Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 47 (2012) 1263 – 1266

Procedia Engineering

www.elsevier.com/locate/procedia

Proc. Eurosensors XXVI, September 9-12, 2012, Kraków, Poland

Ethanol sensing properties of PMMA-coated fiber Bragg grating

M. Latino[a,b], R. Montanini[a], N. Donato[c,*], G. Neri[a]

[a] *Dept. of Industrial Chemistry and Materials Engineering, University of Messina, Messina, I-98166, Italy.*
[b]*Dept. of Chemical Science and Technologies, University of Roma Tor Vergata, Roma,I-00133, Italy.*
[c]*Dept. of Matter Physics and Electronic Engineering, University of Messina, Messina, I-98166, Italy.*

Abstract

In this paper some preliminary results about the sensing properties of a single-mode silica fiber Bragg grating (FBG) coated with a poly(methyl methacrylate) (PMMA) thin layer are reported. The PMMA coating on the fiber grating was deposited by using a micro-pipette bulb as mechanical vessel filled with polymer solutions in acetone. For ethanol sensing tests, the FBG sensor was placed in a measurement chamber equipped with a controlled gas system, then the output response was acquired using an optical spectrum analyzer which also provided laser illumination. Absorption of ethanol from the gas phase onto the PMMA layer causes swelling which can be recorded as an extension/compression of the fiber grating. As a consequence of this transduction effect, the peak shift response can be related to the ethanol concentration. Based on this simple principle, detection of low alcohol concentrations can be easily obtained.

Keywords: fiber optic chemical sensors; fiber Bragg grating (FBG); ethanol concentration; poly(methyl methacrylate) (PMMA)

1. Introduction

Ethanol monitoring is an important issue in many fields, spanning from biomedical to safety applications, therefore several typologies of sensors were developed and employed, such as resistive [1], capacitive [2] and SAW [3] chemical sensors, depending on the application involved and concentration to detect. Recently, etched fiber Bragg gratings were employed as refractometric sensors, in the analysis of water-ethanol mixtures in solution [4]. Here we report a different approach to employ a FBG sensor as a

* Corresponding author. Tel.: +39-090-397-7270; fax: +39-090-397-7464.
E-mail address: ndonato@unime.it.

doi:10.1016/j.proeng.2012.09.383

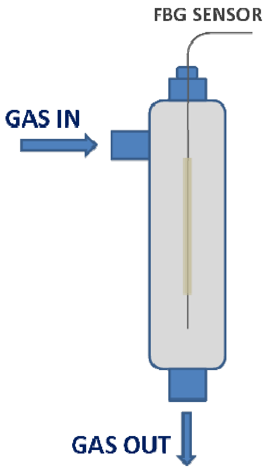
chemical one, by simply depositing a poly(methyl methacrylate) (PMMA) thin sensing layer on the fiber grating. Due to the swelling effect of the polymer, when exposed to the gas target, the sensing film deformation can be transduced by the FBG grating, then it is possible to detect the presence of ethanol in a gaseous mixture.

2. Experiments

The PMMA coating on the fiber grating was deposited, after removing the buffer of the optical fiber, by using a micro-pipette bulb as mechanical vessel filled with polymer solutions in acetone. The thickness of the fiber sensing coating was controlled by further deposition steps and is about 50 µm, while the active length of the grating is about 14 mm. To perform the experimental tests, the PMMA-coated fiber was firstly placed inside the stainless-steel measurement chamber, schematized in Fig. 1.a, then connected to the measurement system shown in Fig. 1.b.

The experimental bench for the characterization of the sensor allows to perform measurement activities in controlled atmosphere. The measurements were carried out at room temperature, under a synthetic dry air total stream of 50 sccm. The ethanol vapours coming from the bubbler at controlled temperature were further diluted in air at a given concentration by mass flow controllers. The optical characterization is performed through an optical spectrum analyzer (Micron Optics mod. SI 720) with ± 3 pm accuracy. The OSA was interfaced to a personal computer using a standard IEEE-488 communication protocol, whereas data acquisition was accomplished by means of a graphical user interface (GUI) written in Labview™ .

The sensor response was retrieved from the relative wavelength shift $\Delta\lambda = \lambda - \lambda_0$, where λ_0 is the baseline wavelength in dry synthetic air (at a reference temperature T_0) and λ is the wavelength of the sensor at different ethanol concentrations in dry synthetic air. In addition to record wavelength shifts, the use of an optical spectrum analyser allows the complete frequency response of the PMMA-coated FBG sensor to be investigated as well.



(a)

(b)

Fig. 1. (a) Picture of the chamber with the FBG sensor placed in; (b) Photograph of the sensing apparatus.

3. Results

The reflected spectrum of PMMA-coated FBG sensor at room temperature and under a dry synthetic air total stream of 50 sccm is reported in Fig. 2. Preliminary tests have shown a shift of the reflected spectrum towards higher wavelength values in the presence of ethanol in the stream. The changes in wavelength during ethanol addition coming from a bubbler and opportunely diluted at a given concentration in the range from 0 to 3 % by a mass flow controller array were then closely monitored, in order to exploit the use of PMMA-coated FBG as an ethanol sensor in the gas-phase.

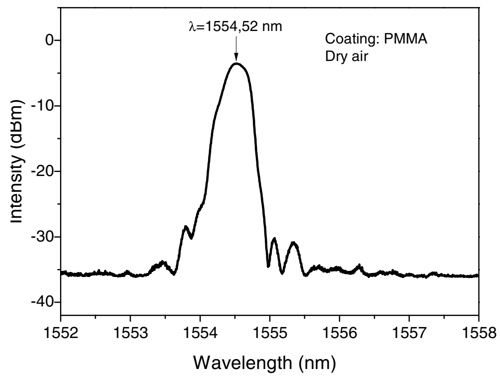
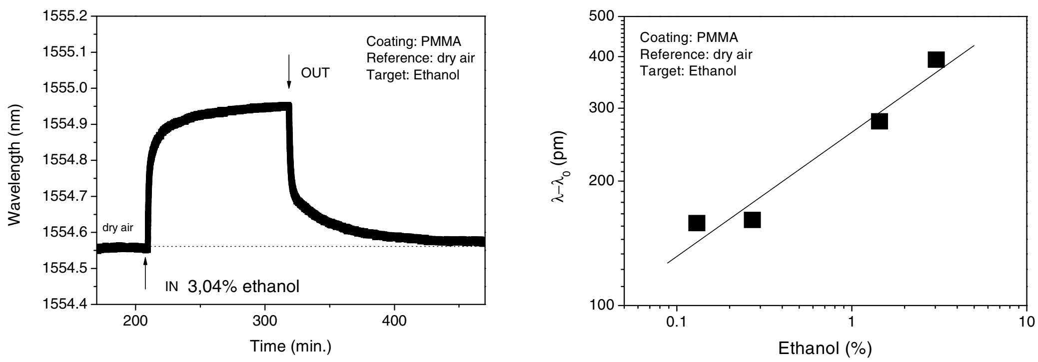


Fig. 2. Reflected spectrum of the PMMA-coated FBG sensor under dry air.



(a) (b)

Fig. 3.(a) Dynamic response of the PMMA-coated FBG sensor to a pulse of 3 % of ethanol in dry air. (b) Calibration curve vs. ethanol concentration.

Figs. 3.a and 3.b show results obtained by exposing the PMMA-coated FBG sensor to a pulse of 3 % of ethanol in dry air and the corresponding calibration curve constructed on the basis of the dependence of the output shift towards ethanol concentration. From the last figure, it can be observed that the developed sensor highlights a linear response with respect to the amount of adsorbed ethanol. These results demonstrated that detection of low alcohol concentrations can be easily obtained, but the response and recovery times are very long. In order to decrease the time between successive pulses, sensing tests were also performed by a pulse method. Fig. 4 shows the practical applicability of this latter method, allowing the number of measurements for unity of time to be increased considerable.

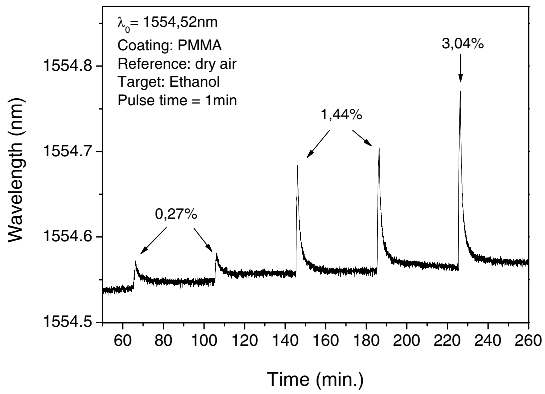


Fig. 4. Sensing tests performed by pulse method.

Acknowledgements

The authors of this paper would like to acknowledge funding for this work that has been provided by the Italian Ministry of Education University and Research under the research project of national interest PRIN2008.

References

[1] G. Neri, A. Bonavita, G. Micali, N. Donato, F.A. Deorsola, P. Mossino, I. Amato, B. De Benedetti, Ethanol sensors based on Pt-doped tin oxide nanopowders synthesised by gel-combustion, Sensors and Actuators B 117 (2006) 196–204

[2] Seong-Jeen Kim, Byung-Hyun Jeon, Kyu-Seong Choi and Nam-Ki Min, Capacitive porous silicon sensors for measurement of low alcohol gas concentration at room temperature, Journal of Solid State Electrochemistry,Vol. 4, 6,(2000) 363-366.

[3] S. J. Ippolito, A. Ponzoni, K. Kalantar-Zadeh, W. Wlodarski, E. Comini, G. Faglia, G. Sberveglieri, Layered WO_3/ZnO/36 ◦ $LiTaO_3$ SAW gas sensor sensitive towards ethanol vapour and humidity, Sensors and Actuators B 117 (2006) 442–450.

[4] U. S. Raikar, V. K. Kulkarni, A. S. Lalasangi, K. Madhav, S. Asokan, Etched fiber Bragg grating as ethanol solution concentration sensor, Optoelectronics and Advanced Materials, Vol. 1, No. 4 (2007) 149 – 151.