BULLETIN OF THE POLISH ACADEMY OF SCIENCES
TECHNICAL SCIENCES
Vol. 53, No. 2, 2005

Spectrophotometric analysis using poly(dimethylsiloxane) microfluidic detectors

D. STADNIK, M. CHUDY, Z. BRZÓZKA, and A. DYBKO*

Department of Analytical Chemistry, Warsaw University of Technology, 3 Noakowskiego Str., 00-664 Warsaw, Poland

Abstract. Two constructions of microfluidic structures are described in this paper. A fibre optic microcell for spectrophometric measurements and a microcell for fluorescence experiments were designed and tested. The structures were made of polymer optical fibres which were incorporated into polymeric material i.e. poly(dimethylsiloxane). The structures were tested as detectors in absorbance measurement (solutions of bromothymol blue with different pH were used) and in fluorescence tests (solution of fluoresceine was used).

Key words: poly(dimethylsiloxane), polymer optical fibres, microfluidic structures.

1. Introduction

Micro total analysis systems (μTAS) are based on the use of microfluidic structures. Originally small channels were made in a silicon wafer using traditional semiconductor technology like photolithography, etching and bonding. There are many constructions developed in which the achievements of micromechanics are applied [1,2]. The idea of μTAS structures is the integration of the whole analytical process on one single chip i.e. all necessary operations like sampling, sample pre-treatment, separation, mixing, reaction and finally the detection of analytical signal will be carried out. Such devices are utilized in biological and medical experiments, for example in DNA analysis.

Due to constraints of silicon as a basic material for the development of microstructures (e.g. limited resistivity to alkali solutions) microfluidic structures are fabricated from polymeric materials. Various polymers can be applied: poly(dimethylsiloxane) PDMS, poly(methylmethacrylate) PMMA, poly(carbonate) PC [3]. A microfluidic channel can be made in these materials using several techniques ranging from laser ablation [4] to photolithography and lift-off [5]. The primary requirement is to form a microchannel capable of delivering a sample/analyte to a mixer, a reactor or a microdetector. Constructing such devices the designers faced many phenomena specific for miniature channels, for example hydrodynamics of fluids, air bubble formation, detection of very small signals.

Optical methods are frequently used to detect the analytical signal in μTAS structures [1,2,6,7]. Especially fluorescence spectroscopy is very attractive allowing the sensitive and selective detection of various species. However, in many cases additional pre-treatment of the analyte is necessary in order to make it fluorescent. Optical fibres are used to guide an optical signal to a microfluidic structure and then to an optical detector. The goal of this paper is to present some possibilities of the application of optical fibres in microfluidic structures.

2. Spectrophotometric microcells

The spectrophotometric microcells were fabricated by pull out technology [8]. To create a cylindrical microchannel inside the structure, the mixture of PDMS prepolymer and curing agent was poured into a custom-made mould, and cured for 1 h at 70°C. There were thin stainless steel tubes mounted in the mould in order to form microchannels and places where fibres will be inserted. The cured PDMS structure was peeled off the mould, the tubes were pulled out, and the inlet/outlet were fabricated using a metal punch. Next, a polymer optical fibres (a diameter of 1000 μm, made of poly(methylmethacrylate)) were inserted into the channel in such a way to form a 1 cm gap between their faces creating a microcell for absorbance measurements. In the second microstructure, optical fibres were inserted perpendicularly in order to allow fluorescence detection. Schematic cross sections of the spectrophotometric microcells are presented in Fig. 1.

3. Results

The performance of the designed microstructures was determined in a measuring set-up presented in Fig. 2.

A red or a blue LED was used as a light source in dependence on the type of the experiment conducted. A red LED (650 nm) was utilized in experiments with the spectrophotometric microcell whereas a blue LED (470 nm) served as a light source to induce fluorescence of an indicator. Typical SMA connectors were used to connect the fibres to the light source and the detector. We have used an array spectrometer (Control Development Inc.)

*e-mail: dybko@ch.pw.edu.pl

which photodetectors were cooled down to −15°C to minimise their thermal noise. The appropriate solutions were pumped by means of a peristaltic pump (flow rate 750 µl/min). The work of the whole system was governed by software created in our laboratory using LabVIEW (National Instruments), which was implemented on a personal computer. We can measure either the spectral changes either select the specific wavelength and measure the relative changes in the signal. The following figures present the data in arbitrary units.

Figure 3 shows the calibration curve of the microfluidic system when solution of bromothymol blue was pumped. A typical sigmoidal shape of the curve was observed.

Figure 4 presents the dependence of the fluorescence signal versus time when the same volume of solutions at different concentrations of fluoresceine was injected into the tube delivering the sample. The linear dependence on the peak intensity and the concentration of solution injected was observed.

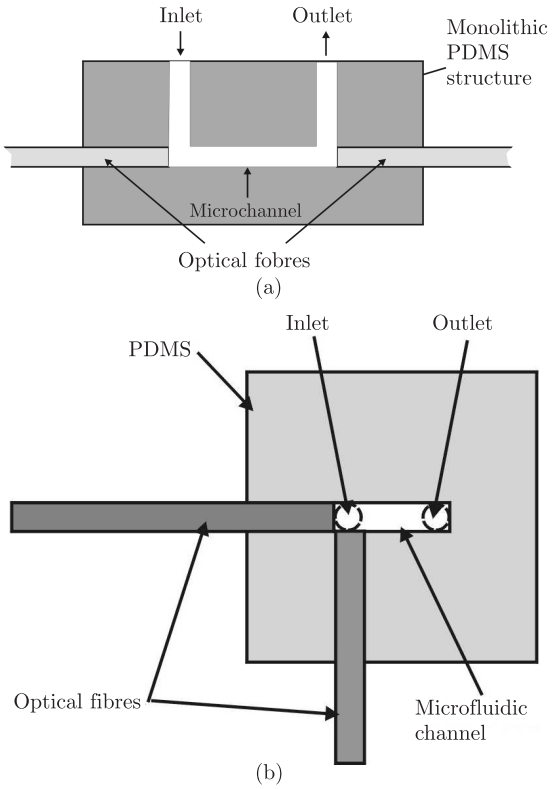

Fig. 1. Schematic cross sections of the spectrophotometric microcells: a structure for absorbance experiments (a), a structure for fluorescence experiments (b)

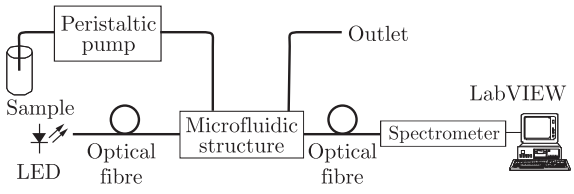

Fig. 2. Measurement arrangement of the equipment used to test microfluidic structures

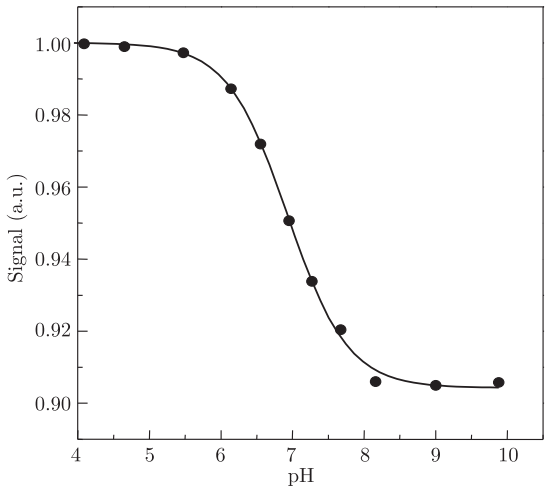

Fig. 3. Relative changes in the signal of spectrophotometric microcell for solutions of bromothymol blue with different pH

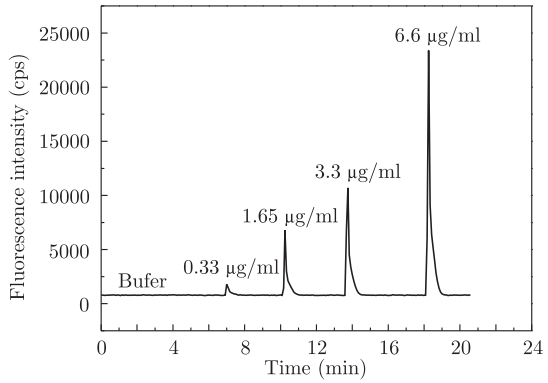

Fig. 4. Fluorescence signal versus time for different concentrations of fluoresceine solution injected

4. Summary

Two microfluidic structures were designed and manufactured. Ordinary polymer optical fibres were used in both constructions. The microcells were fabricated in a block of PDMS with a circular channel formed by a stainless steel tube. The fibres were inserted from both sides to the channel creating a gap into which a liquid under the test can be delivered. This construction is a miniaturized version of an ordinary spectrophotometric cuvette. Second microstructure was used in fluorescence experiments. Two fibres inserted into a PDMS block were allocated perpendicularly, creating a useful detector.

Acknowledgements. This work was financed by a professor grant of Foundation for Polish Science and by a grant of Polish Ministry of Science No. 4 T10C 003 25.

References

[1] A. Van den Berg, W. Olthuis, and P. Bergveld (eds.), *Proceedings of the mTAS 2000*, Kluwert Academic Publishing, Boston/London, 2000.

[2] A. Van den Berg, *Proceedings of the mTAS 2002*, Kluwert Academic Publishing, Boston/London, 2002.
[3] H. Becker and L.E. Locascio, "Polymer microfluidic devices" *Talanta* 56, 267–287 (2002).
[4] D. Snakenborg, H. Klank, J.P. Kutter, "Microstructure fabrication with a CO_2 laser system", *J. Micromech. Microeng.* 14, 182–189 (2004).
[5] X. Yu, D. Zhang, T. Li, L. Hao, and X. Li, "3-D microarrays biochip for DNA amplification in polydimethylsiloxane (PDMS) elastomer", *Sensors and Act.* A 108, 103–107 (2003).
[6] M.A. Schwarz and P.C. Hauser, "Recent developments in detection methods for microfabricated analytical devices", *Lab on a Chip* 1, 1–6 (2001).
[7] *Proceedings of the mTAS 2003*, Kluwert Academic Publishing, Boston/London, 2003.
[8] D. Stadnik, M. Chudy, Z. Brzozka, and A. Dybko, Polish Patent Application, No. P.368954, date of application 06.07.2004.