Zinc oxide coated optical fiber long period gratings for sensing of volatile organic compounds

L. Coelho[a], D. Viegas[b], J. L. Santos[a], José Manuel Marques Martins de Almeida*[,a,c]
[a]CAP / INESC TEC - Technology and Science and FCUP - Faculty of Sciences, University of Porto
[b]INL – International Iberian Nanotechnology Laboratory, Avenida Mestre José Veiga 4715-330 Braga, Portugal
[c]Department of Physics, School of Sciences and Technology, Universidade de Trás-os-Montes e Alto Douro, Apartado 1013, 5001-801 Vila Real, Portugal

ABSTRACT

The detection of volatile organic compounds is accomplished with a sensing device based on a long period fiber grating (LPFG) coated with a zinc oxide (ZnO) thin layer with self-temperature compensation. The ZnO coating structure was produced onto the cladding of the fiber by thermal oxidation of a metallic Zn thin film.

The morphological characterization of ZnO thin films, grown at the same time on silicon substrates, was performed using X-ray diffraction, X-ray Photoelectron Spectroscopy and Scanning Electron Microscope which shows very good agreement.

LPFGs with 290 nm thick ZnO coating were fabricated and characterized for the detection of ethanol and hexane in vapor phase. For ethanol a sensitivity of 0.99 nm / g.m^{-3} was achieved when using the wavelength shift interrogation mode, while for hexane a much lower sensitivity of 0.003 nm / g.m^{-3} was measured, indicating a semi-selectivity of the sensor with a spectral resolution better than 3.2 g.m^{-3}.

Keywords: Long period fiber gratings, Optical fiber sensors, Ethanol sensor, Zinc oxide thin film

1. INTRODUCTION

In recent years optical fiber sensors have been increasingly applied in the monitoring of physical, chemical and biochemical parameters[1-3] due to its properties such as small dimensions, high melting temperature, high sensitivity and bandwidth, real-time monitoring of several parameters simultaneously, multiplexing, long-distance transmission and low reactivity of silica[4].

The development of long period fiber gratings (LPFGs) sensors is an active area of research which already led to the demonstration of sensors for strain, bending and temperature[5], food quality control[6], recognition of bacteria[7] and DNA/Aptamer detection[8].

The fabrication of sensors for the detection of liquid and volatile organic compounds is of significant interest in monitoring industrial, environmental and physiological processes, like detection of explosive or pollution gases, and medical breath analysis. An ethanol vapor detection probe[9], a gas sensor of amine[10] toluene and benzene odors[11] and a toluene sensor for use with water contamination[12] were demonstrated using LPFGs functionalized with a polyelectrolyte multilayer, calixarenes thin films and metal oxide nanoparticles.

LPFGs are produced by different methods by introducing a periodic modulation in the refractive index (RI) of the fiber core in the range of hundreds of micrometers and a length of a few centimeters[13]. The period of the RI modulation is such that phase matching between the core mode and a forward propagating cladding mode occurs causing light to be coupled into cladding modes[14]. In this way several attenuation bands are formed in the transmission spectrum of the fiber[5]. The interaction with external media of the fiber is reached due to the evanescent field of the cladding modes, thus making the optical properties of the LPFGs dependent of the characteristics of the materials surrounding the fiber.