The Fabrication Of Light Sensors Using Chemical Solution

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Abstract

The fabrication and development the optical fiber sensor has been developed for pH measurement which based on evanescent wave absorption is presented .In order to desired performance, the middle portion of plastic optical fiber is unclad and worked as sensing element. The sensitive film is prepared by mixture the (bromophenol blue and cresol red) and (TEOS) which used as fundamental liquid to make the pure silica thin film. Also we added polyethylene glycol (PEG) to solution that deposited on the surface of unclad portion optical fiber using sol-gel technology. The sol-gel coated the unclad optical fiber is dipped into

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various pH solutions from pH2 to pH12. in this device pH sensing based on the change colour pH indicator .when the light travel thought the solution and outgoing colour light would analysed by spectrometer. The change in colour of dye induces a change in the optical spectrum of the outgoing light collected by optical fiber. The intensity of each spectrum change with different pH value and we calculate the area for peak one and two to determine the change in transmitted light.

***Keywords**: Fabrication; pH; the Sensor; optical fiber; Sol-Gel.*

1. Introduction

The optical fiber has become a revolution over the two last decades, since it has many characteristics that allow it to use in variety fields of science and technology, for instance in the monitoring many processes in industrial production and medicine which require both physical and chemical measurement [1] . The optical fibers were resolved to be very important waveguides, have been changed into sensors by small induced perturbation of their structure. The fabrication of optical fiber pH sensor based on the immobilization pH sensitive onto the sides of silica- cored optical fiber by the sol-gel technology. We can easily determine the pH value by using these sensors instead of other routinely performed measurements of pH that suffer from some limitation ,such as the lack of accuracy measuring extreme pH value[2] **.**

The sol-gel processes offers the right way to the reparation of porous glass substrates in which pH sensitive dye can easily entrapped .This way allows the creation of Si-O-Si linkages between the silica of sore optical fiber and silica porous matrix of sensitive element. We mix the organic - inorganic matrices obtained by sol-gel process, doped with pH sensitive dye to be coated on plastic optical fiber .the organic matrix has many roles(i) it is needed to obtain good connection between the plastic core of the optical fiber and the whole sensitive element; (ii) its presence allows to tune the kinetic of response of the sensor by influencing the diffusion rate of the analyze inside the porous matrix and its interaction with the indicator; (iii) its nature of organic compound allows better physical and chemical interactions with the organic pH indicator dispersed in the hybrid matrix[3-4].

1.1.Optical Fiber

The most critical factor that has made the optical fiber communication possible is the development of low- cost silica fibers. Since the optical fiber lightness and small size and its ability to carry a lot of information that made it the main tools in many applications .typically ,the fiber optical can make out of glass or plastic because it is easy to make them long and thin. Also both glass and plastic are transparent at particular waveguide [5].

The construction of fiber optical is core with high refractive index surrounding by layer of cladding with low refractive index. The core of optical fiber used to transmit the light, while the cladding prevented the light from leaking out of the core by reflecting light within the boundaries of the core[5]. Since the cladding has lower refractive index (with respect to the core) causes the light to be back into the core and we can know the constriction of this device as shown in figure (1).

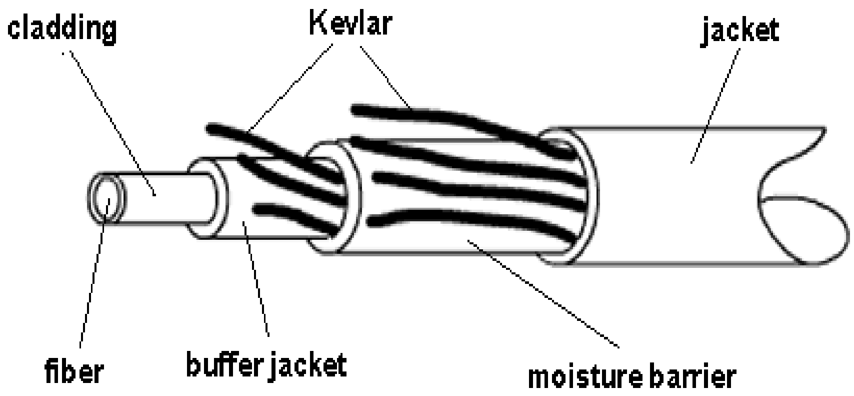


Figure 1. Optical Fiber

One of these studied was done in, Indian Institute of Technology in 1997 [1], where the optical fiber pH sensor based on evanescent wave absorption .A small length of the cladding removed from middle to get the probe that coated by thin porous of glass using sol gel technique[1] **.**

Theory of this work based on the optical fiber using the evanescent wave absorption ,when the light lunched into fiber the absorption of evanescent field by penetrating into unclad area. To determine the concentration of fluid by change of transmitted power at other end of fiber. Where the light interacts with **(**H +ions) through the dye immobilization on the surface[1-2]**.**

1.2. Characterization Of pH Chemical Sensor

Fiber optical chemical sensor can offer many benefits than traditional sensor, which can be defined as the device that convert the chemical sate into electrical signal. Since the fiber optical sensor made from glass so environmentally can tolerance the temperature, vibration, shock and can be operated in stringy condition. The sensor consists of three main parts the light source, opt rode and detector. The most important part of this device is protruding that contains the indicator that changes its optical properties in dependence of analyst. The indicator can change for example absorbance or fluorescence[3-6] . The light source matched to analytical wavelength of the indicator. The detector usually photodiode or PMT, converts the optical signal to electrical signal which is electrically processed. The principle operated of optical fiber pH chemical sensor based on absorbance is that when the pulse of light from light source coupled into optical fiber and transmitted to sensitive area .the sensitive area changes its absorbance dependence on pH of solution[3-6]. The absorbance is slightly low and the light is little absorbed .when the pH of solution change then the absorbance increase and the returning pulse of light is smaller[5].

The signal converted in optical fiber sensor in many steps. The chemical signal caused by analyst is converted into optical one by chemo optical interface which consist the veneer and appreciated indicator that change its properties dependence on analyst[5].

2. MATERIALS AND METHODS

2.1.Early Preparation

The early preparation is a required before we start this experimental. The important thing in this preparation is prepare the sol-gel solution. Then the optical fiber is dipped coated manually in the sol-gel solution . Before the coating step, the optical fiber has to unclad the fiber in different length 1cm, 2cm, and 3cm.After coating step is done, the unclad optical fiber is dried in laboratory. After that the unclad optical fiber is immersed in the different PH solution.

2.2.Preparation of Sol-Gel

To prepare the coating solution, 0.6*gm* of polyethylene glycol (PEG) was added to 60ml of TEOS and 60ml of absolute ethanol in 250ml containing flasks and the solution was stirred continuously using magnetic stirrer shown in figure a.. Wait until all the PEG has dissolved. After that, 4ml of deionised water was added into the solution followed by 92*mg* of cresol red and 164*mg* of bromophenol blue. All of this substance was mixed at room temperature and atmosphere pressure. After mixing process, the solution was stirred using magnetic stirrer for 60 minutes at room temperature as shown in figure.2.(b)

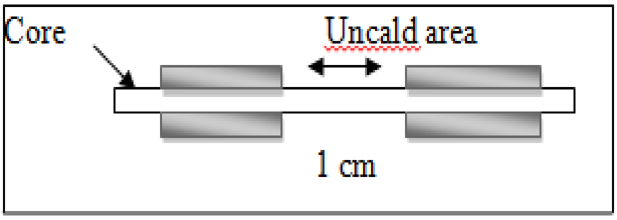
(a)

(b)

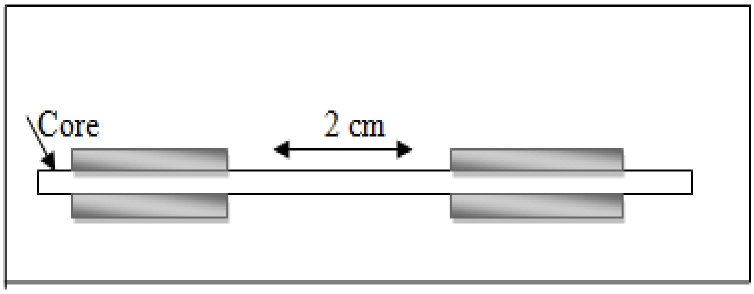
Figure.2. Magnetic Stirrer

2.3. Preparation of Uncladding Optical Fiber

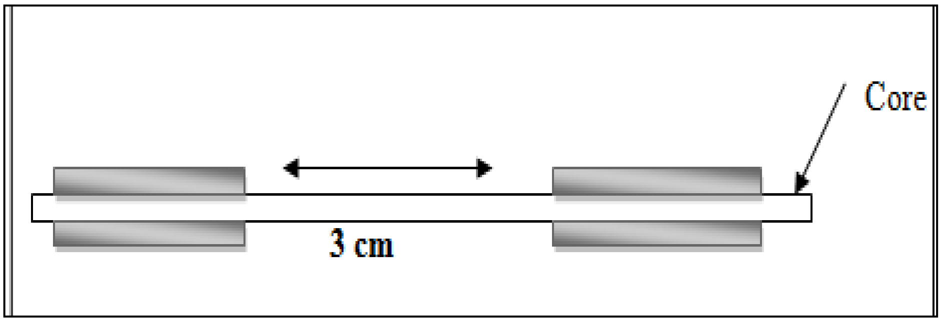
The plastic optical fibers were cut using fiber optical cutter. We use 15cm length of optical fiber. A4 cm portion was unclad at the end of optical fiber, which use as output light detector. While the center area were 1 cm, 2cm and 3 cm that used as sensor area as shown in figure 3.(a),(b) and (c) . We prepare 6 optical fibers for each length of center area. We have to be careful when cut because it’s to broken **.**



(a)



(b)



(c)

Figure 3. (a), (b) and (c): The Unclad Area Lengths

2.4. Sol-gel Coating Process on the Surface of Unclad Optical Fiber

First, a desirable amount of sol-gel solution was poured into a suitable container. We use the beaker for this process we enter the unclad optical fiber in beaker and put sol-gel solution in beaker and left 1 minute before it was slowly move out from the solution again at a constant speed. The thin film coating on unclad optical fiber was left to dry in the air at room temperature and atmosphere pressure for a few minutes before next coating applied. In this work some steps repeats many times to get the desired layers of thin film coating with suitable thickness **.**The coating unclad optical fibers were then left to dry at room temperature and atmosphere pressure for 3 days. We apply this step on all six optical fibers that we prepared in previous step**.**

3. Experimental Set Up

3.1.Preparation of pH Solution

It is important to prepare these pH solutions from pH2 to pH 12 to study the relationship between them and the behavior of light when the sol-gel doped on unclad area. These preparations were done in the material physical laboratory as shown in figure (4) . Acid and base is compound of acid acetic**)** CH3COOH **(**and sodium hydroxide (NaOH) .we put the acid acetic solution into 600 ml beaker, then the pH meter rod was put into the beaker and at the same time slowly adds the sodium hydroxide until the pH screen display the exact pH value, the figure.(5), shows the preparation of pH**.**

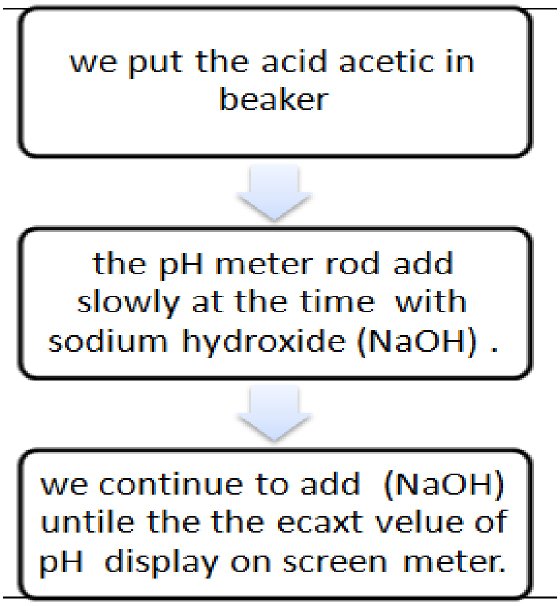


Figure 4. The Steps of Preparation of pH Solution

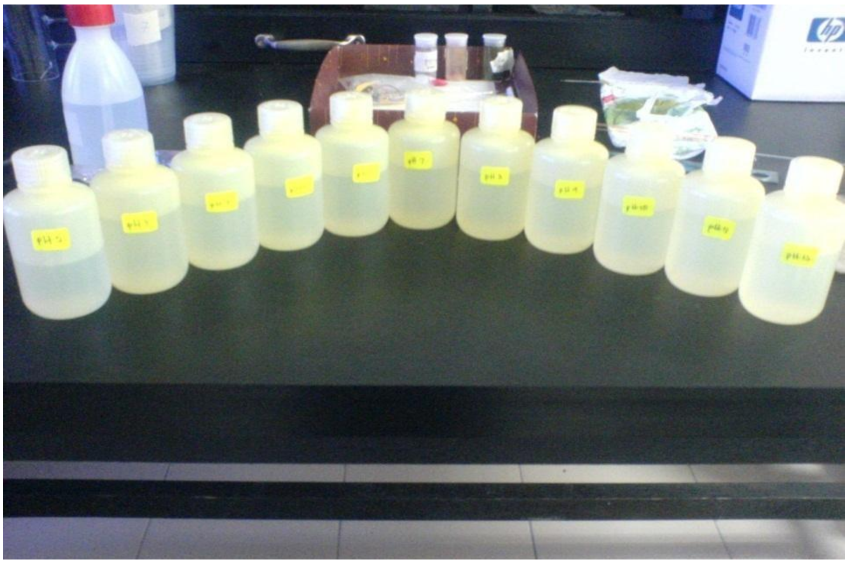


Figure 5. The Steps of Preparation of pH Solution

3.2.Preparation of Test Bed for Sensor

This includes the designing of beaker which was prepared in chemical lab. It must suitable with the dimensions of fiber and the amount of pH solution as show in figure. The length of beaker is 5cm and width is about 4 cm and the width of tube is 2.5cm to be suitable for fiber**.**

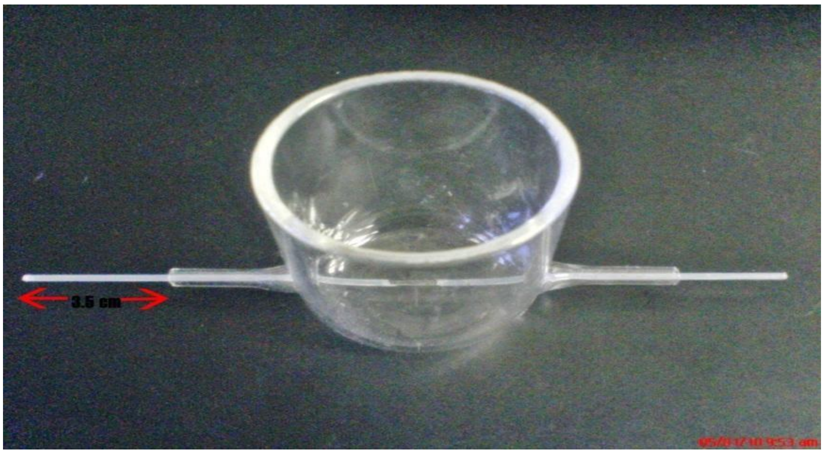


Figure 6. the designing of beaker which was prepared in chemical lab

4. RESULTS AND DISCUSSION

4.1.The Spectrum of Response of the Sensor

For the visible test .the pH indicator doped silica sol-gel film is tested with a with light source and USB2000 spectrometer to analyze spectrum which produced by each optical fiber that has been immersed into different pH solutions. Figure intensity versus wavelength that has been display on the computer screen is printed out. First we have to consider which length of doped area is suitable for our work. For the different length of doped area, the result was **:**

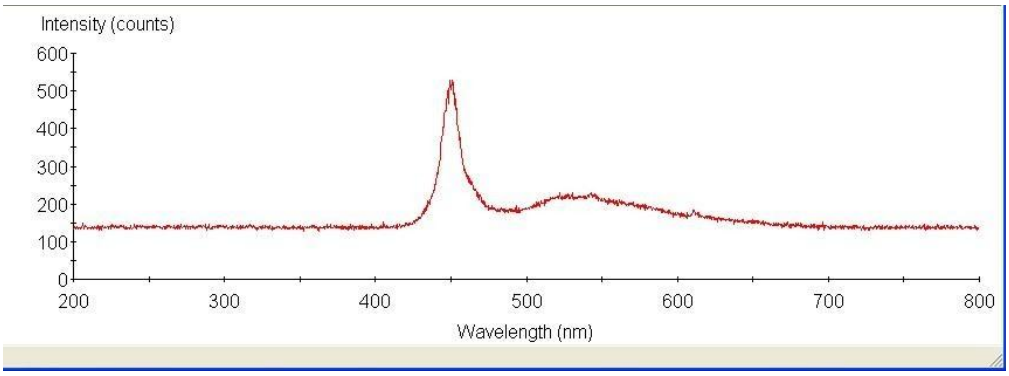


Figure 7. Peak Ratios 1cm

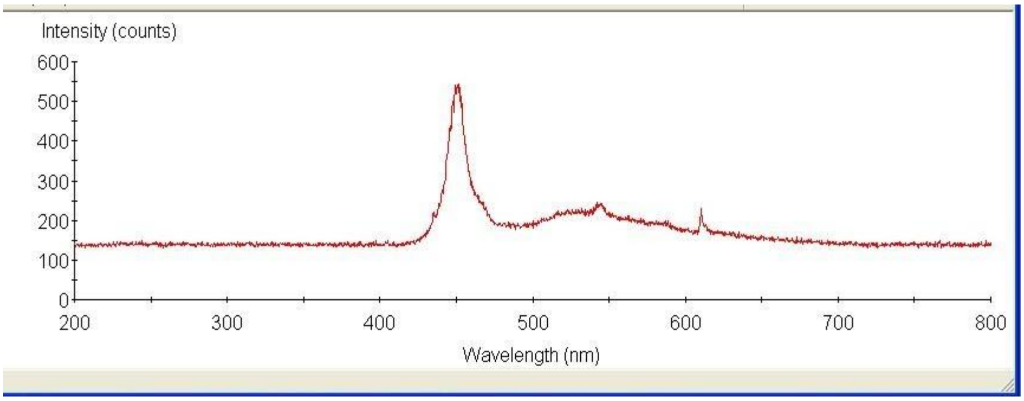


Figure 8. Peak Ratio for 2cm

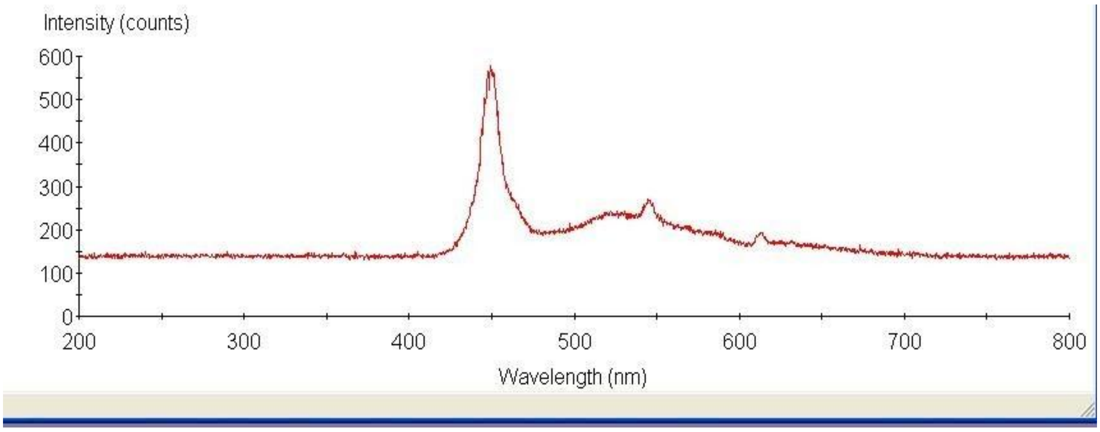


Figure 9. Peak Ratios for 3cm

Table.1. Peak Ratio for Different Length of Doped Area

Length of unclad area cm	Peak1 (count)	Peak2 ((count	Peak 3 (count)	Ratio of peak 1/peak2	Ratio of peak 2/peak3	Ratio of peak 2/peak3
1.0	510	210	190	2.428	1.105	2.684
2.0	510	240	200	2.125	1.2	2.125
3.0	560	260	200	2.153	1.3	2.8

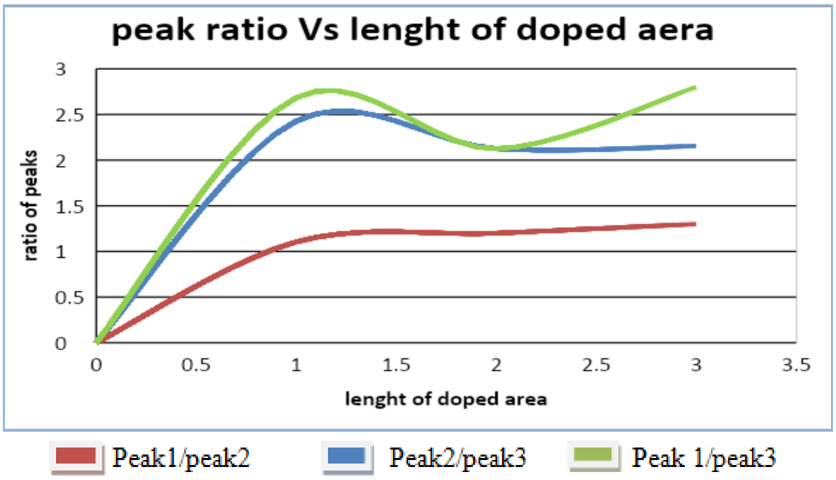


Figure 10. peak ratio Vs length of doped area

The figure shows that, the peak ratio Vs length of doped area .the highest peaks is for 3cm which is 560nm. Since there is clearly change at peak 1/peak3 and high value when the length 3cm was applied in this work than 1cm and 2cm. So the 3cm length of uncladding are was suitable in this work. Therefore, the next experimental work was applied on 3cm length **.**

4.2.Calibration of Relationship between Intensity and pH

Table below shows the relationship between intensity and pH for peak 1, peak 2 and peak 3**.**

Table 2. List of pH and Intensity of Peak 1, Peak 2 and Peak 3

pH	Intensity peak 1	intensity peak2	Intensity peak3
2	450.0	290.0	200.0
3	460.0	250.0	190.0
4	500.0	300.0	210.0
5	440.0	240.0	200.0
6	610.0	310.0	240.0
7	350.0	240.0	190.0
8	500.0	290.0	210.0
9	520.0	230.0	190.7
10	600.10	290.0	210.0
11	550	290.0	210.0
12	490.0	250.0	200

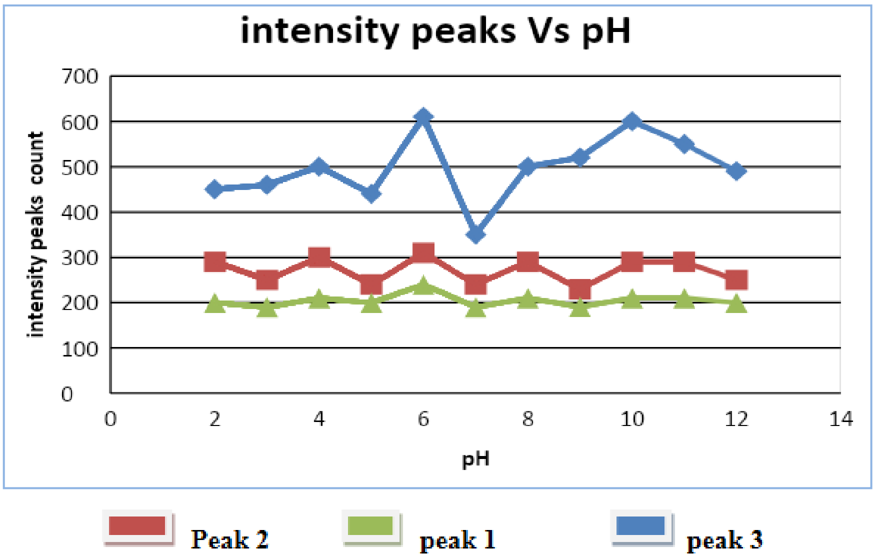


Figure 11. Intensity Peaks Versus pH

The figure shows the relationship between the pH and intensity for peak 1, peak2 and peak 3. the maximum intensity happened at pH6 while the reading is 610 for peak 1. For peak 2, the maximum intensity at pH6 that has reading 310.0 and the minimum intensity at pH7, for peak 1 at

190. Therefore we can consider that, the intensity of all peaks change with change pH value.

Determined of Intensity Ratio for Three Peaks

In our work, we try to see if the ratio of these intensities is accurate to determine the change in transmitted the light and measurement pH . The table below shows the ratio value for wavelength.

Table 3. Ratio of Intensity for Three Peaks

pH	Ratio of peak 1/peak2	Ratio of peak 2/peak3	Ratio of peak 1/peak3
2	1.55	1.45	2.25
3	1.84	1.31	2.41
4	1.66	1.43	2.38
5	1.83	1.2	2.2
6	1.69	1.29	2.54
7	1.45	1.26	1.84
8	1.72	1.38	2.38
9	2.26	1.2	2.726
10	2.06	1.38	2.85
11	1.89	1.38	2.62
12	1.96	1.25	2.45

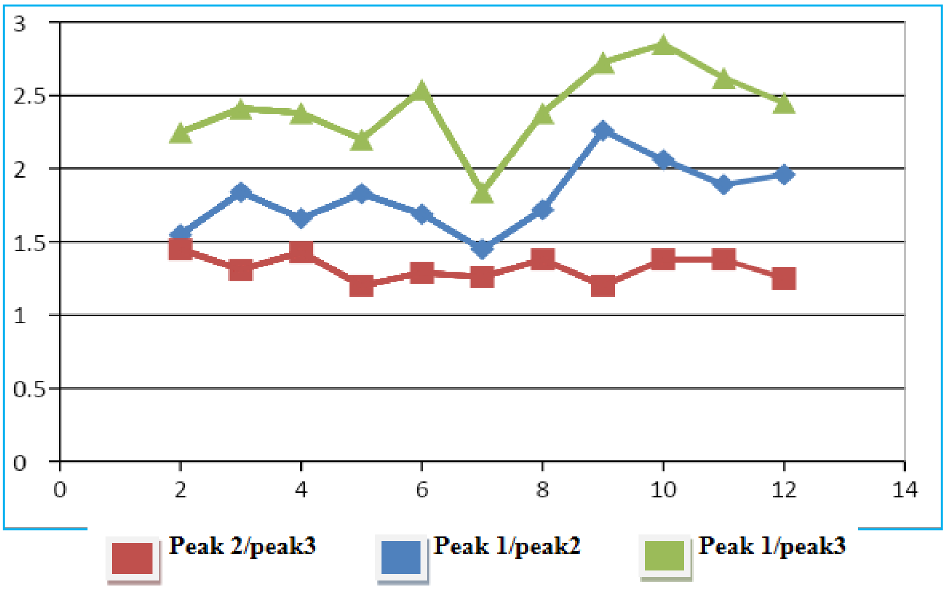


Figure 12. ratio intensity versus pH

We can deduce from the figure (12) that, the ratio of intensity with pH is not strong enough to allow us to know pH value, there slightly change for ratio peak2/peak3 with different pH value. Moreover, there is clearly change for others ratio before and after pH7 but this method seem to be not more accurate to consider pH value maybe due to misalignment of the light source. We have to find out other method to determine the change of transmitted light. We know from previous thesis which was done on sol-gel film preparation and analysis for determination the pH value which was observe the change in color ,the color glass change from pink to orange and yellow was for acidic environment (pH 2 to pH6) and the change of glass slide from green to blue was or base environment (pH8 to pH12) . In this work, the determination of area for peak 1 and peak 2 is seemed to be more suitable to determine the absorption of light for peak 1 and reflected light for peak 2

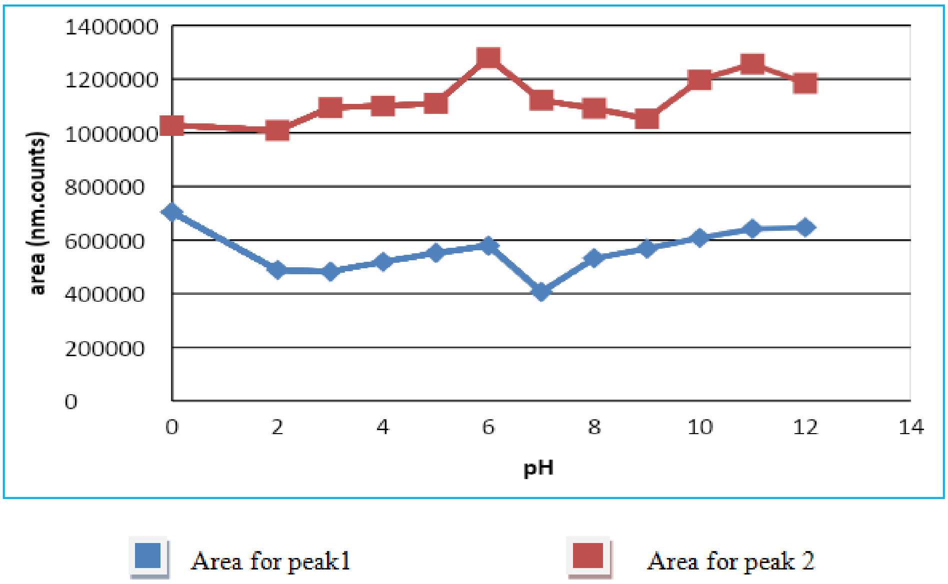


Figure 13. The Area for Peak 1 and Peak 2

We can conclude from figure (13) that, the area of absorption for peak 1 there are change with pH before and after natural pH solution. Where there are losses of energy when we compare the area with pH and without pH due to the reaction between pH solution and sol-gel. This peak gives us information about absorption of light which has high energy than peak two. There is increase in energy from pH2 to pH6 and the color in this area change from orange to yellow for acidic environmental and there is increase too in energy from pH8 to pH 12 for environment base but it's greater than acidic environmental which mean it has wavelength less than acidic environmental which enquired the wavelength for this base environment has color from green to blue. For beak 2 there is change in reflected area with pH **.**

Conclusion

In this paper the measurement of pH value by using unclad plastic optical fiber is presented. We can deduce from the result of spectrum that has been determined, there are different shapes of spectrum according to change the pH value. Most of spectrum that have been observed consist three maximum peaks. There is clear change in spectrum shape when pH value increase, which can conclude that the alkaline detector is more sensitive to the sol –gel solution than acidic detector. The ratio of intensities is not strong enough to determine the change in transmitted light maybe due to misalignment of the light source The activity is still in progress such as, chemical research to improve the mechanical properties of sensor. There are many advantages of pH sensor .first; it is cheaper than other devices .second, the pH equilibrium of the test fluid is not affected by the probe because the signal is optical and not electrical .moreover, the pH sensing based on evanescence wave absorption so can be used to distribute sensing. In contract, it has disadvantage, it is easy broken. We can conclude the pH sensor is suitable for this measurement by using light source **.**

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