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MANUFACTURE OF FIBER OPTIC SENSORS TO MEASURE THE PH WATER

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Abstract
A fiber-optic pH sensor based on evanescent wave penetration is presented. Evanescent wave penetration is generated by removing the clad and contact the core with the solution. Testing samples were perpetrated by add a strong acid (HCL) or a strong base (NaOH) at distilled water to produce different value of pH (from 4 to 13). To determine the absorption or transmission of the evanescent waves, that generate after where obtained on appropriate calibration curve to determine a wide range of pH, by using pH indicators. Where using methyl red, by add fixed amounts of this dyes to the water samples were obtained on samples with colors vary with pH values. Calculate the transmission and absorption with draw a relationship between the transmissions or absorption with the pH values, to obtain on suitable curves, considered as calibration curves. Calibration curve for methyl red is best, where extends (from 4 to 12) for pH value. Can calculate the pH value for any water sample to tested, by the add the same ratios of the organic dyes it used.

Keywords: pH sensor, fiber optic sensor, intensity modulated

1. INTRODUCTION

PH value is an important chemical parameter of the solutions. Measuring and controlling the PH value is very important in the fields of biochemistry, clinical medicine, and environmental science, etc. Compared to the traditional pH measuring methods, such as using pH test strips, pH glass electrodes, etc., the optical fiber PH sensors are particularly suitable for in vivo detection of the physiological and medical samples (Li et al., 2013; Yasin, 2012).

Fiber optic sensors in this work depend on intensity modulated. These sensors are based on total internal reflections. When light travels from a denser to a rarer medium and is totally reflected at the interface, an evanescent wave propagates parallel to the interface. The amplitude of the wave decreases approximately exponentially in the rarer medium with a characteristic penetration depth (Lee, 2003). If the rarer medium is an absorbing one, the evanescent wave intensity is attenuated, giving rise to a reduction in the power propagating in the denser medium. The attenuation increases with the number of reflections at the interface. Thus an unclad optical fiber is more useful as an attenuation sensing element.

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The theory

Light travelling through a step index optical fiber is guided within the medium as a result of total internal reflection (TIR) if the critical angle criterion is fulfilled. At each point of TIR, the interference between the incident and reflected signals, at the core/cladding interface generates a standing wave which extends beyond the core of the optical fiber and penetrates into the cladding region (Li et al., 2013). The method of evanescent wave (EW) sensing allows optical fiber to be using in intrinsic (FOS).The evanescent field created at interface interacts with the target solution that surrounds the core fiber, where replaces a portion of the original fiber optical cladding figure (1), and giving information as result of optical change refractive index, absorption and scattering (Lin, 2000). Although light wave radiation strikes the core-clad interface of the multi-mode fiber optical at angles greater than "critical angle". This generates the evanescent field in cladding region with the amplitude E_x. Amplitude is decays as exponentially with the distance at away from core-clad interface region as the equation (1) (Cisco Systems, 2008):

$$E_x = E_0 \, e^{-x/dp} \ldots\ldots\ldots \; (1)$$

where:-

E is represent amplitude of the evanescent field.
E_0 is represent initial value of amplitude of the evanescent field.
d_p is represent the penetration depth of the evanescent field.
x is represent the distance.

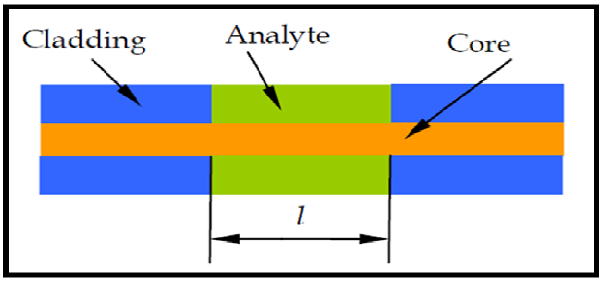

Figure 1. Schematic diagram of the solution that surrounds the core of optical fiber sensor [5]

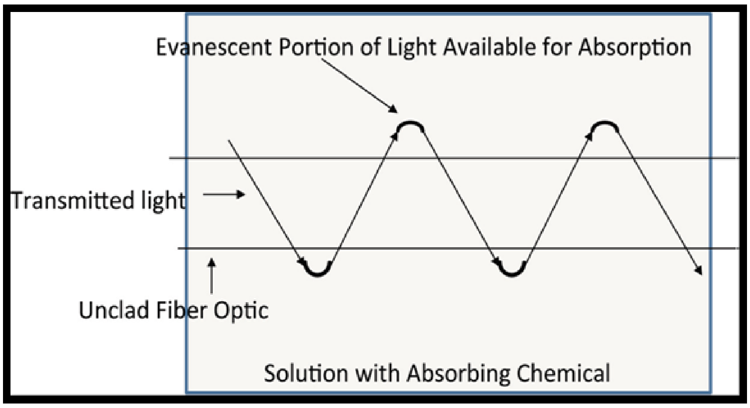

Figure 2. Concept of evanescent light absorption around an unclad fiber optic [6]

The evanescent field is propagating with parallel to fiber axis, can interact with the species about the core region when stripping the cladding. If this evanescent light wave is absorbed by the species surrounded core region and gives increase to phenomenon of the attenuated total reflection (ATR).

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Therefore the output power of the fiber optical will becomes correspondingly less (Cisco Systems, 2008). The evanescent field sensor design uses the EF related with propagation the light in optical fibers. This field can be used to transfer power of light out of the core to absorbing different particles in the outer medium Evanescent absorption, shown in figure (2), or find fluorescence in the outside region of core Evanescent excitation or to couple this fluorescence from outside medium into the core of fiber Evanescent collection (Lin, 2000). The change in optical transmission properties is caused by optical absorbance of the solution and resulting of the light absorption phenomenon on fiber optical structure when increase the radiation losses (Cao and Duan, 2005).
One portion of the clad fiber is removed, and its core is exposed directly to the analyte or solution. The power of the evanescent field can interact with the analyte, and the concentrations of the analyte can be detected by the loss is measuring of output power of the sensing fiber. The extent of the power loss can be marked by the absorbency of this sensor (A), which is described as follows equation (2) (Lin, 2000).

$$A = \log_{10}\frac{P_o}{P} \text{.........}(2)$$

Or by using intensity

$$A = \log_{10}\frac{I_o}{I} \text{.........}(3)$$

Where the P and P_o in equation (2), are the output and input power of the fiber optical evanescent wave sensors with and without an absorptive analyte for sensing. Also the intensity I and I_O in equation (3). At detecting the same sample with the same concentrations. When crossing light rays from core to clad at the beginning interface of the region between core-clad, Appears the depth of penetration dp of evanescent wave rays in cladding as the and defined , the depth which the amplitude E_x of the evanescent light field has decay to (1/e) of initial value E_0 at the core-cladding interface. The penetrates is a small distance into the cladding, where electromagnetic light wave is decay in exponentially with the distance in cladding region (Cisco System, 2008). The *dp* of the evanescent field is related to the incidence angle θ at the interface, figure (3), refractive indexes of the core n_1 and cladding n_2, and the wavelength of the radiation λ in equation (4) (Aljaber, 2014).

$$d_p = \frac{\lambda}{2\pi\sqrt{(n^2{}_1 \sin^2\theta - n^2{}_2)}} \text{.........}(4)$$

Where: *dp* : is represent the penetration depth of the evanescent field.
λ : is represent wavelength of light.
θ : is represent the angle incidence.
n_1: is representcore refractive index.
n_2 :is represent cladding refractive index.

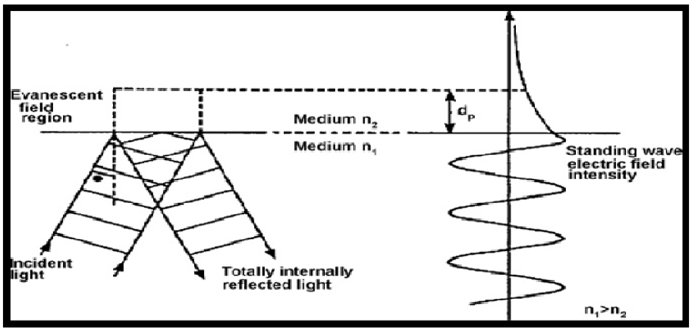

Figure 3. Concept of the penetration depth of evanescent wave rays [7]

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The evanescent field EF in clad region interacts directly with the solution or analyte, produce fluorescence or absorbance be coupled with fiber core (Maddu et al., 2007).

2. EXPERIMENTAL ARRANGMENT

The block diagram and photograph experimental setup of the pH sensor are shown in figure (4) and figure (5). The setup is consisting of:

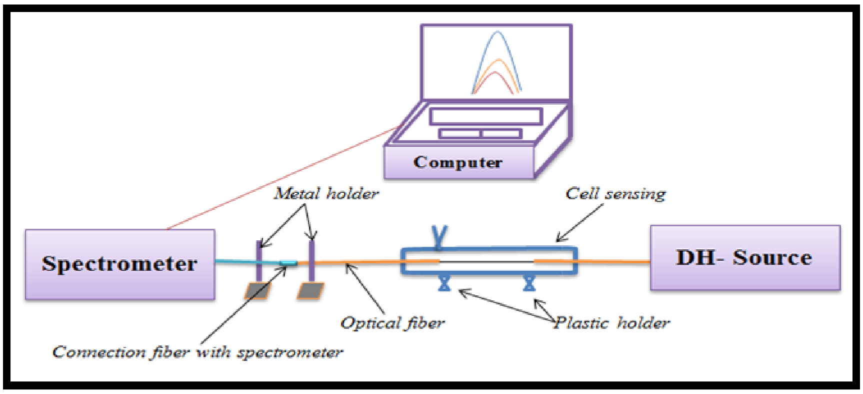

Figure 4. The block diagram of the second pH setup of experimental work

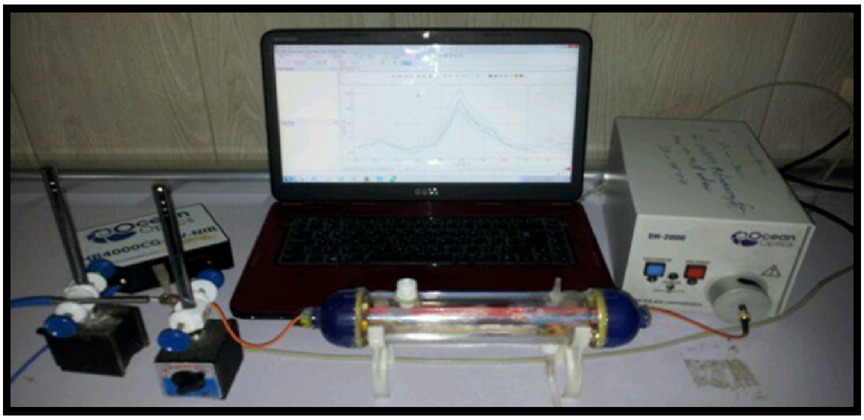

Figure 5. The photograph picture of the experimental setup

The multimode fiber is used in the present experiment is of 1-m length. At the mid-point along its length, a 5 cm outer plastic jacket is first removed. After removing the plastic jacket the fiber is gently washed in distilled water, allowed to dry for some time and then dipped in HF acid at 25 min for removal of cladding material, then washed by distilled water.

3. RESULTS AND DISCUSSIONS

Where using the setup experimental shown in figure (7). The intensity of light must be determine and accounted by letting it passes through an optical fiber with original cladding without any change as shown in figure 7. The value of this intensity is 8629; this intensity is representing the reference intensity (I_0).

A distributed fiber optics pH sensor has been demonstrated by decladding a short length of this fiber and exposing the core to an aqueous methyl red solution over a range of pH values. The pH samples with methyl red indicators are tested the response was high and graduated of change with pH as shown in figure 8.

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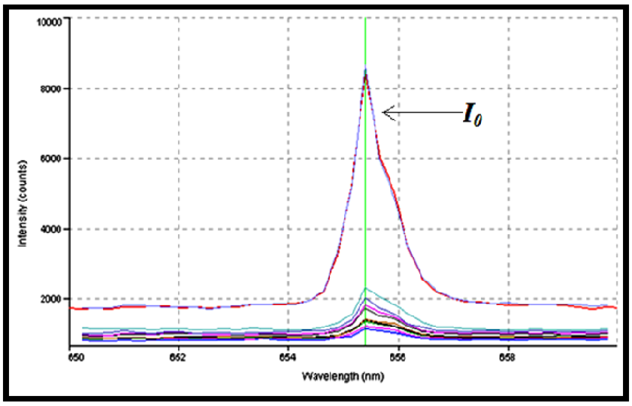

Figure 7. Relation between output intensity and wavelength shows the highest intensity through optical fiber

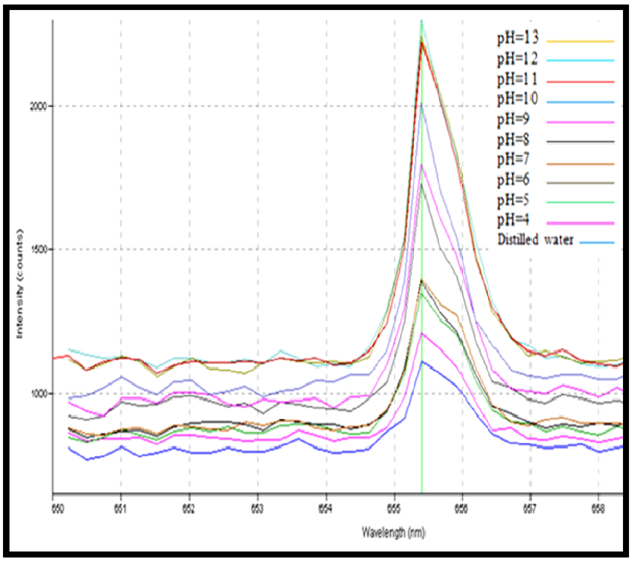

Figure 8. The intensity vs. wavelength at different pH value by using methyl red indicators

From above, can show the absorption and the transmission of light, and this is represented by the table 1.

Table 1. Shows the information that obtained from figure (7) at λ= 655.4nm

T	A	I_0	I	pH
0.129099	0.889075	8629	1114	Distilled water
0.138486	0.858593	8629	1195	4
0.154943	0.809829	8629	1337	5
0.162244	0.789832	8629	1400	6
0.165604	0.780928	8629	1429	7
0.197937	0.703473	8629	1708	8
0.213698	0.6702	8629	1844	9
0.235949	0.627183	8629	2036	10
0.253795	0.595516	8629	2190	11
0.266543	0.574233	8629	2300	12
0.257388	0.589412	8629	2221	13

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Drawing the relationship between Absorption, and also transmission of light intensity, shown in figures (9) and (10) respectively. The attenuation and transmission of light, are changed gradually with pH values.

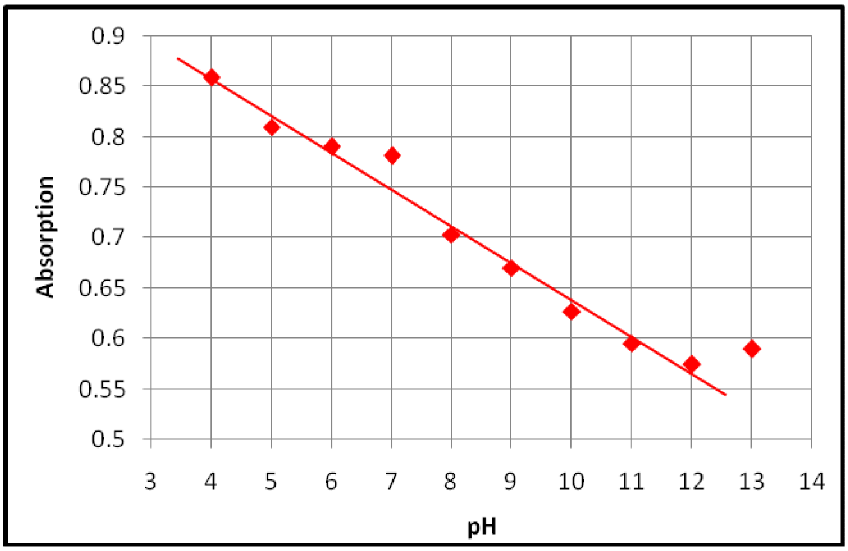

Figure 9. The relationship between absorption with various pH values at λ= 655.4nm by using methyl red indicator

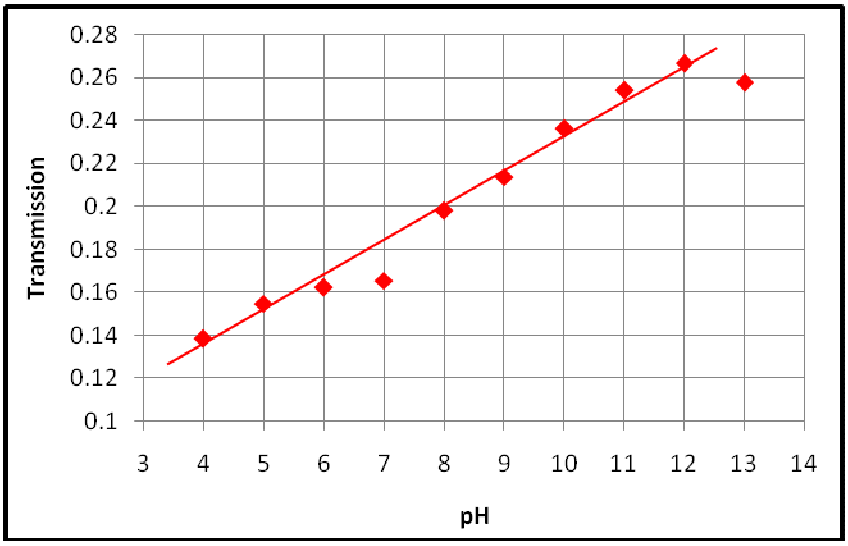

Figure 10. The relationship between transmission with various pH values at λ= 655.4nm by using methyl red indicator

The principle of work of this sensor based on the use of methyl red as an indicator which exhibited a linear range for pH=4 to pH =12. From the figures above, with greater pH value, the transmission of light increasing and the absorption becomes less. This occurs in a gradual and systematic. Methyl red is a well-known pH indicator that changes colour from red (acid) to yellow (alkaline). The 655.4nm red light launched into the fiber optics is absorbed more at low pH. Where at increasing the hydrogen ions H^+ in water becomes very acidity (low pH) value, and the solution become most redness, therefore, the absorption of light is increases and in conversely, light transmission become less. However, the gradation pH value cause change in colors, moving towards yellowing with more

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pH, this colors is different from each other with each pH value and the human eye cannot distinguish between many adjacent colors. The relationship between pH and absorption or transmission, is used as calibration curve, measure the pH value from attenuation or transmission value. There is a significant increase in absorbance at λ= 655.5 nm, as the solution becomes more acid. This would explain the higher absorption experienced by the fiber optics in increasingly acid methyl red environments.

4. CONCLUSIONS

Lack of seriousness fiber optical sensor for sensing pH contain without using pH indicators "dyes". The variation in optical power of light is very tiny i.e. there is very small response of optical power with the change of pH value.

Using pH indicators, methyl red (methyl red is a well-known pH indicator that changes color from red (acid) to yellow (alkaline), for the purpose of obtaining the calibration curves can be relied upon. Where the amount of light transmission or absorbance, is vary according to pH values.

Calibration curve for methyl red extends from 4 to 12 for pH value.

Possible to determine the pH value of the water sample, by calculate the transmission of light or absorbance with use of a suitable pH indicator and compared the result with the calibration pH curve.

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