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FIBER OPTIC SENSOR UTILIZING INTENSITY MODULATION FOR THE ASSESSMENT OF CONCENTRATION AND REFRACTIVE INDEX IN LIQUIDS

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ABSTRACT

This study describes the usage of a fiber optic sensor that uses a reflector and two fiber probe to measure the refractive index and concentration of liquids based on variation of the reflecting intensity. Typically, this type of sensor is employed to gauge the tiny displacement of the fiber tip in relation to the reflector. In a previously published study, we demonstrated that the same configuration may be utilized directly to sense changes in the medium's refractive index as long as the distance between the fiber tips and reflector is kept constant. The liquid being tested fills the space between the reflector and the probe. The angle of emittance will vary depending on the liquid's refractive index, determining the output power that the receiving fiber will receive. In addition to pure solvents with varying refractive indices, several kinds of combinations can also change a medium's refractive index. The created sensor measures the amount of alcohols, such as methanol and ethylene glycol, in a mixture with water.

Keywords: Fiber optic sensor, intensity modulation, refractive index, alcohols.

Introduction

The application of fiber optic sensors has advanced significantly in the last several years (FOSs). Due to their comparatively tiny size and light weight, FOSs have well-known benefits such as high sensitivity, EMI, spark free, and little intrusiveness. Intensity-based optical fiber sensors are among the earliest and maybe most fundamental types of optical fiber sensors, despite the fact that a variety of FOSs have been documented in the literature [1].Refractive index is an important characteristic of optical material. Simple and high- precision method of measuring refractivity of liquid has been required for the material analysis and also for applications like environmental pollution monitoring of both river and sea water[2].

Accurately determining a clear liquid's refractive index is essential for designing optical instruments and is also highly beneficial in chemical research. The identification and measurement of organic substance concentration can be facilitated by an understanding of a substance's refractive index. Methanol (CH_3OH) is the simplest alcohol, containing one carbon atom. It is a colorless, tasteless liquid with a very faint odor and is commonly known as "wood alcohol." Methanol is used in a number of consumer products, including paint strippers, duplicator fluid, model airplane fuel, and dry gas. Most windshield washer fluids are 50 percent methanol. Methanol's physical and chemical characteristics result in several inherent advantages as an automotive fuel. The commercialization of methanol-powered fuel cells will offer practical, affordable, long-range electrically-powered vehicles with zero or near-zero emissions while retaining the convenience of a liquid fuel.

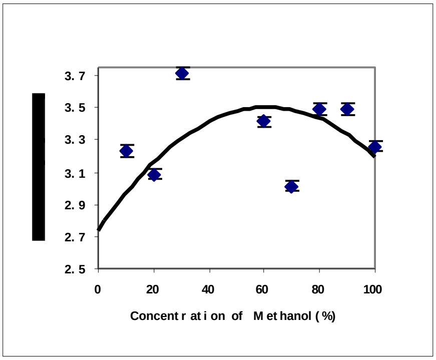
The clear, colorless, odorless, viscous liquid ethylene glycol has a sweet taste and has the potential to be extremely poisonous. It is frequently found in establishments and houses. The most typical places to find it are in hydraulic brake fluids, antifreeze, and automobile cooling systems. It is utilized as a raw ingredient or as a solvent in a number of industrial processes[6]. Since the chemical tastes delicious, many cases of ethylene glycol poisoning are caused by children inadvertently consuming significant amounts of it. This drug can also be consumed by alcoholics as a replacement for ethanol. Considering the important uses of these alcohols, it is necessary to detect the concentrations of these alcohols in mixture with water. The developed sensor is used to detect the concentration.

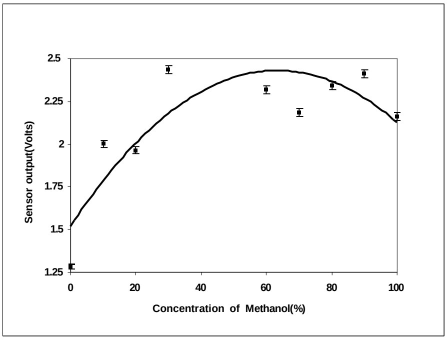
Experimentation

By combining pure methanol with distilled water, various concentrations of methanol solutions were created. Concentration ranges from 0% to 100%. The created sensor was applied to measure the mixture's methanol concentration. Water does not readily dissolve ethylene glycol. Hence, magnetic stirring was used to create a homogeneous blend. The magnetic stirring process was run at room temperature for five minutes. The remaining steps are the same as previously described. These solutions are utilized to measure concentration and refractive index using a developed fiber optic sensor, which comprises of a fiber probe and reflector based on intensity modulation[1].

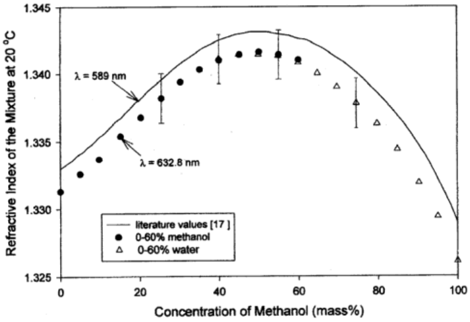
Results and Discussion

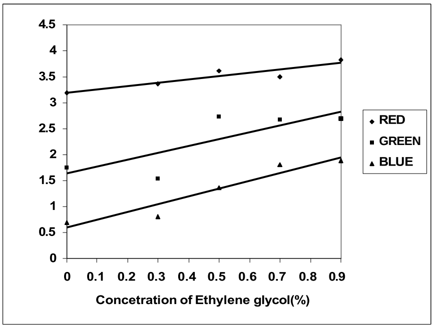
Figures 1(a) and 1(b) display the response of the developed sensor for methanol water mixture with various colored LED illuminations.

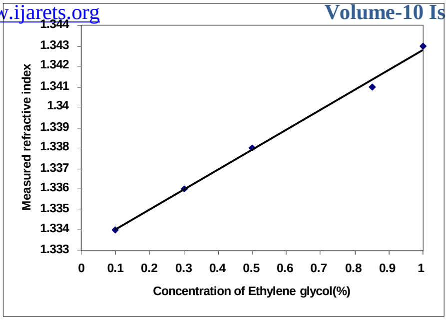




It is seen that the sensor output first rises, reaches a maximum, and then decreases as the quantity of methanol in the water increases. A review of the literature found that reports of this type of refractive index variation are in fact present. Figure 2 displays the standard data from CRC Handbook4 in conjunction with the experimental observation made by Jon P. Longtin and Ching-Hua Fan [3]. In order to precisely monitor the beam deflection across the cuvette, Longtin and Fan used a laser-based refractive index measurement device in conjunction with a PC-based system and a UDT SL5-2 linear position sensor. It is easy to see how the curves in figures 1 and 2 are similar to one another. The deviations of the observed sensor output voltages from the trend curves in figure 1 can be attributed to the experimental approximations in preparing the mixtures. However, the purpose of demonstrating the usability of developed sensor is served. Figure 1 also shows the color depend ace of the variation.







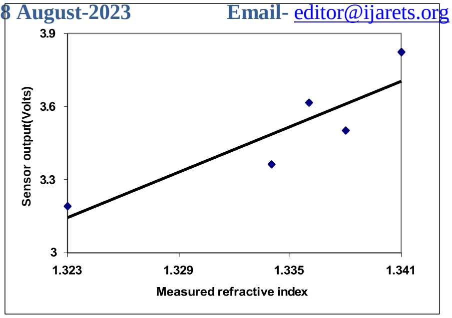


Figure 3 shows the results obtained for the ethylene glycol-water mixture. There is a almost linear rise in the sensor output predicting a linear change in the refractive index of mixture as the ethylene glycol concentration increases. Refractive indices of the same samples were measured using standard Abbe’s refractometer. Figure 4 shows the variation of refractive index of the mixture with concentration. Similarity of the nature of two plots is revealing.

Figure 5 shows the sensor output voltages plotted against the measured refractive index. Esteban et al[5] have used a surface plasmon resonance based fiber optic sensor for the determination of refractive index of ethylene glycol and obtained similar results. The empirical formula for the refractive index variation of ethylene glycol-water mixture with concentration is as[6]

$$(T)+0.111\frac{V_{eth}}{V_{tot}}$$

Where $n(T)$= refractive index of mixture, $n_{H2O}(T)$=refractive index of water

V_{eth}=volume of ethylene glycol & V_{tot}=total volume of mixture This also suggest linear variation further supporting the results shown in figure 5.

Conclusion

One crucial aspect of optical materials is their refractive index. In this work, alcohol-water mixes have been used to investigate the usage of fiber optic sensors for refractive index variation measurements. To alter the refractive index, two combinations are used: methanol-water and ethylene glycol-water. The results obtained are consistent with those published in the literature. The created sensor has a lot of potential. Appropriate mechanical design and circuit packing enable the created sensors to be applied in various domains, such as sugar factories, food industries, and chemical industries.

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