Etched fiber Bragg grating sensing system thermically assisted for analysis of water- ethanol mixtures

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ABSTRACT

This work presents a sensing system based on an etched fiber Bragg grating, applied to the refractometric analysis of water-ethanol mixtures. The system configuration employs one etched-FBG operating at two temperatures, (20.0 ± 0.5) °C and (3.0 ± 0.5) °C. The sensing system performance in measuring the ethanol-water proportions is evaluated in the concentration range between 0.0 and 100.0 % v/v of water in ethanol, resulting in uncertainties less than 3.9 % v/v. The sensor capability to determine the ethanol concentration is shown, even for the range of concentrations where the correlation between refractive index and ethanol proportion in the sample presents an ambiguous behavior.

Keywords: etched-FBG; ethanol-water mixture, fiber optic sensor.

1 INTRODUCTION

The ethanol is an important solvent employed in industrial sectors as pharmaceutical, chemical and fuel; however the product commercialization requires a carefully monitoring of its purity. The ethanol purity can be affected by the process used in the ethanol production, which can result in undesirable water content in the final product. Besides, as the ethanol is miscible in water, the product adulteration with this substance is a common malpractice. Particularly in the fuel sector, the water-ethanol proportion must be periodically monitored and compared to standardized conditions. The usual techniques employed in the ethanol quality determination involves laboratorial procedures that demands long times; therefore, the development of monitoring systems able to supply fast and reliable results assumes great importance in the ethanol quality control. Some fiber optic devices have been proposed as sensors to determine the ethanol concentration in ethanol-water mixtures. These devices are based on the evanescent field interaction with the sample[1], refractive index sensitivity of long period grating[2-6] and etched fiber Bragg grating; nevertheless, its operation is limited to samples with ethanol concentrations up to 60%[7]. For operation above this concentration, the main difficulty presented by the refractometric analysis of ethanol-water samples is the non-linear dependence between the refractive index and the ethanol concentration in the sample. When the ethanol concentration increases beyond a critical value, the refractive index relation presents an ambiguous range for the determination of the ethanol proportion in the mixture. This behavior was attributed to hydrophobic solute association in aqueous solution of ethanol and to hydrogen bonding clusters formation[8].

In this work is proposed a sensing system based on an etched Fiber Bragg Grating interrogated at two temperatures for the determination of ethanol concentration in ethanol-water samples. The sensor metrological characteristics are presented and the performance of the sensor in the ambiguous region of concentration is also discussed.

2 EXPERIMENTAL

The fiber Bragg grating (FBG) was engraved in a standard telecommunication optical fiber by the direct illumination of a phase mask with a KrF excimer laser (Xantos XS, Coherent) at 248 nm. The FBG was submitted to a chemical etching (1.4 μm/min rate) by the fiber immersion into an aqueous solution of hydrofluoric acid (HF 40 %) resulting in final diameter about 57 μm. To stop the etching, the fiber was removed from the acid and neutralized by a NaOH solution (2

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