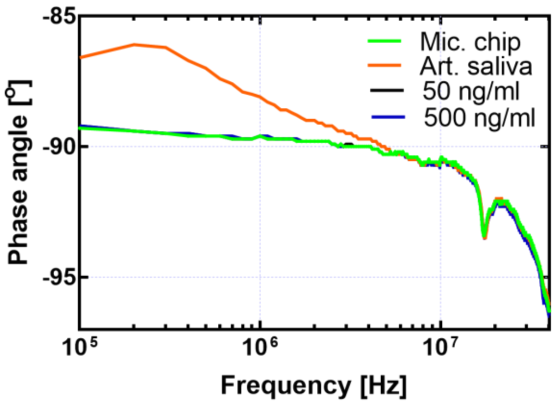


Fig. 7. Phase angle as a function of frequency.

First, the pair of impedance and phase angle were measured for fabricated chip without any fluid inside (curve donated with Mic. Chip in Figures 6 and 7). After that the same parameters were measured with artificial saliva solution inside of the microfluidic channel. Inside the artificial solution of saliva, the concentration of psychoactive substance “Trodon” was prepared with 50 ng/ml and 500 ng/ml. These variation in the concentration can be successfully detected with presented method based on non-destructive technique of impedance spectroscopy. Moreover, we measured the variation in the capacitance with the increase of the psychoactive drug and for example we obtained capacitance between contacts equal to C = 2.38 pF for artificial saliva solution, C = 2.45 pF for 50 ng/ml and C = 2.59 pF for 500 ng/ml at 1 MHz frequency spot.

IV. Conclusion

New psychoactive substances have become in recent years. This paper is aimed to design and manufacture microfluidic detection system as an effective portable device for determination of concentration of psychoactive substances in aqueous and biological media, such as saliva. The cost-effective detection system is based on PVC foils laminated with conductive electrode system in order to create an optimal point-of-care screening device. Further research will be conducted for different design of the channel (such as zig-zag) as well as for different materials (such as aluminium) for conductive interdigitated electrode structures.

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