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Survey on Etched Fiber Bragg Grating based Senor Applications

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Abstract - *FBG is fast and source intensity independent temperature and strain sensor. It is chemically inert and immune to electromagnetic interference so best suited for chemical and bio sensing related application. FBG can be modified to EFBG at low cost without any need for sophisticated set up. The sensor is sensitive to surrounding refractive index change and its Sensitivity can be varied. EFBG sensors are desirable due to silent features like RI sensing, high sensitivity, multi-modal sensing capability, large operational bandwidth and multiplexing capability over surface plasmon resonance (SPR) or interferometric configurations sensor or any other conventional sensor. Sensitivity of EBFG is enhanced drastically by means of nano structured coating over its surface .These properties makes it extensively appropriate for adulteration finding and biomechanical , chemical sensing , label free bio sensing related applications. In next decade FBG can become promising irreplaceable sensor for chemical and biomedical industry. In this paper we have presented detailed survey regarding the sensitivity, limit of detection of EFBG sensor while using in different applications*

Key Words: **EFBG, etching, biosensor, refractive index, biochemical**

1. Introduction

Fiber Bragg Grating based sensor are achieving wide popularity since last two decade due to its high sensitivity, smaller size, light weight , electromagnetic interference immunity , multiplexing capability, inertness to chemical[1] . The different types of grating measure strain, temperature, RI [1-4]. In EFBG reflected properties are varied in accordance with refractive index of surrounding medium due to interaction of evanescent wave [5, 12].

EFBG is playing dominating role in the chemical and biochemical sensing through [6-8]. Unbeatable advantages of FBG sensor are integrated with deposition of thin film of oxides or nanostructures, over it to improve field interaction at molecular scale [9-10]. Application areas of EFBG sensor are implementation of amplifier and filters, multiplexers [11] as well aerospace, civil, Bio medical, chemical sensing [12]. This sensor can be configured for temperature insensitive based applications [13]. Need for cost-effective, innovative, easily fabricated, in house and usable option for refractive index measurement, adulteration detection or label-free bio sensing or chemical, gas detection in real time provokes use of EFBG.

2. Fundamentals

FBG are basically sensitive to physical parameter like temperature and strain but not sensitive to variation of refractive index of surrounding. FBG structure reflects wavelength of λB satisfying bragg condition given by equation (1) where Λ is pitch and neff is the effective refractive index of core1.

$$\lambda_B = 2\Lambda\ n^{eff} \quad (1)$$

$$\delta\lambda_B = 2\Lambda\,\eta_{po}(n_{cl} - n_{sur}) \quad (2)$$

Partial or total removal of cladding achieved through wet chemical etching process frames different modified characteristic relation as given in equation [7] Where $\delta\lambda_B$ is change in bragg wavelength, η_{po} is the fraction of the total power of the unperturbed mode that flows in the etched region, n_{cl} is the refractive index of the cladding and n_{sur} is the refractive index of the surrounding medium.

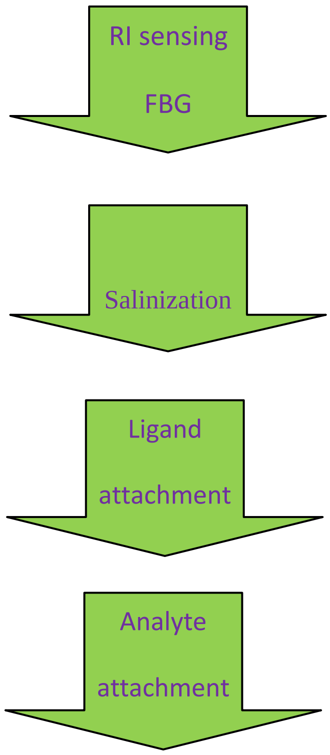


Figure 1. Overview of sequence of steps for developing an EFBG label free biosensor.

This means that sensor measures chemical or biochemical interaction at surface by, measuring RI variation at surface Biosensor makes response to selective biological spices [9, 14]. Detection of target using ligand after following set of procedure mentioned in Figure 1. In some case, EFBG is coated with nano structure or thin film enhances the RI sensitivity [15-17].

3. Applications of EFBG

Kumar et al, demonstrate graphene oxide (GO) coated EFBG sensor for minimum detection of ethanol of 0.5% in petrol [14]. Takhmina Ayupova et al, present a wavelet density estimation method applied on response of EFBG to analyze the spectrum [18]. Nazirah Mohd Razali et al, observe over all shift of 0.12 nm shift for 0-50 ppm of nitrogen concentration [19].

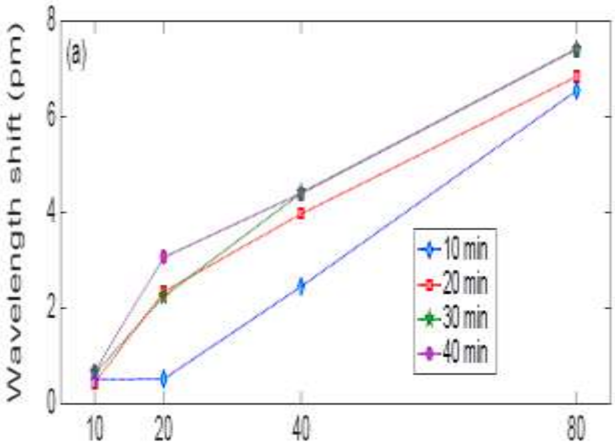


Figure2: Response of the EFBG for thrombin detection. Wavelength shift observed for each concentration, after 10, 20, 30, and 40 min from the start of the experiment [6]

Aliya Bekmurzayeva et al, demonstrate EFBG implemented for detection of 10 nM to 80 nM thrombin using aptamer. Response for thrombin of 10, 20, 40, 80 nM conc. are observed for 10, 20, 30, 40 min and corresponding wavelength in pm are noted. Figure 2 represents relation between concentration of thrombin, time interval of sensing and shift in wavelength[6].

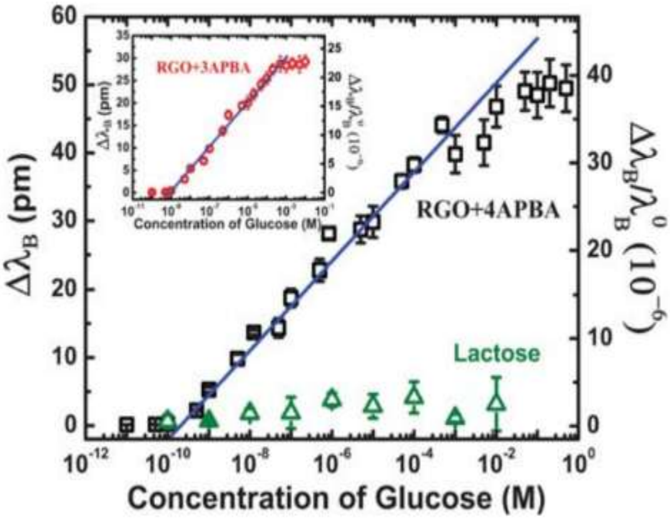
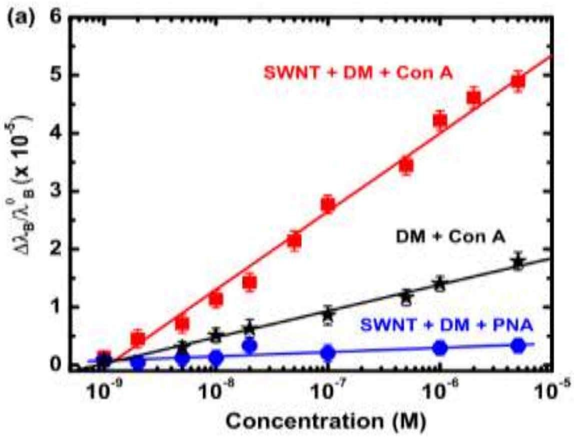


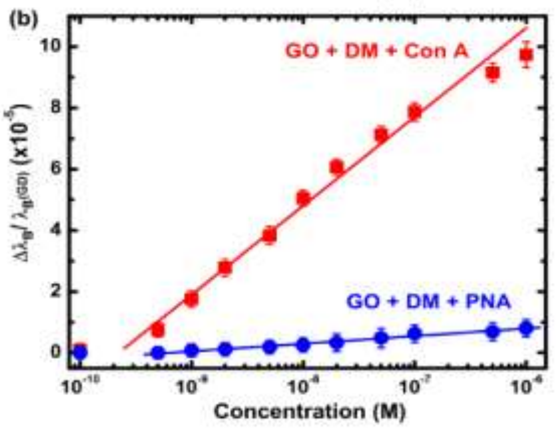
Figure 3 : Normalized Shift in the Bragg wavelength for D-glucose concentration (open black squares for 4APBA–RGO coated EFBG and open green triangles for lactose)[15]

Ruaa K. Musa et al, demonstrate EFBG sensor for measurement of NaCl and glucose conc. of 5 to 10 % and 10 to 50 % and achieving the sensitivity of 8.3 □ 10−5nm/(%w/v) and 3. 085 □10 −3 nm/(% w/v) respectively20. Shridevi et al, perform experiment on grapheme oxide coated EBFG for detection of glucose and glycated hemoglobin. Detection of D glucose is shown in Figure 3 shows change in coating to 4APBA-RG yield more sensitive biosensor and liner response15. Sven Schulze et al, implements a label free online detection for a C reactive Protein using single standard aptamer21. Minimum detectable CRP is 0.82 pg/L with sensitivity of 8 nm/RIU12.

Agarwal et al, implements. Adulteration sensor for benzene, toluene and xylene: hydrocarbons volatile organic compound detectable up to 10 %22. Sridevi et al, demonstrate single wall carbon nanotube (SWCNT) or graphine oxide (GO) coating on functionalized EFBG for detection of concanavalin A (con A).GO coated graphine shows lower limit of detection as compared to SWNTS coated EFBG.



(a)



(b)

Figure 4 (a) response of SWNT-DM coated EFBG fop concentration of lectins ranging from 1 nM to 5 M and (b) GO-DM coated EFBG concentrations of lectins ranging from 100 pM to 1 M[9]

Figure 4 (a) and (b) shows response for SWNTS + DM and GO + DM coating for Con detection [9]. Zhou et al, partially etch cladding till 20-11 µm to implemented magnetic field sensor and achieve of sensitivity 2.3 pm/mT23.

Figure 5 shows schematic for measurement of magnetic field. Kumar J. et. al, [7] used etched FBG for measurement of 0 mM to 1.5 mM concentration of laser dye ethanol solution and achieve sensitivity is 70 pm/mM. Chryssis et al. detects hybridization of DNA using evenscent field of etched fiber bragg grating [8].

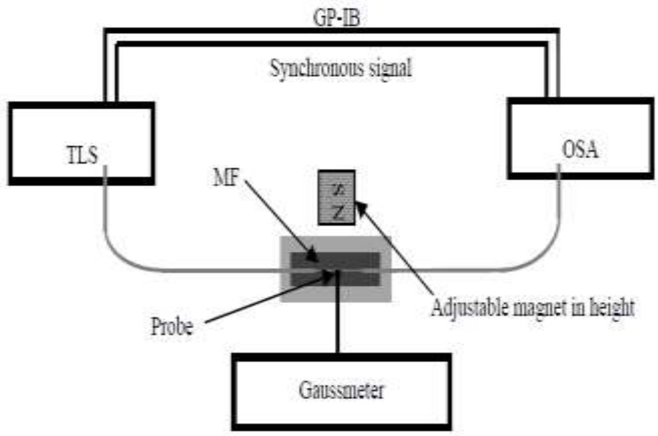


Figure 5 Schematic diagram of the experimental setup for measuring the magnetic field [23]

4. Conclusion and future scope

Paper is brief overview of the recent application of EFBG sensors specifically in, bio sensing, chemical and refractive index sensing for adulteration based application. EFBGs have shown a great potential due to unique and irreplaceable inherent features like chemically inert, smaller size, sensing RI, variable sensitivity. Survey of EFBG revels limit of detection for various bimolecular targets. Sensitivity of biosensor depends on fiber diameter, bio recognizing element (BRE) , type of functional molecule , surface density, size and orientation of BRE , nanomaterial coating , along with this ambient temperature, time interval for observation. Bio sensing provides label free sensing and sensitivity is enhance by means of coating and reaching minimum limit of detection. Reputability can ensure reliable LOD and sensitivity of biosensor. Refractometric sensor is different than biosensor as volumetric RI change matter rather than surface modification. Uniform etching along FBG ensures reliability in response. Spectrum boarding and peak detection issue with EFBG can be solved. EFBG is best senor as cost-effective, innovative, easily fabricated, in house and usable option for refractive index measurement, adulteration detection or label-free bio sensing or chemical; gas detection in real time is concern. Magnetic field sensor can find restricted area for radiation. EFBG sensors can be best suited for both in vivo and in vitro measurements related medical, laboratory application where fabrication cost is minimum.

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