Investigation of a U–Shaped Glass Rod Chemical Sensor – Determination of Refractive Index of Transparent Liquids in the Dynamic Range 1.33n_D to 1.49n_D using Toluene and Methanol Mixtures

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ABSTRACT:

Optical fibers have become most popular in the recent fast due to their wide spread advantages in sensing various environmental parameters. For the determination of changes in the physical or chemical parameters an apparatus is required, which comprises of a sensing U- shaped glass rod surrounded by a relatively sensitive cladding, the absorption spectrum of which varies with chemical parameters when they are applied as a cladding and two transmissive optical fibers having core surrounded by relatively insensitive cladding for connecting one end to a light source and other to a light detector. The U-shaped glass rod core has the same diameter and refractive index as that of the core of the trasmissive fiber. Both the relatively insensitive and the relatively sensitive claddings are less than the refractive indices of the cores of both sensing U-shaped glass rod and transmissive optical fiber. The input transmissive optical fiber extends from the light source to the input end of the glass rod and the output transmissive fiber extends from output end of the U-shaped glass rod to the power detector. A relationship is absorbed between the light reaching at the detector and the Refractive Index of the chemical surrounding the U-shaped glass rod. Thus by selecting the mixtures of Toluene and methanol at different ratios, Refractive Indices of the mixtures and the corresponding output power are noted and calibration curve is drawn which can be used to determine varies transparent liquids in the dynamic range of 1.33n_D to 1.49n_D

Keywords: Dynamic Range, Methanol, Optical Fibers, Refractive Index, Sensitive Cladding, U-Shaped Glass Rod, Toluene.

I. INTRODUCTION

For a long time it has been known that the transmission properties an optical fiber are influenced by certain external perturbations and certain internal perturbations. It is as well possible to alter the transmission characteristics of the optical fiber when a chemical is surrounded by core at certain portion of the fiber, which acts as a sensing zone. Based on this an intensive worldwide activity has been picked up decades back. Some of the most important advantages offered by the optical fiber in comparison with other sensing system are 1) The transmitted signal inoptical fiber sensor is immune to electromagnetic interference (EMI) 2) It gives no spark or shock 3) It is easy to handle and portable 4) Cheap in cost and light in weight 5) It offers very low losses compared to other sensing system 6) It offers very high bandwidth (10^{15} Hz) 7) It can sense the parameters from otherwise inaccessible regions. 8) It can multiplexed to measure the various parameters at a time. 9) It also can be used to design various Optical Time Domain Reflectometry (OTDR) systems to measure the parameters at different locations at a time. Optical fiber sensors basically can be classified into two types i) Intrinsic optical sensor ii) Extrinsic optical fiber.

In intrinsic sensors the light modulation takes place within the fiber whereas in the extrinsic sensors the light modulation takes place outside the fiber. During modulation one of the parameters of the light gets changed and can be seen between input signal and output signal [1-5]. To enhance the sensitivity of a sensor the geometrical parameters of the core has to be changed in the form of a U-shape at the region of sensing, which will increase perturbation of the evanescent field [6]. This was reported by king et al [7]. The similar techniques which was used in the Optical Time Domain Reflectometry reported by Barnoski and Jensen in 1976 [8]. Optical fiber sensors for many applications used to rectify the difficulties arising from other parameters cross sensitivity [9].

II. EXPERIMENTAL DETAILS

The investigation of present sensor consists of a simple experimental setup consists of three basic components such as a light some of 630nm, a benchmark light detector and a sensing system consisting of a U-shaped connected with two PCS fibers of 200/230 nm diameters. The experimental setup is shown in below figure [1].

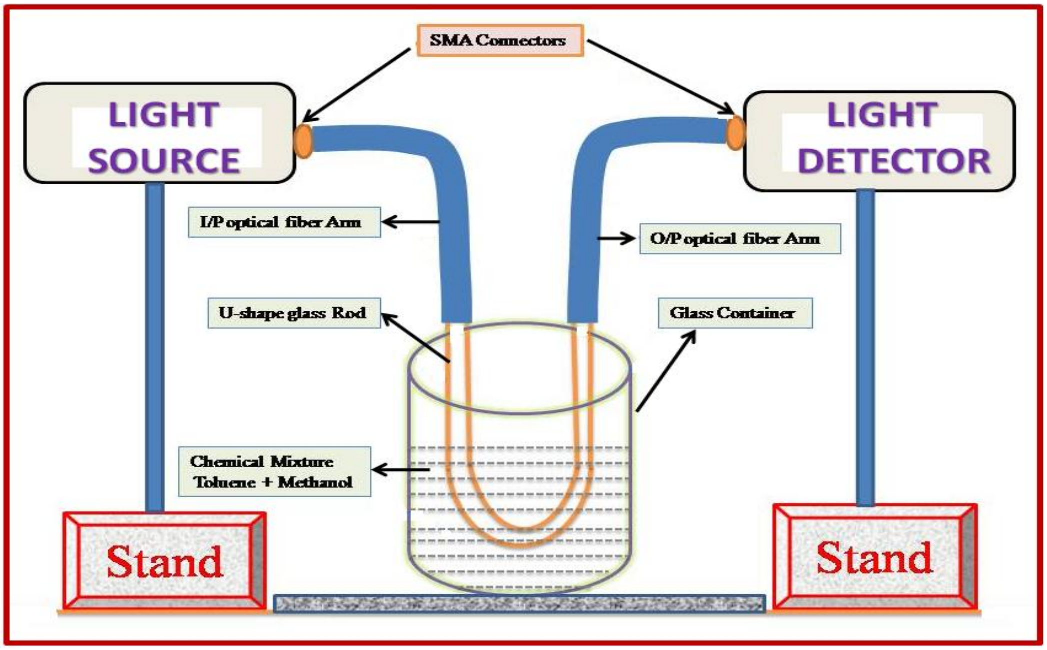


Fig.–1: Experimental arrangement of U–Shaped Glass Rod Chemical Sensor

Initially by using a two buret system chemical mixtures of toluene and methanol mixtures at different ratio are prepared and Refractive index of all the mixtures are determined by using Abb's refractometer. Each time the U-shaped glass rod is immersed into one of the chemical mixtures consisting of a specific ratio light is launching into the input fiber and the output light power is noted from the power detector. When light launched from the light source it couples to the input fiber and transmits through the non-sensitive part of the fiber, and then couples into the input end of the U-shaped glass rod. During the course of U-shaped glass rod a fraction of the light will be absorbed into chemical surrounding the U-shaped glass rod. The amount of the power that lost into the chemical depends upon the depth of penetration of light into liquid that inturn depends upon the chemical nature of liquid. This evanescence's of light into the liquid at the region of the sensing is studied at specific wavelength of 630nm and at room temperature.

III. RESULTS AND DISCUSSION

The experiment is carried out by selecting a binary mixture consisting of toluene (Refractive Index=1.33n_D) and methanol (Refractive Index= 1.49n_D). The ratios of mixtures selected in such a way that the total volume becomes equal to a constant (10ml), so that the range of Refractive Index lies between 1.33n_D to 1.49n_D covering whole range between methanol and toluene. Initially mixtures consist of specific ratio having a fixed Refractive Index is taken in a beaker into which the U-shaped glass is immersed. By launching light into the input fiber the output power is noted from the detector. This is repeated for all the mixtures and values are tabulated and the graph is plotted taking Refractive Index Vs output power figure [2].

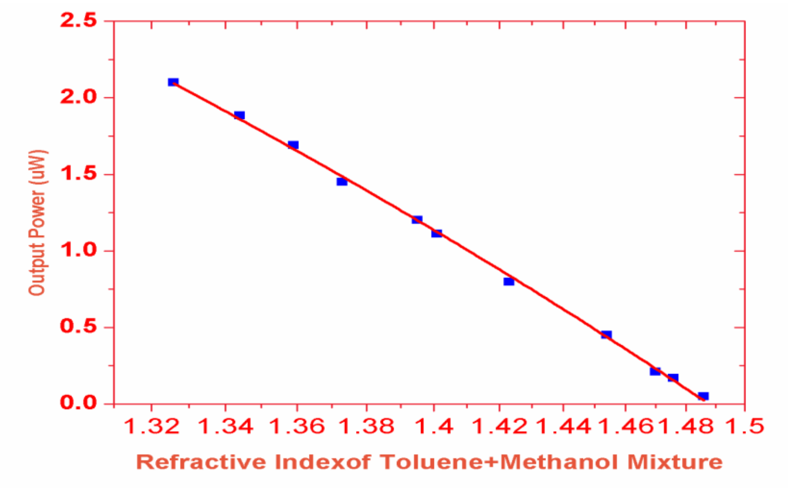


Fig.–2: Relation between Refractive Index Vs Output Power (μW) of Toluene + Methanol mixtures

The losses of light during its course of transmission from light source to detector were also recorded and corresponding graph between losses Vs Refractive Index was drawn in figure [3].

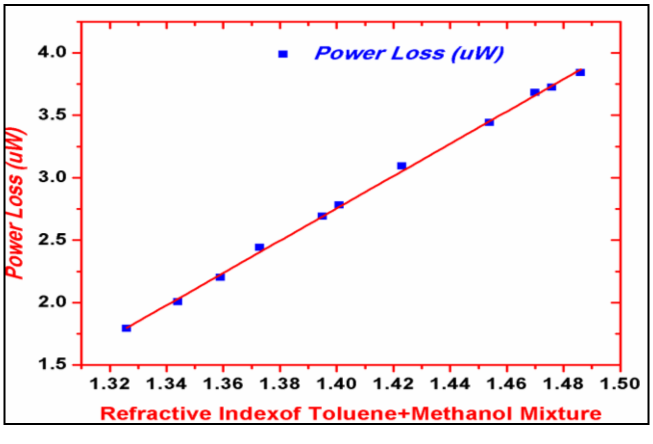
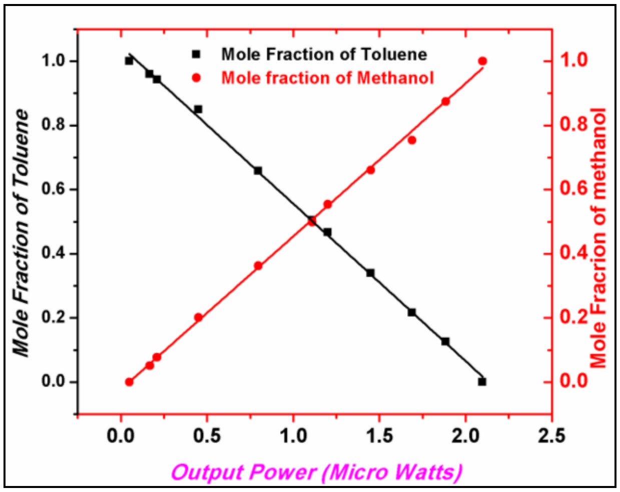


Fig.–3: Relation between Refractive Index Vs Power Loss (μW) of Toluene + Methanol mixtures

The mole fraction of methanol in toluene for all mixtures were calculated and the corresponding graphs is plotted in figure [4-7]



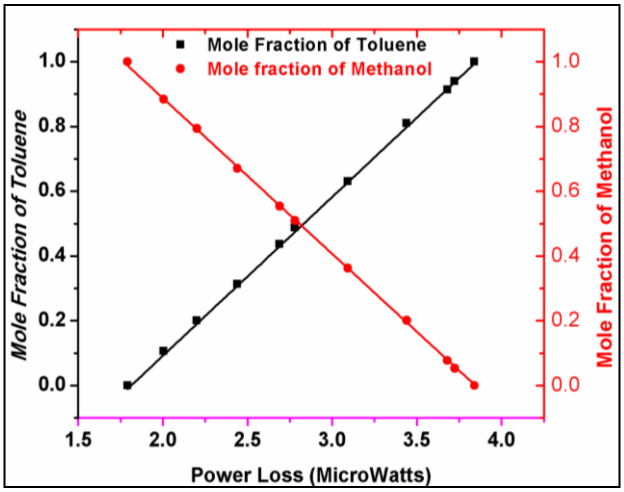
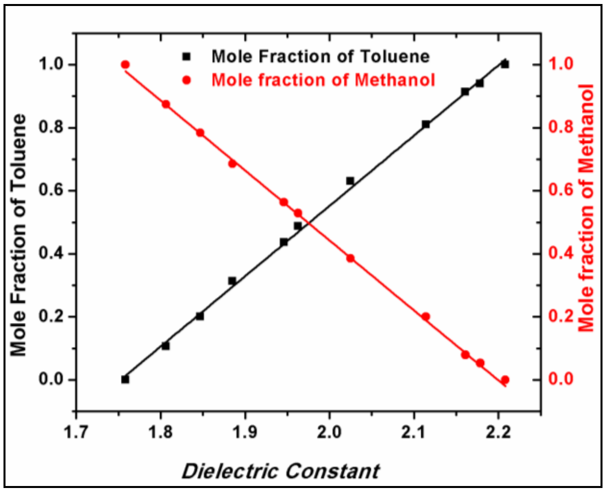


Fig.–4: Relation between Output Power (μW) Vs Molefraction of Toluene + Methanol mixtures

Fig.–5: Relation between Power Loss (μW) Vs Molefraction of Toluene + Methanol mixtures



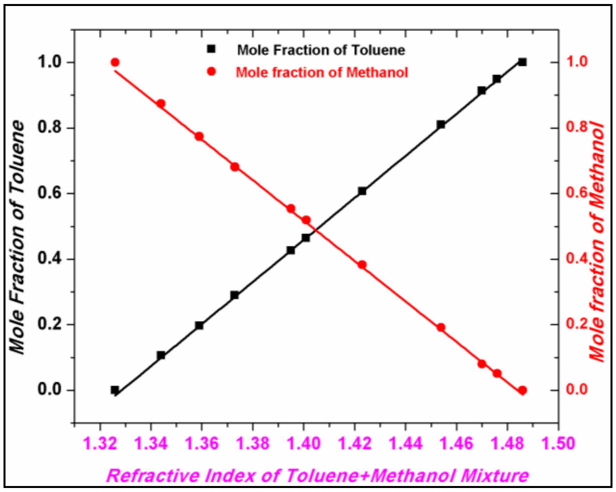


Fig.–6: Relation between Dielectric Constant Vs Molefraction of Toluene + Methanol mixtures

Fig.–7: Relation between Refractive Index Vs Molefraction of Toluene + Methanol mixtures

The relation between the macroscopic quantity of the mixture "n" (Refractive Index) and the macroscopic quantity of the mixture "ε" is $\varepsilon_r = n^2$. By relating the light transmission with respect the microscopic quantity ε_r gives the complete picture of the influence of the polarization on the light transmission. Thus the dielectric constant for all the mixture has been calculated and graphs are plotted in figures [8&9].

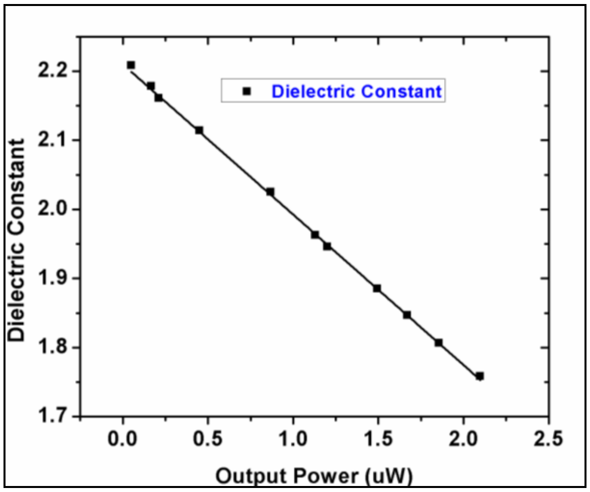


Fig.–8: Relation between Dielectric Constant Vs Output Power (μW) of Toluene + Methanol mixtures

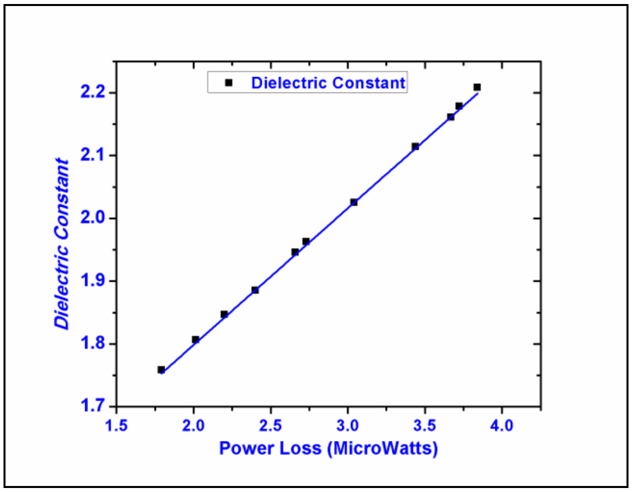


Fig.–9: Relation between Dielectric Constant Vs Power Loss (μW) of Toluene + Methanol mixtures

IV. CONCLUSION

For the study of the refractive index of transparent liquids whose dynamic range lies between $1.33n_D$ to $1.49n_D$ two chemical mixtures (Toluene and Methanol) are selected. To enhance the sensitivity of the sensor a U-bent glass rod element is used and by using this arrangement refractive index, out power, power losses, mole fraction, dielectric constant are studied. The variation of power with respect to Refractive index, mole fraction and dielectric constant variations are measured and are represented graphically. Therefore detect the this optical fiber sensor, which is easy to setup, offers values are more accurate measurement of parameters and cheap in cost cab be used to Refractive index of any unknown transparent liquids whose dynamic range lies between $1.33n_D$ to $1.49n_D$ at room temperature.

REFERENCES

[1] Prajapati, C. S. Limberkar, "Study of Concentration Dependent Physico–Chemical Properties of 1–Propanol, Benonitrile and their Binary Mixtures", International Journal of Advancement in Electronics and Computer Engineering (IJAECE), Vol. No.3, Issue No. 1 (April 2014), pp. 297–301.

[2] Lyons W. B., Lewis E., "Neural Network and Pattern Recognition Techniques Applied to Optical Fiber Sensors", Transactions of the Institute of Measurement and Control 22 (5), (2000), pp.385–404.

[3] A.K. Ghatak, B. Culshaw, V. Nagarajan and B.D. Khurana, "Trends in Fiber Optics and Optical Communications", Viva Books Pvt. Ltd., New Delhi (1995).

[4] Pal B P., 1991, "Fundamentals of Fiber Optics in Telecommunication and Sensor Systems", 1st edn. (Delhi: Wiley Eastern), pp.571–573.

[5] S.V.S. Prasad et al "Design and Analysis of a Liquid (Oil) Level Sensor using an Optical Fiber", J. Pure & Appl. Phy., Vol.17, Issue No.4, July–Aug., 2005.

[6] Gupta B. D., Ratnanjali, "A Novel Probe for a Fiber Optic Humidity Sensor", Sensors and Actuators B 80, (2001), pp.132–135.

[7] King D., Lyons W. B., Flanagan C., Lewis E., "Interpreting Complex Data From a Three–Sensor Multipoint Optical Fibre Ethanol Concentration Sensor System Using Artificial Neural Network Pattern Recognition", Measurement Science Technology 15(8), 2004, pp. 1560–1567.

[8] Barnoski M. K., Jensen S. N., "Fiber Waveguide: a Novel Technique for Investigating Attenuation Characteristics", Applied Optics 15 (9), (1976), pp.2112–2115.

[9] S. SRINIVASULU, DR. S. VENKATESWARA RAO, "Influence of Geometrical Parameters on the Transmission Characteristics of a U-Shaped Glass Probe: Determination of the Sensitivity of an Extrinsic Fiber Optic Refractometer", Journal of Emerging Technologies and Innovative Research (JETIR), Vol. No.5, Issue No.9, pp.341-346, September, 2018.