RESEARCH ARTICLE

Synthesis and Analysis of Planar Optical Waveguides as pH Sensors

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Abstract: Objective and Method: In this paper, dye is used as pH sensors. We here report the study of the effect of pH solutions on Methyl red doped polystyrene and Bromocresol Purple doped Styrene acrylonitrile waveguides. The effect of pH solutions was observed on the absorption spectra and output intensity of the waveguides.

Conclusion: It was observed that for pH solutions to which the dye is sensitive, output intensity decreased and it was clearly seen in absorption spectra too. Methyl red doped polystyrene waveguides showed sensitivity for pH range 5-6 and Bromocresol purple doped Styrene acrylonitrile waveguides showed sensitivity for pH range 5-9. These dye-doped polymer waveguides can be used as pH sensors.

Keywords: Polymer, pH sensor, waveguides, UV vis Spectroscopy, LEDs, modulators.

1. INTRODUCTION

The polymers have come a long way and are now extensively used in various photonic devices such as optical switches, modulators, LEDs, sensors etc. Various kinds of sensors have been fabricated like gas sensors, biosensors, chemical sensors and pH sensors [1-6].

pH sensors are very useful for monitoring boiler, water or turbid, fouling environments. They can also be used to monitor deterioration in civil infrastructure materials as this involves the chemical reactions, which cause degradation of the physical properties of the materials [1, 5].

There are a lot of studies available on pH sensors devices and have shown promises in optical, chemical and biological applications such as chemical processes and many reactions are pH dependent, environmental monitoring, blood pH measurements, laboratory, clinics and industries pH measurements etc. The pH of any fluid is one of the important parameters for analyzing the device performance. Devices designed to measure the pH levels in any reaction need to have a higher sensitivity and to be more reliable than standard pH sensors. Polymers are considered as a base material for developing varieties of pH sensors. Just by introducing the functional groups in polymer, one can tune its physical and chemical properties such as mechanical strength, swelling and shrinking behavior that can be used for determining the analytical concentration of matter. Electrical and
ion-exchange properties of conducting polymers are the topic of interest for developing chemical sensors [7]. Conducting polymers are one of the classes of polymers that are generally used for sensor applications because they exhibit high conductivity and also show electroactivity. Whereas insulating polymers usually have a highly selective response and a high impedance, which is important for eliminating interference by other electroactive species [8]. There are several reports on insulating polymers doped with dyes or indicators to sense changes in the pH because of their pH-sensitive properties. When a light wave interferes with a particle or molecule, it either gets scattered or absorbed. When the energy of the photon corresponds to the difference between the energy levels in that molecule, absorption occurs. The molecule which absorbs the light is called chromophore. Most of the dyes are pH sensitive chromophores [5].

We report here a planar dye-doped pH sensor. We fabricated dye-doped planar waveguides and have studied the effect of different pH solutions on the output intensity and absorption spectra of the waveguides. Two dyes, Methyl red and Bromocresol Purple were used for doping. Methyl Red dye was doped in polystyrene (chlorobenzene solvent) solution and Bromocresol purple dye was doped in styrene acrylonitrile (dioxane solvent) solution. These dye doped waveguides can be used as pH sensors in various applications such as boilers, monitoring deterioration in civil infrastructures etc.

2. EXPERIMENTAL DETAILS

The planar waveguides were fabricated using Methyl red (C15H15N3O2) with molecular weight 269.30 g. mol⁻¹ doped in polystyrene (C8H8)n with high molecular weight and Bromocresol Purple (C21H16Br2O5S) with molecular weight 540.22 g. mol⁻¹ doped in Styrene acrylonitrile ((C8H8)n(C3H3N)m) with high molecular weight. Dip coating technique is used for the preparation of samples. Polystyrene was dissolved in chlorobenzene (10% wt/vol) and the concentration of methyl red was kept to 0.3 % in the solution. Styrene acrylonitrile was dissolved in dioxane (10% wt/vol) and Bromocresol purple concentration was kept to be 0.03 % in the solution. The waveguides were fabricated using dip coating technique [9, 10].

The characterization of the waveguides was done using prism coupling technique [11]. The light source used was a He–Ne laser (0.6328 μm). He–Ne laser (0.6328 μm) light was coupled into these guides by input coupling prism (SF-16). The output coupling prism was kept at a distance of 1 cm from input coupling prism. The output intensity is measured using the photodetector. The pH solution was applied on the surface with the help of a soft brush and then the output intensity was again measured.

3. RESULTS AND DISCUSSION

We prepared Methyl red doped polystyrene waveguides. We also prepared Bromocresol Purple doped Styrene acrylonitrile waveguides. A detailed study on these waveguides has also been conducted [9, 10]. Fig. (1) shows the chemical structure of the dye and the polymer used in the preparation of the sample.

![Chemical Structures](image)

Fig. (1). Shows the chemical structure of the dye molecule methyl red, Bromocresol purple polymers Polystyrene and Styrene acrylonitrile.

3.1. Methyl Red Dye

The polystyrene solution was prepared using chlorobenzene as a solvent and the concentration of the solution was 10% wt/vol. Methyl red concentration was 0.3% in the solution. The output power was measured using prism coupling method using large area photodetector.
Fig. (2a). Plot between output intensity% and pH value for Methyl Red doped polystyrene waveguides.

Fig. (2b). Plot between output intensity% and pH value for Bromocresol purple doped Styrene acrylonitrile waveguides.

Fig. (3a). Absorption Spectra for Methyl Red doped Polystyrene waveguides.

We applied different pH solutions on the waveguide and we immediately observed the change in output intensity for some pH solutions and for some pH solutions, there was no change in the output intensity. The output intensity changed for pH 5 and pH 6 solutions showing that the dye is sensitive for that pH range. Fig. 2(a) shows the plot between output intensity and pH range.

3.2. Bromocresol Purple Dye

The SAN solution was prepared using dioxane as a solvent and the concentration was kept 10% wt/vol of the solution. The solution was doped with bromocresol purple and the concentration of dye was 0.03 % wt/vol in the solution. The waveguides were characterized using the method described above. The output intensity vs. pH change is shown in Fig. 2(b) and it can be seen from the figure that for certain pH solutions for which the dye is sensitive, the output intensity changes. Bromocresol Purple doped waveguides show the change in output intensity in the pH range 5-9.

3.3. Absorption Spectra

The absorption spectrum of both dyes for different pH solutions was observed. The spectra
were taken of the solution by adding different pH solutions; pH solutions for which the dye is sensitive, an immediate colour change was observed in the dye doped polymer solution. Figure 3(a) shows absorption spectra of the Methyl red doped polystyrene solution for pH 3.8, 5 and 6 solutions. Fig. 3(b) shows absorption spectra of Bromocresol Purple doped Styrene acrylonitrile solution for pH range 5 to 9. From the figures, it is clear that for pH ranges for which the dye is sensitive, the light is absorbed.

CONCLUSION

The effect of pH solutions on the absorption spectra and output intensity was observed on Methyl red doped polystyrene and Bromocresol purple doped Styrene acrylonitrile waveguides. It was observed that Methyl red doped waveguide showed sensitivity to pH solutions in the range of 5-6. Bromocresol purple doped Styrene acrylonitrile waveguides showed sensitivity in the pH range of 5-9. These dye doped waveguides can be used as pH sensors in various applications such as measuring pH, and monitoring deterioration of civil infrastructure materials in boilers. Other dyes which are sensitive to pH ranges, other than that of Methyl Red and Bromocresol Purple, can be used collectively to cover a wide range of pH for detection.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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