Optical sensor based on etched fiber Bragg gratings for assessment of biodiesel quality

João Paulo Toscano da Fonseca, Jafahr Traya Gondek, Gustavo Rafael Collere Possetti, Marcia Muller, José Luís Fabris, Ricardo Canute Kamikawachi
Federal University of Technology - Paraná
Curitiba, Brazil
canute@utfpr.edu.br

Abstract— **In this work, are presented preliminary results of the application of an etched FBG as a sensor for analyzing the biodiesel quality. The method used is based on the thermo-optic effect and the spectral behavior when the refractive index of samples with different concentrations of biodiesel approaches the refractive index of the fiber cladding. The results show that the etched fiber Bragg gratings can be used to measure small concentrations of oil in biodiesel**

Keywords- Optical fiber sensor, etched fiber bragg grating, biodiesel-diesel blends

I. INTRODUCTION

The growing global efforts to reduce greenhouse effect gas emissions have been one of the motivations to the increase in research of renewable and alternative fuels. One of the mainly fuels used in road transportation is the diesel and the harmful diesel engine emissions is well-known. Biodiesel is known as an environmentally friendly fuel due to reduced greenhouse gas emissions. It is a renewable fuel and presents biodegradable characteristics [1]. In Brazil and many others countries, the laws make mandatory the use of biodiesel in diesel oil mixture [2]. Therefore, the quality control in both manufacture and distribution networks is a current necessity and, consequently, a mixture percentile measurement method will be required.

The biodiesel production is based on converting triglycerides to alkyl esters [3-5]. In this process, an unsuccessful reaction step results in a partial or incomplete conversion of the triglycerides, compromising the product quality. Some works have proposed techniques to assess the quality of the biodiesel: methods based on spectroscopy [6], proton nuclear magnetic resonance [7, 8] and capillary gas chromatography [9, 10] have been reported in the literature. These techniques frequently require sample preparation, previous calibrations for analysis, long time of analysis and high-cost equipments. Xie and Li reported a method based on refractive index measurement to assess the conversion to methyl esters in the reaction [11].

For measuring the refractive index of the liquid samples, recent studies employed fiber Bragg gratings (FBG). The refractive index sensitivity (RIS) of etched FBG has been investigated [12] and some applications were proposed [13, 14].

In etched FBG, the cladding is sufficiently reduced, and the effective refractive index (n_{eff}) of the fundamental mode is strongly affected by external refractive index. As a consequence, a change in the refractive index also causes a wavelength shift [15]:

$$\Delta\lambda_B = 2\Lambda\eta_{p0}\Delta n \quad (1)$$

where Λ is grating period, η_{p0} is the fraction of the total power of the unperturbed mode that flows in the etched region when the etching process is complete, and Δn is the difference between the cladding and the surrounding refractive indexes.

Besides when the fiber cladding is reduced the mode field propagating in the etched fiber region penetrates through the external boundary and becomes sensitive to the parameters of the medium surrounding. If the refractive index of the external media is higher than the silica the modes are leaky, because there is no total external reflection at the silica–external boundary. However, for field modes to exist, it is sufficient to provide an external refractive index smaller than the silica refractive index or a small refractive index difference at the external boundary.

In this work, are presented preliminary results obtained with an etched FBG employed as a sensor to the assessment of biodiesel quality. The method used is based on the characteristic temperature in which the refractive index of samples, with different concentrations of biodiesel, approaches to the refractive index of the fiber cladding. To each concentration of sun flower oil in biodiesel can be associated a specific temperature.

II. METHODOLOGY

The FBG used in this work was written into photosensitive fiber optic by the technique based on the direct illumination of a phase mask and using an excimer laser (Coherent Xantos XS KrF248), operating at 248 nm. The grating parameters was λ = 1542 nm, bandwidth of 0.23 nm, reflectivity of 22 dB and the grating length is approximately 3 mm.

To make the FBG sensitive to changes in the surrounding refractive index, the cladding radius around the grating region was reduced by wet etching, 20 mm around the grating. The FBG was chemically etched into an aqueous solution of

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