CINNAMON OIL AND ETHANOL BINARY LIQUID ENABLED CALIBRATION-DESIGN AND DEVELOPMENT OF FIBER OPTIC U-SHAPED GLASS PROBE EXTRINSIC REFRACTIVE   INDEX SENSOR

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Abstract: Opto electronic and fiber optic communication technologies have been integrated into advancements in optical fiber sensing technology. In this study, a novel sensing method has been developed, employing a U-shaped glass rod of specific dimensions as the core element of the sensor. The U-shaped glass rod, positioned between an input fiber connected to a light source and an output fiber linked to a power meter, serves as an extrinsic sensing element to detect transparent liquids based on their refractive index. Light emitted from a semiconductor laser source is transmitted through the input fiber with minimal loss. Upon reaching the U-shaped glass rod, the light is coupled into the first end of the rod, where it experiences significant attenuation due to the bend and absorption by the liquid surrounding the rod as it propagates. The remaining light is transmitted into the output fiber and directed towards the optical power detector. The different proportions of liquids,they are used as cladding for the U-shaped glass rod, so that refractive index of each proportion is measured at different proportions by Abbe's refractometer and the obtained values are noted

Keywords: U-shaped glass rod, chemicals, refractive index, optical fiber, sensor.

1.   Introduction.

Fiber optic sensors have been proposed for measuring both physical and chemical parameters, primarily because of their numerous advantages over traditional sensors. These advantages include immunity to electromagnetic and radio frequency interference, compact size, remote sensing capabilities, multiplexing abilities to gather data from multiple sensors within a single fiber, resistance to explosions, and cost-effectiveness. While there have been a few systematic studies on liquid refractive index measurements at varying temperatures using other techniques, fiber optic sensors are particularly advantageous in such applications. Accurate detection of small refractive index changes in small liquid volumes is critical, especially in fields like bio sensing.The need for refractive index sensors has grown significantly due to their wide applications in industries such as food quality control, pharmaceuticals, beverages, fragrances, petrochemicals, and medical and technical fields. However, there are relatively few methods in the literature for measuring liquid temperatures. Optical fibers are commonly used to transmit light in refractive index sensing experiments, but they are not typically used directly as refractive index sensors. Several studies have emphasized the importance of the cladding of optical fibers in these sensing applications.This paper

presents experimental findings on refractive index sensing using an inexpensive plastic-clad silica fiber that transmits light from one end to the other. The study explores the impact of solute light absorption and the chemical properties of the solute on refractive index measurements, particularly in terms of the power received at the sensor's output end.

2. Materials and methods.

Apparatus

1. Light source(Laser)
2. Optical power meter
3. Optical fiber (1m): plastic clad silica optical fibers
4. Connectors
5. Chemicals:Cinnamon oil and Ethanol
6. Burette system:A Couple of burette fixed to stands vertically
7. Abbe's refractometer
8. U-shaped glass rod
9. Sample holders
10. Beakers

This sensor functions as an extrinsic fiber optic refractive index sensor, where light travels from the input fiber to the output fiber via the U-shaped glass rod, acting as a light conductor. The setup includes a light source with a wavelength of 633 nm and an optical power meter. The fibers, made of plastic-clad silica (PCS), serve as input and output arms, each about 25 cm in length and with diameters ranging from 220 μm.

The U-shaped glass rod is solid and bent into shape, with light injected at one end via a PCS fiber coupled to a semiconductor laser diode. The glass rod dimensions vary from 0.28 mm to 0.5 mm in prong diameter, with lengths ranging between 4 cm to 6 cm. This setup was examined using a traveling microscope to ensure uniformity and proper bending. The light source is connected to the glass rod via an connector, while the other end of the rod is connected to the power meter, ensuring no light escapes at the joint.

The U-shaped glass rod is assembled and placed into the glass container containing the liquid mixture. This setup is positioned on a stable and rigid base, ensuring proper alignment between the light source and the detector. It's critical to isolate the components to maintain the integrity of the system. To prevent stray light from interfering, the glass rod and liquid mixture are shielded from external light. The entire system, including the power meter and liquid container, is connected to their respective components. A black covering helps minimize the exposure of the sensing element to ambient conditions, while a sample cork is used to stop air from entering the system.

3. Experimental Arrangement

Study of Cinnamon oil and ethanol by using U-shaped glass rod:

Shape of the glass sensor: U-shaped glass rod

Thickness of the glass rod:0.28mm

Height of the glass rod immersed in the liquid:2cm

Width of the U-shaped glass rod between the prongs:1.5cm

Depth of the curvature: 1.0cm

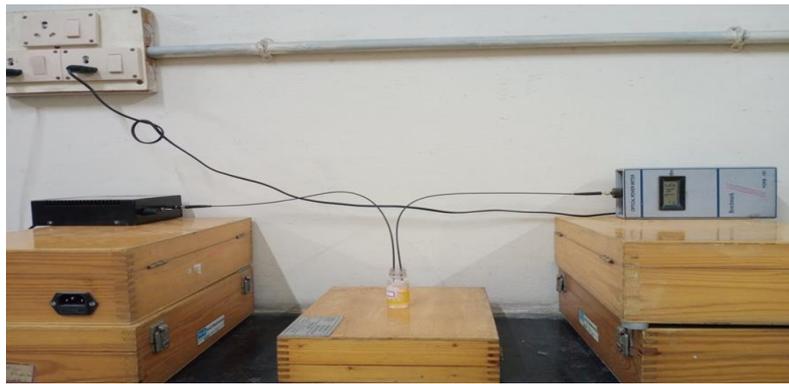Radius of the curvature:1.0cm

Diameter of the fiber:230/200

Fig:1 experimental arrangement

Fig:2 Abbe's refractometer

Fig: 3 Liquids of Different propotions (cinnamonoil+ethanol)

➤   A two-burette setup is employed to measure liquid mixtures, including various proportions of cinnamon oil and ethanol.

➤   An Abbe refractometer is used to measure the refractive indices of all the mixtures prepared through the burette system .

In this experiment, various liquid mixtures of ethanol and cinnamon oil were prepared, each with a total volume of 10 ml. For each mixture, 1 ml of ethanol was initially removed from the beaker, and 10 ml of cinnamon oil was added and mixed thoroughly. This process was repeated for different methanol-to-cinnamon oil ratios, including: (8 ml ethanol + 2 ml cinnamon oil), (7 ml + 3 ml), (6 ml + 4 ml), (5 ml + 5 ml), (4 ml + 6 ml), (3 ml + 7 ml), (2 ml + 8 ml), (1 ml + 9 ml), and (0 ml + 10 ml).The refractive index of each mixture was measured using an Abbe's refractometer, and the results were recorded in a table. Additionally, a U-shaped glass rod sensor was immersed in each container holding the corresponding mixture. After activating the power source, the sensor's output power was measured.A table was compiled to display both the refractive index and output power values for each mixture. A graph was then plotted with the output power on the y-axis and refractive index on the x-axis, illustrating the relationship between the two parameters.

Mole fraction:

Mole fraction is a way of expressing the concentration of a component in a mixture.It is defined as the number of moles of particular substance to the number of mole in the mixture.mole fraction is a dimensionless quantity and it is mainly used for the mixtures for gases also

$$\text{Mole fraction, } X= \frac{\text{Number of moles of component}}{\text{Total no of all components present In the solution}}$$

Let N_a moles of solute' a 'dissolved in N_b moles of a solvent 'b'.then the mole fractions of a and b are calculated as:

Total no of moles in the solution= $N_a + N_b$.

4. Results and discussion.

The below given are the results of the refractive index of the liquids which are mixed at different proportions.

| SL. NO.	Ethanol (C₂H₅OH) (ml)	Cinnamon oil (C₉H₈O) (ml)	Refractive index Trail - 1	R . I Trail - 2	R . I Trail - 3	Average (R.I)	Rounded Off (R.I)
1	10	0	1.341	1.341	1.342	1.3413	1.341
2	9	1	1.357	1.358	1.359	1.358	1.358
3	8	2	1.418	1.418	1.419	1.4183	1.418
4	7	3	1.430	1.432	1.441	1.4343	1.434
5	6	4	1.475	1.475	1.476	1.4763	1.476
6	5	5	1.504	1.505	1.506	1.5053	1.505
7	4	6	1.518	1.519	1.520	1.5193	1.519
8	3	7	1.548	1.549	1.550	1.5493	1.549
9	2	8	1.580	1.581	1.582	1.581	1.581
10	1	9	1.582	1.583	1.585	1.5833	1.583
11	0	10	1.611	1.613	1.615	1.613	1.613

TABLE – 1: Average R.I. values of Ethanol and cinnamon oil mixtures at various proportions The below given are the results of the mole fraction, power output of the binary liquid

Table:2

SL.NO	Ethanol (C$_2$H$_5$OH) or (C$_2$H$_6$O) (ml)	Cinnamon oil (C$_9$H$_8$O) (ml)	R.I. of mixture	Power output (dBm)	Mole fraction
1	10	0	1.335	-54.1	1
2	9	1	1.359	-55.4	0.9627
3	8	2	1.419	-56.6	0.9198
4	7	3	1.441	-57.2	0.8704
5	6	4	1.476	-58.9	0.8117
6	5	5	1.506	-59.1	0.7416
7	4	6	1.52	-60.3	0.6570
8	3	7	1.55	-61.1	0.5516
9	2	8	1.582	-62.5	0.4177
10	1	9	1.585	-64.4	0.2416
11	0	10	1.615	-66.6	0

Graph:1

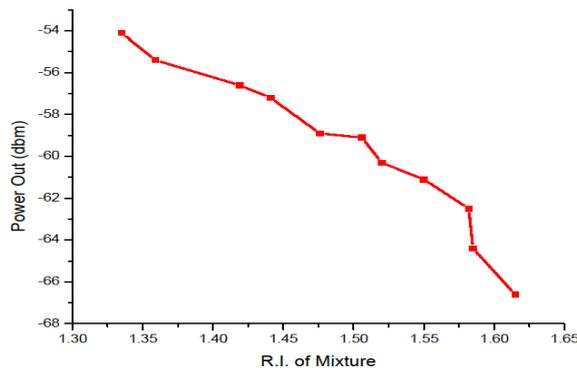Graph plotted between refractive index and mole fraction of the binary liquid
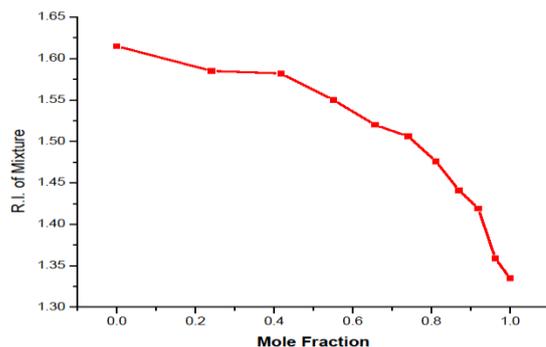
Graph:2

Graph plotted between mole fraction and power out
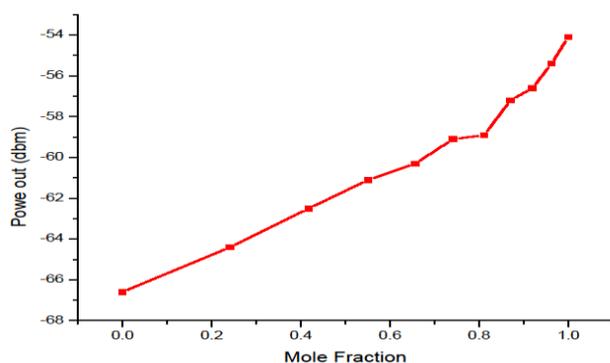
Graph:3

Graph plotted between refractive index and mole fraction.

Graph 1 displays the relationship between the mole fraction and the refractive index (R.I.) of the mixture. As the mole fraction increases from 0 to 1, the refractive index decreases from approximately 1.62 to about 1.35. This indicates a clear downward trend in refractive index as the mole fraction increases, showing an inverse relationship between these two variables.

Graph 2,Graph 3 illustrates the relationship between the refractive index (R.I.) of the mixture and the output power (in dBm). As the refractive index increases from approximately 1.30 to 1.60, there is a noticeable decrease in the output power. The power output starts near -54 dBm and gradually declines, reaching about -68 dBm at the highest refractive index value. This trend indicates an inverse relationship between the refractive index and the sensor's output power.

5. CONCLUSION

Although U-shaped glass fiber or rod fiber optic methods for refractive index measurement are quite common, the tapered fiber optic refractometer provides the highest possible sensitivity. This sensor also functions as a temperature sensor, capable of measuring various liquids at different temperatures. Consequently, the developed sensor serves as a versatile tool for measuring various parameters, even at different temperatures, when properly calibrated. Fiber optic sensors are generally advantageous compared to other conventional sensors because they are cost-effective, durable, immune to electromagnetic interference (EMI), and offer wide bandwidth. This makes them ideal for multiplexing multiple sensors in a single setup, enabling simultaneous measurement of different parameters, even remotely.

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