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DETERMINATION OF REFRACTIVE INDEX OF GLUCOSE SOLUTION USING LOW COST FIBER OPTIC SENSOR

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ABSTRACT

Simple and low cost optical fiber sensors are found to be useful in small and large scale chemical and medical industries. In particular, the physical properties of liquids like concentration, temperature, density and pressure can be measured using the refractive index optical fiber sensors. Optical fiber sensors (OFS) are superior to conventional measurement techniques because of its advantages such as remote sensing, simple setup, cheap and interference free etc.,. The present work demonstrates the measurement of refractive index of Glucose solution using a simple optical fiber sensor. The intensity modulated OFS designed works on the principle of the change in angle of reflected light with refractive index of the medium from which light enters the fiber. By measuring the intensity of the light received by the fiber from glucose solution of different concentrations indicates that it is possible to measure the refractive index of liquid with a simple plastic optical fiber sensor.

KEYWORDS: Refractive index, Optical fiber, sensor and sugar solution, Plastic optical fiber.

INTRODUCTION

Most of the physical properties like refractive index, temperature, density and pressure can be measure using optical fiber sensor(OFS). In case of liquid it is possible to measure such quantities by measuring the refractive index of liquid[1]. Moreover, measurement of refractive index of liquid is useful to test the purity of the liquid as well as the concentration of the solute in the solution [2]. In comparison with the conventional refractometry, OFS are highly sensitive and reliable because of its unique advantages[3]. Several attempts have been reported in the literature for the design of refractive index sensors for liquids such as using radiation losses by liquid medium in a cladded multimode tampered fiber [4] core cladding mismatch [5], measuring total internal reflection change, etched fiber bragg grating[6] and long period grating[7]. Theoretical and experimental fiber optic refractive index sensor based on intensity modulation was demonstrated by Suhadolnik[8] and A.D. Shaligram[9]. Most of the refractive index fiber sensors require extensive experimental setup and hence it is necessary to design a simple and cost effective sensor to find the refractive index of liquid. In the present work, we have developed refractive index sensor to measure the amount of glucose dissolved in water in addition to measure the refractive index.

WORKING PRINCIPLE

Two step index plastic multimode fibers known as transmitter and receiver fiber constitute of OFS. The transmitter fiber collects the light from the source and the output light from the transmitter fiber is allowed to travel in the liquid medium. This light is reflected by the reflector kept inside the liquid. This receiver fiber collects the reflected light and the intensity is measured in terms of output voltage by using photo-detector.

The parallel transmitter and receiver fibers are kept at a distance of 'y' from the reflecting surface fixed inside the liquid of refractive index 'n_L'. The numerical aperture of the transmitting fiber and the cone angle 'θ' is[10],

$$\theta = \sin^{-1}\left(\frac{NA}{n_L}\right)$$

If ‘y’ is the distance of the sensor tip and the reflector, then the radius ‘r’ of the reflected cone at a distance ‘2y’ is given by,

$$r = x + (2y)\tan(\theta)$$

Here ‘x’ is the radius of the transmitting fiber. It is seen that the light gathering by the receiver fiber is determined by the overlap region of the acceptance cone of receiver fiber and that of transmitter fiber. If the medium between the reflector and the fiber is filled with liquid of refractive index higher refractive index the angle of the cone as well as the radius of the reflected cone decreases[11]. The intensity of the light collected by the receiver fiber is low for very closer separation ‘y’. As the distance increases the output intensity increases and it is maximum for a particular distance and thereafter it decreases. The maximum intensity increases with the increasing refractive index since more reflected light is concentrated at the receiver fiber. Hence the measurement of light intensity OFS output at a particular distance enables one to measure the refractive index and its derivative properties of liquids. The basic principle of intensity modulated optical fiber sensor is demonstrated in Fig.1. The characteristic curve of the present sensor is shown in Fig.2.

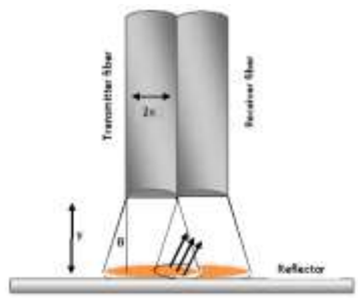

Fig.1. Principle of intensity modulated sensor

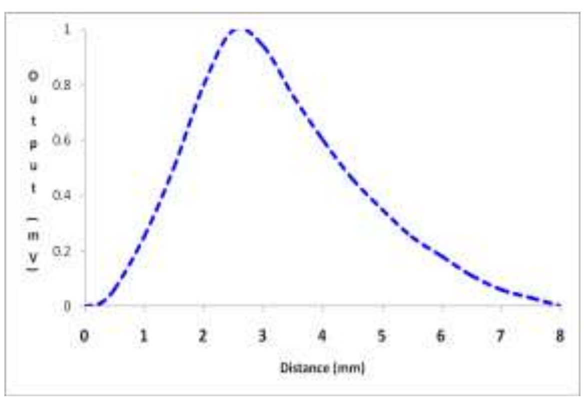

Fig.2. Characteristic curve of intensity modulated sensor

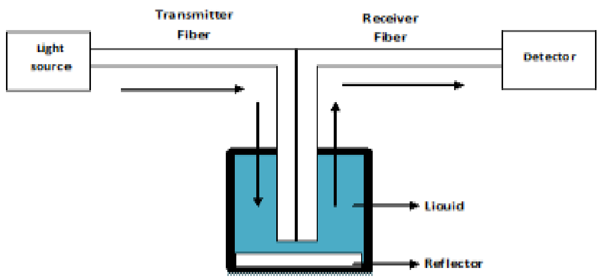

Fig.3. Diagram of experimental arrangement

EXPERIMENT

The experimental arrangement consists of two plastic optical fiber sensors known as Transmitter fiber and Receiver fiber. Light from an LED source (6400 A°) is launched into the TF and for measuring the intensity of reflected light from the RF, a photodiode (IF-D94)[11] was used. The intensity of light is measured by using a voltmeter. The fiber sensor is designed as shown in Fig.3. Plastic optical fibers of length 50 cm fixed together. For the present work we have used the polymethyl methacrylate fiber [12] of core diameter 970 micrometer having refractive index 1.492. The sample liquids are prepared by dissolving 1 – 5 gm of glucose in 100 ml deionised water of research grade. At the bottom of the liquid container, a reflecting mirror is fixed. The intensity of reflected light for different position of fiber tips are determined by displacing the fiber tip using a vertical travelling micrometer. The entire experimental procedure was carried out at room temperature.

Table.1 Refractive index of glucose of different amounts dissolved in water

Amount of Glucose in deionised water (gm)	Refractive Index
0	1.334
1	1.347
2	1.363
3	1.379
4	1.398
5	1.429

RESULT

The intensity of reflected light was measured in terms of output voltage using voltmeter. The output voltages for different amount of glucose content in water are measured at various distance from the reflector and it is displayed in Fig.4. From the characteristic curve of the intensity modulated fiber sensor[15] it is found that the output voltage increases as the distance increases and reached the peak and thereafter the intensity decreases. The same principle is observed for all the sample liquids. There exists a position where the intensity of the reflected light is maximum. The maximum output light intensity increases with the amount of glucose content increases and this is due to the increase of refractive index. Hence by measuring the peak output light intensity by fixing the fiber sensor one could measure the refractive index or the amount of substance dissolved. The plots between the output peak voltage which inturn refers the output light intensity versus the refractive index and the amount of glucose content are seen linear. We have observed a strong correlation between the observed quantities which enable to make use of the

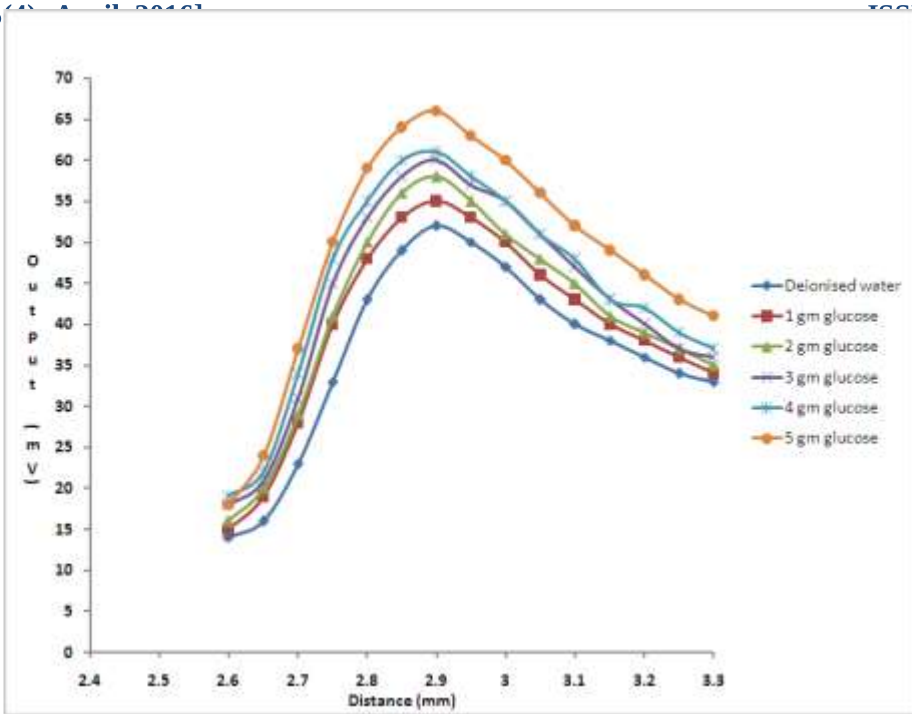

Fig.4. Light intensity (volt) versus distance of fiber from the reflector for different amount of glucose dissolved in water

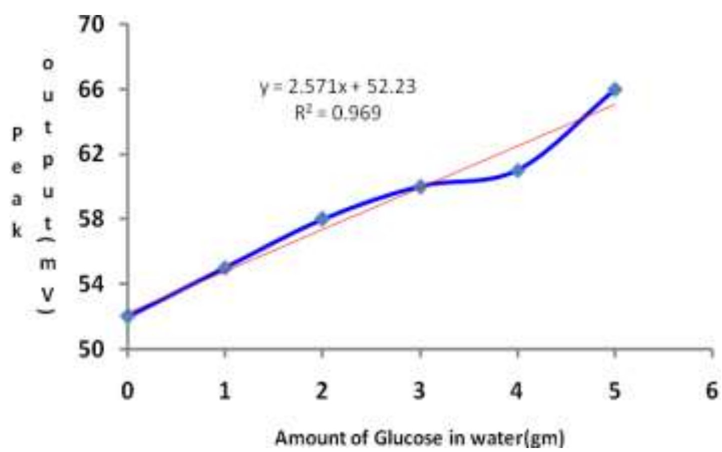

Fig.5. Peak output voltage versus Amount of Glucose in water

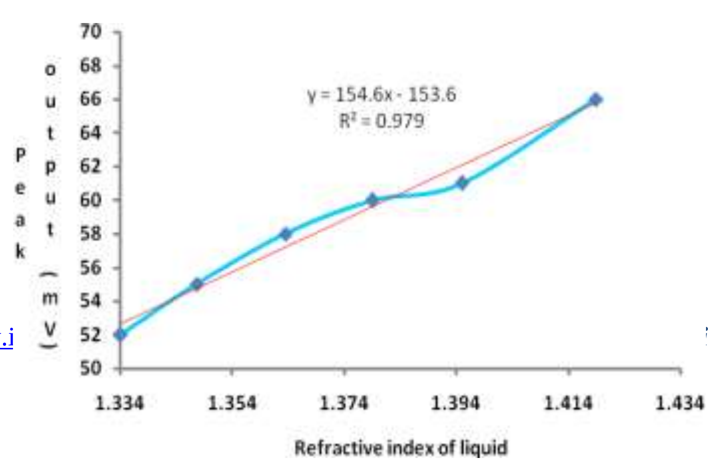

Fig.6. Peak output voltage versus refractive index of glucose solution

The correlation between the reflected peak output intensity with refractive index and amount of glucose dissolved in water is displayed in Fig.5 and Fig.6.. The sensitivity depends on the type of fiber used and the wavelength of light source and detector. The correlation coefficient R^2, are 0.969 and 0.979 for the variation of output voltage with refractive index and amount of glucose content. The basic principle of refractive index and amount of glucose content sensing technique depends on the characteristic curve shown in the Fig.2.

CONCLUSION

The present work demonstrates the measurement of refractive index and concentration of Glucose solution. The obtained results are displayed in terms of output voltage which makes it easy for the design and development of refractive index sensor. The OFS design is very simple, low cost and has excellent repeatability. This type of sensor is helpful in food and medical industries in testing the concentration of glucose content.

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