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Study on Polymer Coated Etched Optical Fiber for pH Sensing

P.V.N. Kishore[(1)], M.Sai Shanar[(1)], P. Vengal Rao[(1)], K. Yugender Goud[(2)] and G. Srinivasa Rao[(2)]
(1) Department of Physics, National Institute of Technology, Warangal, India.
(2) Department of Chemistry, National Institute of Technology, Warangal, India.
Author's corresponding e-mail : jidankishore@gmail.com

Abstract: A low cost optical fiber pH sensor has been proposed. The sensor is configured by coating a pH sensitive film of hydrogel synthesized by Poly (Vinyl Alcohol)/Poly (Acrylic Acid) blend coated on an etched single mode fiber. The pH response of the gel coated fiber is studied.
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1. Introduction

Unique features of optical fibers such as immunity to Electromagnetic interference, Light weight, remote sensing capability, short response time, low cost, resistivity to chemical corrosion, and so on, made them suitable for sensing applications [1]. Optical fiber sensor techniques mainly focused on measuring physical parameters such as temperature, pressure, Electric and Magnetic fields, acceleration etc. [2]. Moreover, the inertness of the optical fibers towards chemical species gaining an escalating attention towards fiber optic chemical sensors [3]. Fiber sensors that use Evanescent field techniques are well known as low cost intensity modulated sensors. The evanescent field of the fiber being absorbed or scattered by the surrounding environment due to change in refractive index, modulates the output intensity of the fiber. The interaction between evanescent field and surrounding chemical can be maximized by removing the cladding or etching the fiber by suitable techniques [4]. Determination of pH value of some chemical and bio species is very important in diverse fields like food processing, drug delivery, blood analysis, contaminated water treatment, environmental and bio medical fields and so on. Conventional pH sensors suffer from the draw back that they are too spacious to be used in *in vivo* applications. This problem has been addressed in literature using optical fibers as pH sensors [5]. The ability of hydrogel to change in volume in response to surrounding pH change makes them one of the best options to fabricate a pH sensor. They show drastic volume change in response to pH, light, Magnetic field, Electric field, Temperature and humidity [6,7] so on. The volume change of the gel leads to an alteration of refractive index [8] which can be utilized to modulate the output intensity of the optical fiber.

The present article reports a fiber optic pH sensor by combining the stimulus responsive property of the gel with the evanescent field of the optical fiber.

2. Preparation of the Hydrogel and Sensor head

2.1. Hydrogel Synthesis

A simple pH sensitive hydrogel synthesized by thermal crosslinking the blend of Poly vinyl alcohol (PVA) and poly acrylic acid (PAA). PVA weighing 5.3 mg is dissolved in 30ml of deionized water and heated to a temperature of 90°C for 7 hrs. Then the solution is cooled to room temperature and Poly acrylic acid (PAA) of concentration 25% measuring a volume of 7.07 ml is mixed with the PVA solution. The combination is stirred slowly for several hours until a uniform blend is obtained. The blend is left to cool to room temperature until a translucent gel phase is reached [9].

2.2. Preparation of Sensor head

An etched fiber is prepared by removing the buffer coating, a small length of approximately 3 mm on the Single mode fiber and immersed in 30% Hydrofluoric acid for 20 minutes at room temperature. The sensor head is prepared by dip coating method. The etched portion of the fiber is dipped for a fraction of minute and removed such that the gel fills the etched portion of the fiber as shown in fig.1.

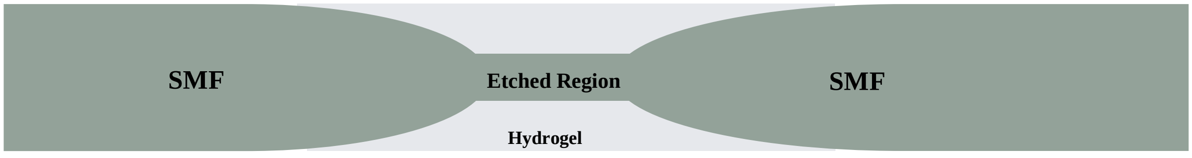

Fig.1. Hydrogel Coated etched single mode fiber

2.3. Sensing Principle

To maintain the charge neutrality, Hydrogels exchange their counterions with the surrounding adequate ions. This exchange of ions affects the osmotic pressure balance of the gel and the surrounding solvent to cause a swelling of the gel. When surrounding ionic concentration is low the exchange of ions is marginal. Increasing pH is nothing but increase of ion concentration of the surrounding medium of the gel. It leads to an exchange of counterions thereby increase of osmotic pressure inside the hydrogel. This pressure increment causes a swelling of the gel. When ionization is stabilized the swelling of gel will be stopped. More addition of ions or increase of pH only increases the ionic strength but not any further swelling which leads to a decrease of osmotic pressure, results deswelling of the gel [10, 11]. When the hydrogel coated on the etched fiber swells, its refractive index decreases which in turn increases the output intensity of the fiber. Similarly, when hydrogel deswell, surrounding refractive index increases causing a decrease in the output light intensity.

3. Experiment

The schematic of the experimental set up is shown in figure 2. The Hydrogel coated etched SM fiber is fitted in a small plastic container in such way that the sensing head is completely dipped in the pH solution. The plastic container is provided with inlet and outlet. The out let is fitted with a pump arrangement so the buffer can be introduced from the inlet and removed from the out let. Light from a Broad band source (peak wavelength at 1525-1565nm) is transmitted through the fiber. The output intensity is measured using a Power meter (Thorlabs PE320E Power and Energy meter) which is connected to a PC.

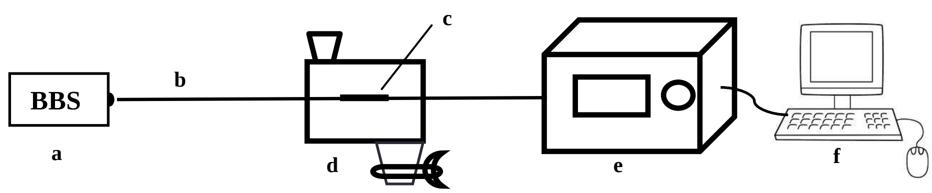

Fig.2 Schematic of the experimental set up.(a) Broad Band light source (b) Single mode fiber (c) Sensor head (d) Plastic container (e) Power Meter (f) PC.

4. Results and Discussions

To study the sensor response against to pH changes, various buffer solutions from pH 2 to pH 10 are introduced into the container in increasing order. The sensor head is allowed to settle in each buffer for fifteen minutes. The intensity modulated signals for each buffer are recorded into the PC. Figure 3.a. illustrates change in intensity against change in pH value in time scale. An abrupt increase in output intensity in response to pH values from 2 to 8 is observed. Further a decrease in light intensity is observed at higher pH values. The data shows a linear response up to pH 8 as shown in fig. 3.b. Such a pH response of the sensor is clearly justified by swelling response of the gel in various pH media [10].

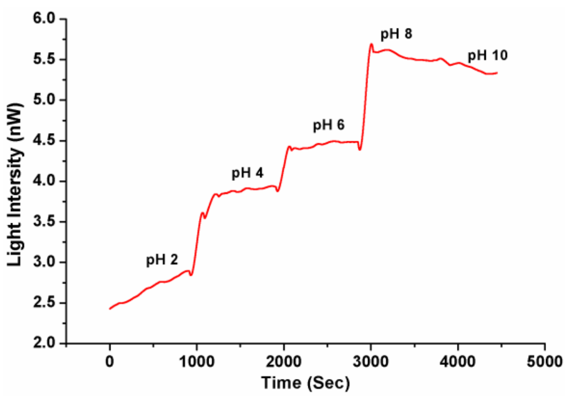

Fig.3.a. Response of the Sensor as a function of pH in time scale

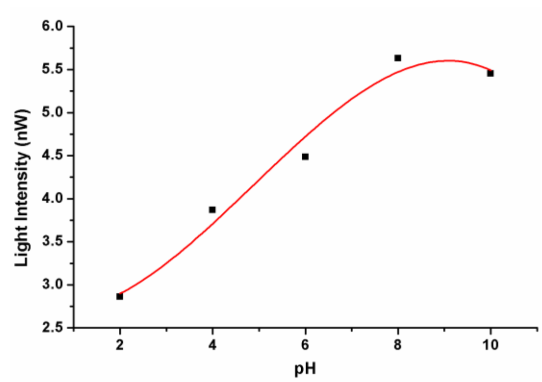

Fig.3.b. Output intensity of the sensor as a function of pH

5. Conclusions

A cost effective polymer coated etched optical fiber based pH sensor was successfully demonstrated. The pH responsive swelling and deswelling nature of hydrogel is utilized for sensing mechanism. The sensor response against the pH buffer solutions in the window of pH 2 to pH 10 was studied. The sensor has shown a linear response from pH 2 to pH 8 and a decrement for higher pH solutions. The sensor may be utilized in various chemical and bio sensing applications.

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