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Variations in Sensing Response of Cladding Modified Fiber Optic Intrinsic Biosensor with The Interaction Between Gox and Glucose

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ABSTRACT

In the present investigation, a cladding modified fiber optic intrinsic sensor using biomolecules has been developed. In this original cladding is removed mechanically and modified it with the polymer-polyaniline, which is suitable to incorporated and bind the biomolecules in its porous structure. The biomolecules used are enzymes-glucose oxidase (GOx) and used to detect the analyte-glucose. The sensitivity of developed sensor has been studied by measuring intensity or power versus time. During the interaction between GOx and glucose; there are variations in sensing response of sensor. A type of uniform pattern or platues has been observed. It shows an ON and OFF i.e. starts and ends of reaction between GOx and glucose.

Keywords: Sensor, Cladding Modified Optical Fiber, Immobilization, Glucose Oxidase

I. INTRODUCTION

In the year 1969 a sensor was developed by Clark of the children's hospital in Cincinnati, Ohio, which was used for sensing the biomolecules called as biosensor [1, 2]. It was investigated with the development of enzyme electrodes. After that ample of mature, reliable, fast and more sophisticated biosensors were developed by researchers throughout the World. In last 30-40 years a simple commercially available small, disposable, single-use, glucose sensitive electrode and the corresponding handheld-sized portable meter containing the integrated circuit (IC) and liquid crystal display (LCD) biosensing device was developed for the testing of blood glucose [3-7]. Biosensors are useful in various fields such as medicine, agriculture, biotechnology, military, environmental analysis, food analysis, health care, biochemical industries etc. [4-11]. Those sensors were the electrochemical biosensors. Due to the advanced properties of optical fibers such as light weight, small size, operated in hazardous environments, without any electromagnetic interference, wide bandwidth, propagation of light over long distances with little loss in intensity and continuous light intensity etc., researchers were investigated the optical fiber biosensors [12].

An optical fiber based sensor; needs a light source, optical detector and sensing element (probe) for the detection of different analytes (which is to be measured). The information of analyte in these sensors is due to change in polarization, phase, amplitude, frequency, intensity or combination of these things. The designing

and development of sensing element in optical fiber sensors decides the type of sensor. In various types, cladding modified approach is the simplest and effective method of designing of optical fiber sensor. Its principle is based on the modulation of optical power / intensity in terms of absorption or interaction of light in the evanescent region.

For the development of such a biosensor; original passive cladding of an optical fiber is removed from a small portion and coated it with a thin layer of suitable matrix/material which can hold or capture the biomolecules without affecting it. For the cladding modification polymers like polyaniline, polypyrrole, polyindole, polythiophene etc. are found suitable and sensitive active cladding materials. It offers a porous matrix like cauliflower to hold or immobilize the biomolecules [13-17].

In the present investigation, variations in the sensing response of a cladding modified fiber optic intrinsic biosensor (FOIB) have been studied. This biosensor is developed by modifying the original cladding of optical fiber with polymer-polyaniline as an active cladding. Then it was incorporated with glucose oxidase (GOx) cross-linked via glutaraldehyde for the detection analyte-glucose. The sensitivity of developed biosensor has been studied by measuring intensity or power versus time. It has been observed that there is a type of uniform pattern or platues are formed, during the interaction between GOx and glucose. It shows an ON and OFF i.e. starts and ends of reaction between GOx and glucose. The results are reported.

II. METHODS AND MATERIAL

Aniline (monomer) and ferric chloride (oxidant) were purchased from Fisher Scientific used for the synthesis polyaniline.

1m long plastic cladded silica core optical fiber (core/cladding-960/40μm) was taken to develop a fiber optic intrinsic biosensor (FOIB). Both the ends of the optical fiber were cut and polished using polish paper. Two SMA connectors were connected to both the ends of the optical fiber. The sensing element of the FOIB was prepared by removing a small portion (1 cm) of original cladding mechanically of an optical fiber and deposited it with a thin layer of active cladding of polyaniline. It was synthesized by chemical polymerization method using monomer-aniline and oxidant-ferric chloride ($FeCl_3$) in an aqueous medium at room temperature. For the purpose, 0.2 M aniline and 0.05 M $FeCl_3$ stock solutions were prepared, separately, in double distilled water. 10 mL solution of aniline was taken in a beaker. The oxidant solution was added drop by drop in it with constant stirring and cladding removed portion was submerged in it during the polymerization to deposit a thin layer. After deposition, sensing portion was washed several times with distilled water. Then the sensing element immobilized with GOx prepared in phosphate buffer of pH 7.4 cross-linked via glutaraldehyde solution.

He-Ne laser (λ- 632.8 nm, power-1mW) was used as a source to illuminate the light at one end of the FOIB. At the other end; the sensing response of FOIB was recorded using a charge-coupled device (CCD) camera (Mels Impex America, Inc.) as a detector. Optical microscope AxioCam ERc 5s was used to record images of optical fiber at various stages in the experiment. Figure 1 shows the experimental arrangement of FOIB.

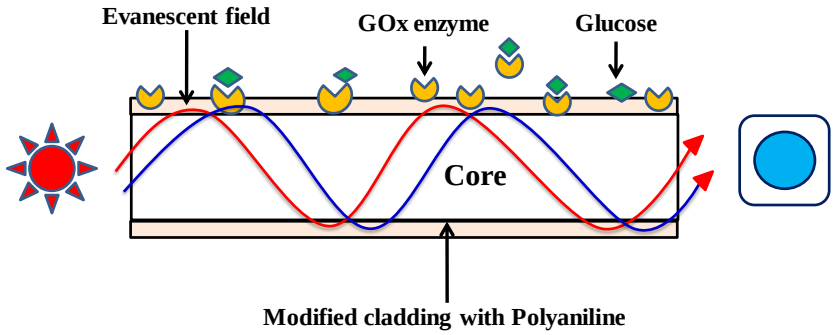

Figure 1 Experimental arrangement of FOIB.

III. RESULTS AND DISCUSSION

A. Optical Micrograph of Sensing Element

Figure 2 shows the sensing element of FOIB in various magnifications (4x and 10x). Figure 2 (a, b) shows the images of the sensing element before removal of cladding. Figure 2 (c, d) shows images of sensing element after removal of cladding. Figure 2 (e, f) shows images of sensing element after deposition of thin layer of polyaniline. As discussed earlier, polyaniline offers a porous matrix to accommodate the biomolecules like enzyme used for sensing analyte as shown in Figure 2 (e, f).

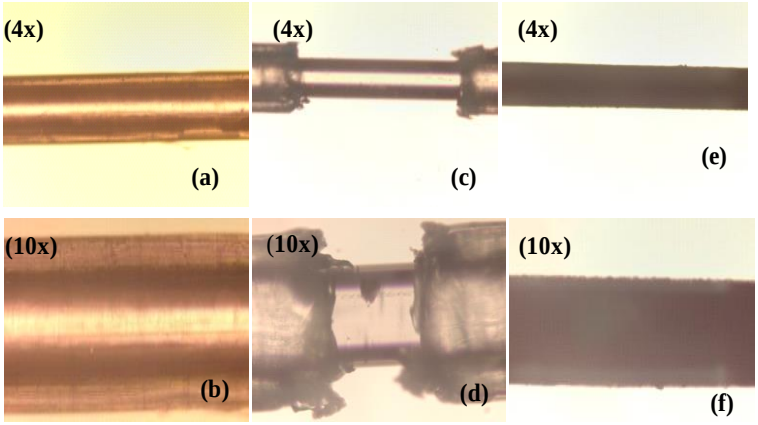

Figure 2 Optical microscopic images of optical fiber (a, b) with original cladding; (c, d) with removed cladding and (e, f) with polyaniline modified cladding

B. Sensing Response

Figure 3 shows the sensing response of FOIB for phosphate buffer solution (pH 7.4). It shows that there is no variation in power with respect to the time. It may shows that there is no interaction or reaction between enzyme-GOx and phosphate buffer solution.

Figure 4 (a, b) and figure 5 (a, b, c) are the sensing response of FOIB after adding the glucose solution in the cell enclosed with sensing element immobilized with GOx. Figure 4 (a) shows the interaction between GOx and glucose solution. It's a type of ON and OFF i.e. starts and ends of reaction and shows the uniform pattern or platues of it. It's in ON condition, while starting the reaction between GOx and glucose. After completion of the reaction it leaves behind Gluconolactone and hydrogen peroxide (H_2O_2), this condition is the OFF condition of reaction as shown in figure 4 (a, b). Again the enzyme GOx ready to interact with another glucose molecules and the reaction starts again. In this way power goes on increasing with respect to time and after the

interaction with all the glucose molecules, the power goes on decreasing as shown in figure 5 (a, b and c). Figure 5 (a) shows the increase in power during the interaction between GOx and glucose and the power starts decreasing as shown in figure 5 (b). Whereas, figure 5 (c) depicts the completion of interaction between GOx and all the molecules of glucose solution.

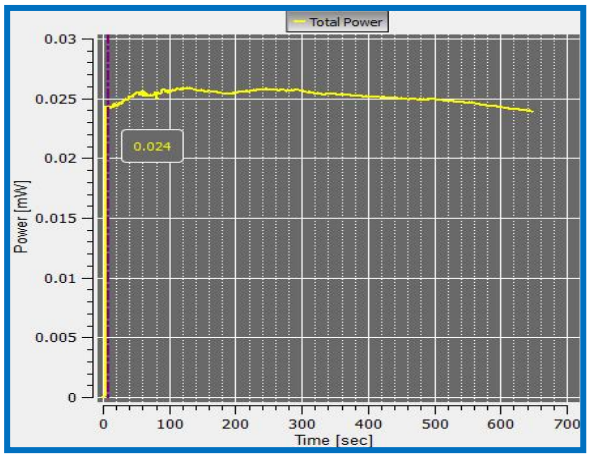

Figure 3 Sensing response of FOIB for buffer solution.

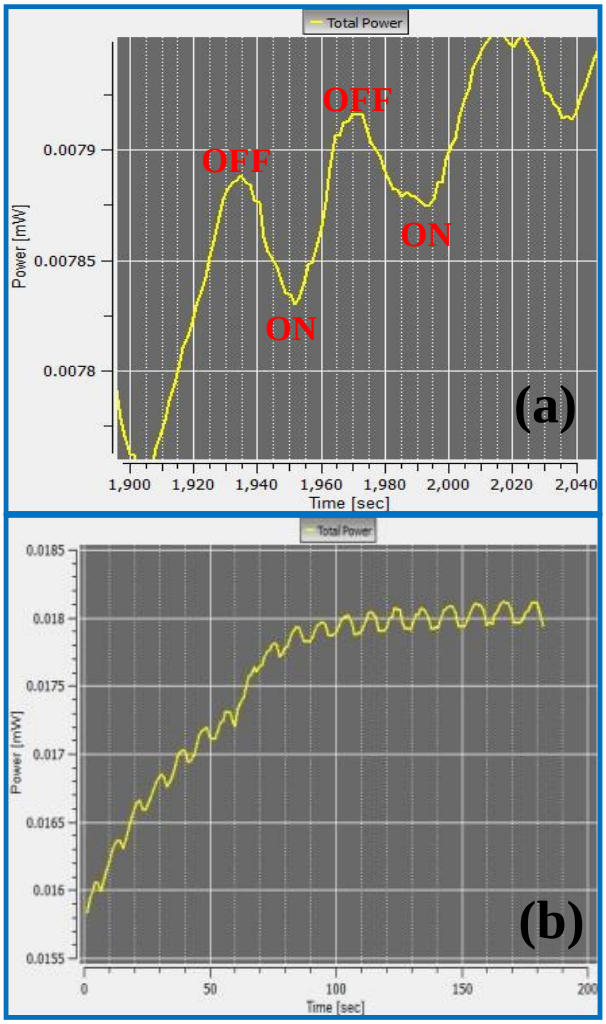

Figure 4 Sensing response of FOIB during the interaction between GOx and Glucose.

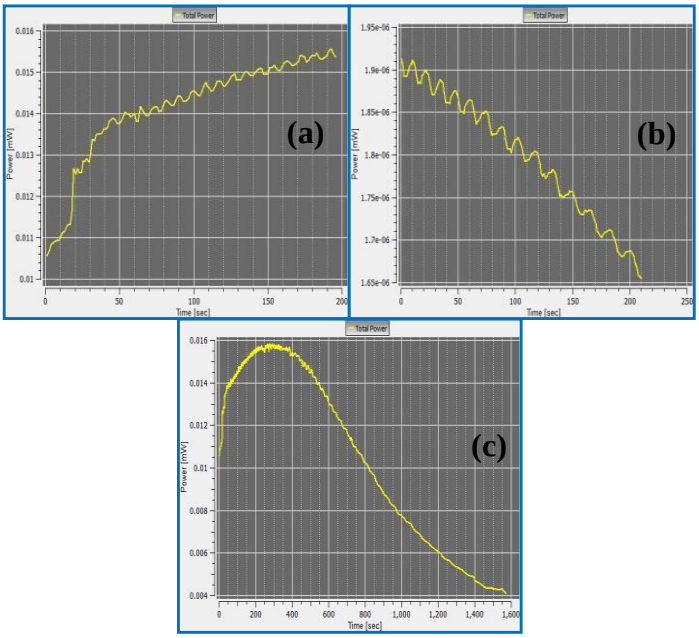

Figure 5 FOIB Sensing response (a) increasing, (b) decreasing and (c) completion of interaction between GOx and glucose.

IV. CONCLUSION

In the present investigation, a cladding modified fiber optic intrinsic sensor using biomolecules has been developed successfully. Polyaniline founds a suitable matrix for the immobilization of enzymes-GOx. Cladding modified FOIB has been successfully detected the glucose and shows sensing response or variations during interaction between GOx and glucose. At time of sensing, a type of uniform pattern or platues has been observed. It shows an ON and OFF i.e. starts and ends of reaction between GOx and glucose. It confirms the possible use of FOIB for immobilization of various biomolecules and detection of different analytes. It can also be effectively used in various fields.

V. ACKNOWLEDGEMENT

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