

Etched fiber Bragg grating as ethanol solution concentration sensor

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A fiber optic sensing system for measurement of concentration of ethanol solution, based on fiber Bragg grating (FBG) technology is presented. The fabrication process is described and its performance is evaluated. Concentration change of surrounding chemical solution can be detected by the peak wavelength using an optical spectrum analyzer. The ethanol solution under test was thermo saturated at 25 °C in order to avoid wavelength shifts due to temperature variation. We observed shifts in Bragg wavelength for various concentrations of ethanol. Peaks were well resolved. The sensor performance is very good at lower concentrations of ethanol.

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1. Introduction

Optical sensors are very attractive in chemical and bio-chemical applications due to some unique characteristics, such as immunity to electromagnetic interference and to aggressive environments, high sensitive and fast response. In recent years fiber Bragg grating sensors have been widely used in many sensing applications including temperature, strain and pressure measurements [1]. The research field in optical fiber grating technology has opened a new platform in both communication and sensor field [2-5]. A fiber Bragg grating is a periodic perturbation of the refractive index along the fiber length, which is formed by exposure of the core to an intense optical interference pattern. The principle of the FBG sensing operation realizes the dependence of the Bragg wavelength on the grating period and effective refractive index. Since the light coupling takes place only between well-bound core modes, which are screened from the influence of the surrounding medium refractive index (SRI) by the cladding, normal FBGs are intrinsically insensitive to SRI. However, if fiber cladding is reduced along the grating region, the effective refractive index is significantly affected by external refractive index [6]. In such cases, only the effective refractive index n_{eff} is affected by measuring changes while grating pitch practically remains unchanged. This effect was used by Kumazaki et al. [7] to realize a fiber tunable filter.

Recently FBGs have been used to realize a concentration sensor [8-10]. This paper reports the spectral (response) characteristics of the FBG sensor to various ethanol concentrations. A complete experimental analysis,

on the use of Ge-B doped FBG for a concentration measurement is presented. The spectral changes in the grating response due to variation of concentration have been investigated in relation to new sensing configurations.

2. Fabrication technique

Two methods are widely adopted for fabrication of FBG, interferometer technique and phase mask technique. Phase mask technique is proved advantage over interferometric technique [11,12]. A single mode Ge-B co-doped photosensitive fiber (Newport F- SBG -15, step index profile of NA 0.12 - 0.14, Cladding diameter 125 ± 1 μm , and operating wavelength 1550 nm) on one of its end, gratings are formed using phase mask technique. Phase mask is a diffractive element (on silica slab) exposed through UV source to produce interference pattern, which in turn produces a permanent change in refractive index of the photosensitive fiber core which is immediately kept behind the phase mask in proximity and parallel.

The acrylate coating of one end of the Ge-B co doped photosensitive fiber is removed with razor completely. Now this region of photosensitive fiber is ready for exposure to KrF* source at 248 nm. The schematic diagram is shown in Fig. 1. The KrF* source is allowed to pass through phase mask and a cleaved fiber is kept behind very close to phase mask. Within a small time interval of 20 seconds, the gratings are produced on fiber and have reflectivity of 74 % and Bragg wavelength is at 1.54028 nm, which can be analyzed with Optical spectrum analyzer. The reflected spectrum is shown in Fig. 2.

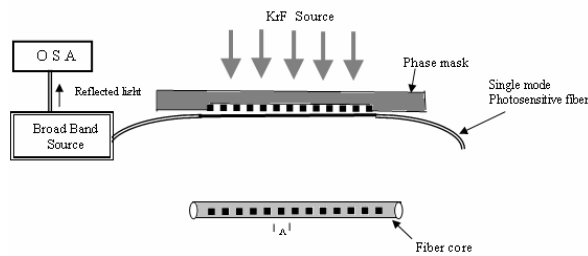


Fig. 1. The schematic diagram of FBG on photosensitive single mode fiber.

The exposed region where the gratings are formed is now etched with 40% HF for around 55 minutes. The wavelength versus cladding diameter was closely monitored during etching. Careful manipulation of the etched fiber region has been undertaken in order to avoid breaking at etched region.

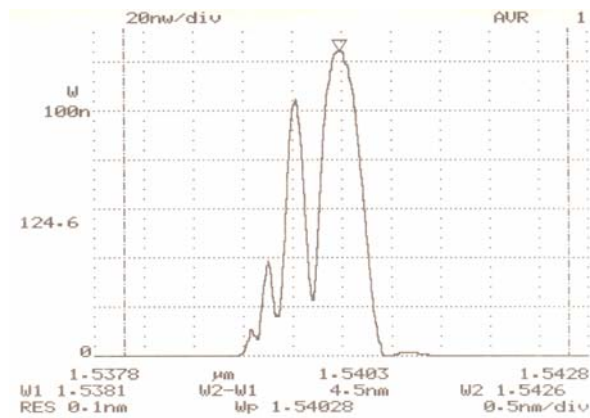


Fig. 2. Reflected spectrum of Fiber Bragg Grating.

3. Experimental setup

The experimental setup is shown in Fig. 3. In order to characterize the spectral response of FBG to act as an ethanol concentration sensor, sample ethanol solutions of different concentrations are prepared. The experimental fiber is kept in a test tube containing ethanol solution. The light beam from broadband source was injected into the fiber and the reflected spectrum from FBG for different concentrations of ethanol solution was observed with an optical spectrum analyzer. Changes in Bragg wavelength are noted at different concentrations. Reflected spectra are recorded for air, distilled water and different concentrations of ethanol solution. Methanol solution is used to wash the grating region before using the next concentration of ethanol.

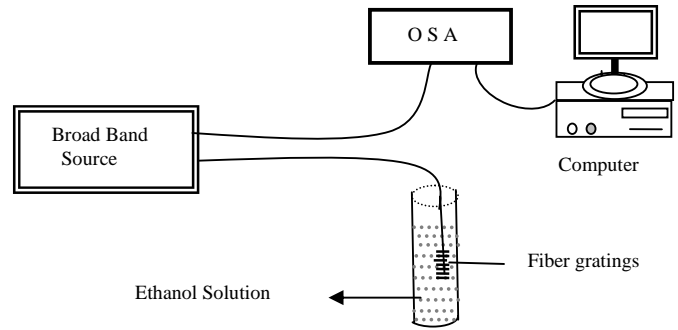


Fig. 3. Experimental setup for concentration measurement of ethanol solution.

4. 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 are reported in Fig. 4 that shows the measured wavelength shift for different concentrations of ethanol solution. From Fig. 5 results that wavelength shift decreases with the increase in solution concentrations. The setup is able to discriminate wavelength shifts with a resolution of pico meter range at lower concentrations.

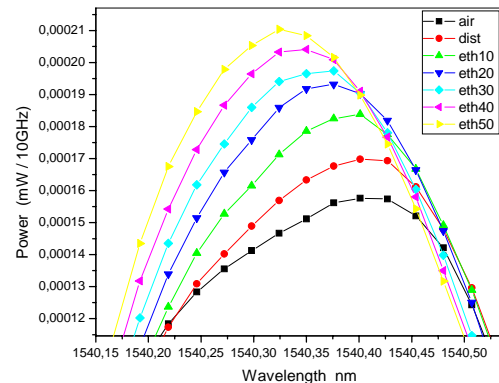


Fig. 4. Spectral response FBG to various ethanol concentrations.

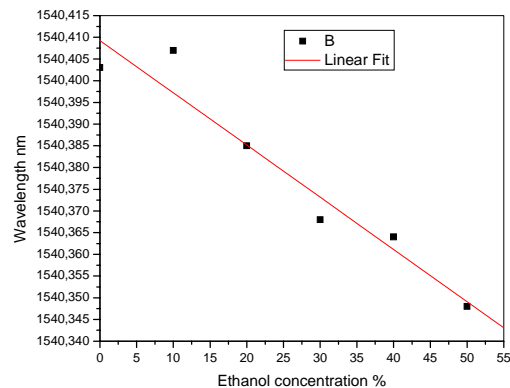


Fig. 5. Wavelength shift vs concentration of ethanol solution.

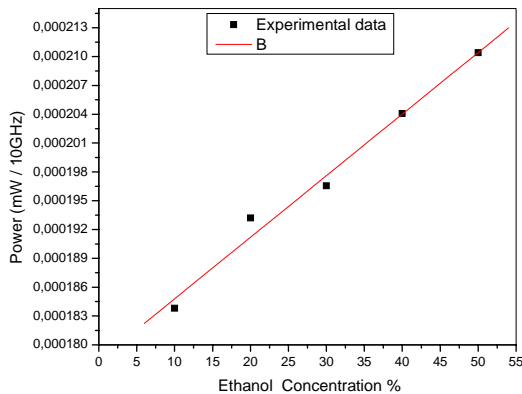


Fig. 6. Measured power vs concentration of ethanol solution.

5. Conclusions

Simple and low cost fabrication technique involving chemical etching in a HF solution has been carried out for sensor preparation. Sensor sensitivity depends on the concentration of the solution, which measures the concentration with a sensitivity as high as 0.002 nm/%. From Fig. 6 we can see that there is a good linear relationship between the liquid concentration and the measurement output. This linear measurement characteristic agrees well with the theoretical analysis. The advantages of this method are: the faster response time and very easy implementation for measurement. The sensor may be used to detect chemical or biological changes in the surrounding media. The sensor can be used for medical, pharmaceutical, industrial fluids, photochemical, plastic and food industry applications.

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