Journal of Engineering and Applied Sciences 11 (6): 1377-1378, 2016
ISSN: 1816-949X


# Etched Fiber Bragg Grating to Detect Ethanol Concentrations

[1]C.H. Tan, [1]B.K. Yap and [2]F.R. Mahamd Adikan
[1]Department of Electronics and Communication Engineering, University Tenaga National, 43000 Kajang, Selangor, Malaysia
[1,2]Integrated Lightwave Research Group, University of Malaya, 50603 Kuala Lumpur, Malaysia

**Abstract:** Fiber optic sensing based on etched Fiber Bragg Grating (FBG) for concentration of ethanol solution is presented in this work. Different concentrations of ethanol solution were analyzed by observing the peak wavelength shift via Optical Spectrum Analyzer (OSA). FBG fiber sensor SMF-28 were chosen in this experiment with fiber cladding diameter 125 μm and fiber core diameter of 8.2 μm. A broadband signal from an Amplified Spontaneous Emission (ASE) light source was injected into the fiber through a 3-port circulator and the reflected spectra from the FBG was observed and monitored via an Optical Spectrum Analyzer (OSA) during the etching process. FBG wavelength was taken at time zero in room temperature environment before the etching experiment start. The fiber cladding was wet-etched by dipping the FBG in an aqueous solution of Hydrofluoric (HF) acid of 49% concentration, to enhance the FBG sensitivity to the surrounding Reflective Index (RI) change. Final FBG fiber thickness was then inspected and measured via Scanning Electron Microscope (SEM). The entire etching duration took about 20 min whereby the FBG thickness was etched from 125-9.7 μm. A total of nine different FBG thicknesses (125, 90, 58.30, 28.20, 12.60, 11.20, 10.90, 10.60 and 9.70 μm) were prepared by immersing in five different concentrations of ethanol (10, 15, 20, 30 and 40%). It is observed that the Bragg wavelength shifted more in higher concentration of ethanol and with thinner FBG. Peak wavelength for FBG with 9.7 μm thickness shifted 0.46 nm in concentration of 40% as compared to in 10% concentration with 0.33 nm shift. The peak wavelength for FBG with 90 μm shifted 0.03 nm in 40% of ethanol concentration compared to 0.01 nm in 10% of concentration. This proved that the FBG is more sensitive when the cladding thickness is reducing while in contact with high chemical concentration.On the other hand, FBG sensitiveness has linear relationship with FBG thickness.

**Key words:** Fiber bragg grating, etching, ethanol concentration, sensitiveness, concentration

## INTRODUCTION

In recent, Fiber Bragg Grating (FBG) sensor plays an important role in various industry such as civil, food and medical industries, due to its advantages. Advantages of FBG included, corrosion resistance, immunity to electromagnetic interference and ease of installation as well as being inexpensive (Wu *et al*., 2013; Park *et al*., 2011).

Ethanol is an important solvent used in chemical industrial and it requires an accuracy monitoring of its concentration. The ethanol concentration can be affected by the manufacturing process in production which can result in undesirable concentration in the final product (Raikar *et al*., 2007).

However, to increase the sensitivity for detection via FBG, the FBG cladding needs to be etched. As the cladding thickness decreases, evanescent waves will project through the cladding layer to enhance the detection sensitivity. The effective refractive index ($n_{eff}$) is significantly affected by external refractive index (Raikar *et al*., 2007). While the Refractive Index (RI) of solution changes with the change of the concentration of solution (Kumar *et al*., 2014). The Bragg wavelength shifted with the change of the effective refractive index. Concentration of the solution can be known by observing the Bragg wavelength shift throughout the monitoring progress.

In this research, a sensing system based on an etched FBG for ethanol concentration were proposed and tested. The performance of the sensor system in this work is also discussed.

## MATERIALS AND METHODS

FBG needs to be etchedto enhance the FBG sensor sensitivity. The experiment set-up for etching is shown in Fig. 1, signal from an Amplified Spontaneous Emission

**Corresponding Author:** B.K. Yap, Department of Electronics and Communication Engineering, University Tenaga National, 43000 Kajang, Selangor, Malaysia

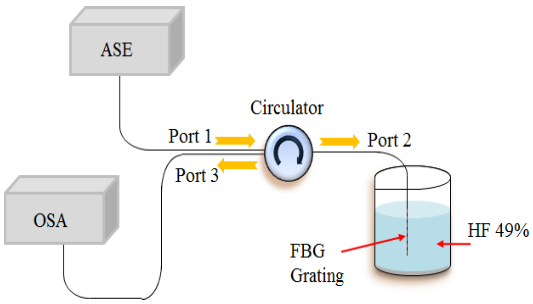


Fig. 1: Experiment set-up for etching process

(ASE) light source was injected into the fiber through a circulator and the reflected spectra from the FBG was observed and monitored through an Optical Spectrum Analyzer (OSA) during the etching process. The fiber cladding was etched by dipping the FBG in Hydro Fluoric (HF) acid of 49% concentration. FBG fiber thickness was also inspected and measured via high power microscope to prevent over etched to the core. FBG were etched to a different thickness (90, 58.30, 28.20, 12.60, 11.20, 10.90, 10.60 and 9.70 μm). The entire etching duration was about 20 min whereby the FBG thickness was etched from 125-9.7 μm.

In order tocharacterize the Bragg wavelength shift of FBG to act as an ethanol concentration sensor, sample ethanol solutions of different concentrations (10, 15, 20, 30 and 40%) are prepared.Each of the FBG thickness were then immersed into the five different concentrations of ethanol. Shifted in Bragg wavelength are noted at different concentrations.

Bragg wavelength were recorded at room temperature before the ethanol samples were tested out. FBG need to be washed, dry and the Bragg wavelength to be back to its original peak before the next concentration ethanol to test out. In this experiment, Distilled (DI) water is isused to wash the grating region.

## RESULTS AND DISCUSSION

The dependence of the sensor sensitivity on concentration in terms of wavelength shift has been analyzed. The results of ethanol concentration measurements via different FBG thickness are reported in Fig. 2.

Peak wavelength for FBG with 9.7 μm thickness shifted 0.46 nm in concentration of 40% as compared to in 10% concentration with 0.33 nm shift. The peak wavelength for FBG with 90 μm shifted 0.03-40% of ethanol concentration compared to 0.01 nm in 10% of concentration. Overall, Bragg wavelength shift increases with the increase in solution concentration.

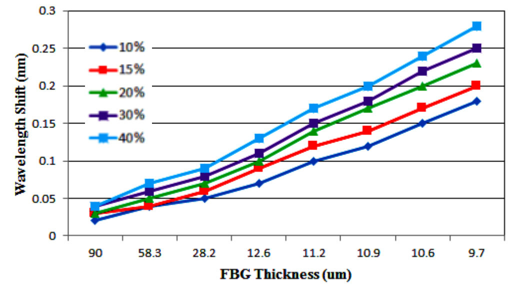


Fig. 2: Bragg wavelength shift for different FBG thickness under different ethanol concentration.

## CONCLUSION

FBG based sensor to study the concentration of ethanol is presented in this work. The cladding of the FBG was partially removed using HF based etching to make FBG sensitive to the changes in surrounding RI. The overall results of the total different fiber diameters show that, there is a linear relationship between the wavelength shifts from lower to the higher concentration of ethanol solution. It is observed that the Bragg wavelength shifted more in higher concentration of ethanolwith thinner FBG. This proved that the FBG is more sensitive when the cladding thickness is reducing while in contact with high chemical concentration. Furthermore, this approach with the FBG based sensing system is able to provide a real time monitoring system for chemical industries.

## ACKNOWLEDGEMENTS

This research was supported in part by the University of Malaya under the PPP (PG023-2013B), UMRG(RP024B-13AET)and BKP(BK020-2013)research grants and in part by University Tenaga National under 20140109FRGS and 20160111FRGS research grants.

## REFERENCES

Kumar, J., R. Mahakud, O. Prakash and S.K. Dixit, 2014. HF-based clad etching of fibre Bragg grating and its utilization in concentration sensing of laser dye in dye-ethanol solution. Pramana, 82: 265-269.

Park, C.S., K.I. Joo, S.W. Kang and H.R. Kim, 2011. A PDMS-oated optical fiber Bragg grating sensor for enhancing temperature sensitivity. J. Opt. Soc. Korea, 15: 329-334.

Raikar, U.S., V.K. Kulkarni, A.S. Lalasangi, K. Madhav and S. Asokan, 2007. Etched fiber Bragg grating as ethanol solution concentration sensor. Optoelectron. Adv. Mater., 1: 149-151.

Wu, Z., X. Yu, E. Gu, Z. Kong and W. Li, 2013. Characteristics analysis of chemical concentration sensor based on three-layer FBG. Opt. Photonics J., 3: 268-271.