Journal of Engineering Science and Technology
Vol. 15, No. 4 (2020) 2178 - 2189

DESIGN AND FABRICATION OF FIBER OPTIC CHEMICAL SENSORS (FOCS) SYSTEM FOR SALINITY DETECTION OF NaCl SOLUTIONS

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Abstract

The research aims to design and fabricate fiber optic chemical sensor (FOCS) system which can be used to detect the salinity concentration of NaCl solution. The system can transmit data signals from the transmitter to the receiver using LED of the SFH 756 and SFH 250 as transmitter and receiver, respectively. The signal can be sent via an optical fiber cable intermediary that has been made into a sensor by removing the cladding of the fiber optic cable and utilized the influence of placing the liquid on top of the sensor so that a signal change appears as a result of the liquid. The results of measurements depend on the concentration of salinity placed on the sensor of the fiber optic cable. The signal transmitted can be detected using an optical power meter. The value of each intensity received by an optical power meter depends on the salinity concentration of the NaCl solution. The higher the salinity in the NaCl solution, the higher the intensity received. The the rate of increase in the salinity of a substance is proportional to that of intensity of the light sent by the sensor. According to linear regression, the graph can be made as an equation, and the results $Y = 30.7012083+0.010275X$ with X is the salinity of NaCl and Y is the intensity in dB.

Keywords: Fiber optic chemical sensor, NaCl solution, Salinity.

1. Introduction

Optical fiber is thinner than copper wire and can transmit data over longer distances [1]. It is also resistant to corrosion and moisture [2]. Fiber optic cables have been widely used in many functions, such as for remote sensing, powering networks and is even used in medical applications [3, 4]. Optical fiber has a huge market potential every year because many industrial sectors have been using it as data transmission and other media, such as sensors. Many sensors are now made from fiber optics, and this emphasizes the potential of a more favorable optical fiber sensors compared to other conventional components. Some of the the advantages of optical fiber sensors over opposing electrical transducers are inherent in electromagnetic interference [5, 6], higher sensitivity, small unit error, safety avoiding the danger of explosion, allowing the exchange of a low loses signal, and the ability to work under temperature conditions very high and very high pressure. Modulated optical fiber intensity sensors for the measurement of salinity is based on radiation losses that have been developed [7].

The use of fiber optic has been extensively used in chemical sensors as well. One of the fiber optic chemical sensors is used to monitor acid rain levels. In the development, fiber optic chemical sensor (FOCS) is used to detect acid rain, and evanescent field type FOCS is used to assess chemical conditions at acid rain levels. With drastic changes in natural conditions, the measurement of FOCS in acid rain involves hydrocarbon oxides, ammonia, and nitrogen (NOx) [8]. In chemical sensor research studies for measuring acid rain using FOCS, the NOx sensor is used to calculate the rainfall index and chemical emission index [9]. Unfortunately, the calculation results used to calculate the rainfall index are not good because of the lack of rainfall indices taking place. To improve the rainfall index from calculating acid rain levels, Cai proposes to use new sensors such as zirconia to stabilize and compile the Nano MoO_3-ln_2O_3 developed by him [10]. The sensor is a very sensitive and uses stable zirconia and MoO_3-In_2O_3 given an increase in NOx gas sensors to improve calculation results. However, the use of zirconia and stabilized MoO_3-ln_2O_3 is not safe because it has a chemical reaction that has an impact on electrochemical materials. Thus, it is necessary to develop a sensor that has no impact on electrochemical materials.

Previous studies [11, 12] have succeeded in developing a Micro-ring resonator to monitor ammonia during acid rain. Micro-ring resonator is a dielectric ring sensor with the smallest refractive index based on optical principles developed to measure chemical reactions to electrochemical materials [13, 14]. This has the advantage that what Cai's research cannot do with micro-ring resonators that have no impact. Micro-ring resonators can convert ammonia from acid rain, change the optical wavelengths from 5000 nm to 10,000 nm, and are based on chemical transducers [15, 16]. However, the high cost of developing a micro-ring resonator is burdensome to farmers; Thus, it is necessary to develop an ammonia prototype sensor and ammonia detectors above the acid rain level.

2. Fiber Optic Chemical Sensor (FOCS)

In recent days, optical fiber has been functioned to a wider extent, such as in fiber optic chemical sensor (FOCS) to monitor the level of acid rain especially in plantation areas [17]. Two models have been previously established in the development of optical fiber chemical sensors, and they are recommended to obtain an ammonia mass that exceeds the monitoring of the rain level at the time of measurement. Figure 1 shows the two FOCS designs: the distal probe type and the evanescent wave-type. The two models have different fluid levels stored as measurement indicators or named by the indicator layer. In its development, several FOCS design conditions are used as a measuring instrument by using a microcontroller. This indicator layer is used to take the effect of absorption of light by the indicator layer to see how much the difference in the output.

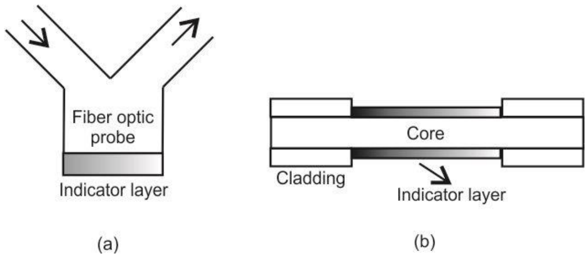

Fig. 1. Common FOCS design: (a) Distal type probe and (b) Evanescent wave-type. Figure is adopted from reference [17].

The FDS10X10 photodiode is integrated between a microcontroller and a fiber optic chemical sensor (FOCS) to get the conversion value from the light captured by the photodiode. The analog value is transmitted through Atmega328 as a microcontroller. In addition, an optical light source (OLS) with a wavelength of 1310 nm is used as a source of input data that will be transmitted by fiber optic cable and will be received by the FDS 10X10 photodiode. The signal output will then produce analog voltage and be processed by the Atmega328 microcontroller as shown in Fig. 2. The results of the conversion of the amount of light will be carried out by a photodiode. This will eventually allow changes in input and output trays that can be digitalized. After the signal is digitalized, it will be easy to monitor these changes where the measurement results will be calibrated.

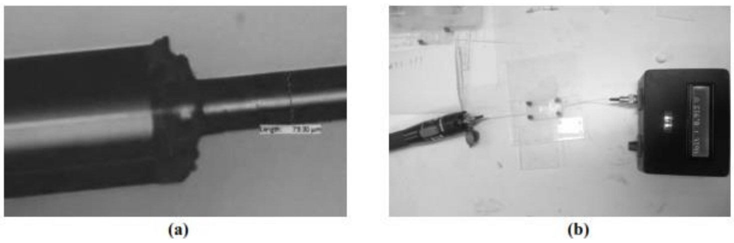

Fig. 2. The system development FOCS in (a) first and (b) second steps to monitor acid rain level [17].

Figure 2 shows that the input light source comes from OLS which is transferred to the ammonia refractive index under acid rain conditions. Here, the FOCS sensitive layer absorbs the light transmitted through an optical fiber cable by OLS. The absorption of the light will be detected by a 10×10 FDS photodiode. Besides, the previous development of the FOCS prototype was equipped with a 16×2 LCD data display to display the results of the detection of acid rain levels by the photodiode. After that, the measurement results using a prototype will be juxtaposed with the optical power meter gauge to validate the results of acid rain measurement using a prototype. The results of the comparison between the optical power meter and the ammonia prototype detector are then analyzed to get the results of Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), and Percent True (PT). At this stage, a fiber optic chemical for the detection of ammonia has three steps during the process that are tested to obtain α value between the optical power meter and the ammonia prototype detector as some of the processes is shown in Fig. 3.

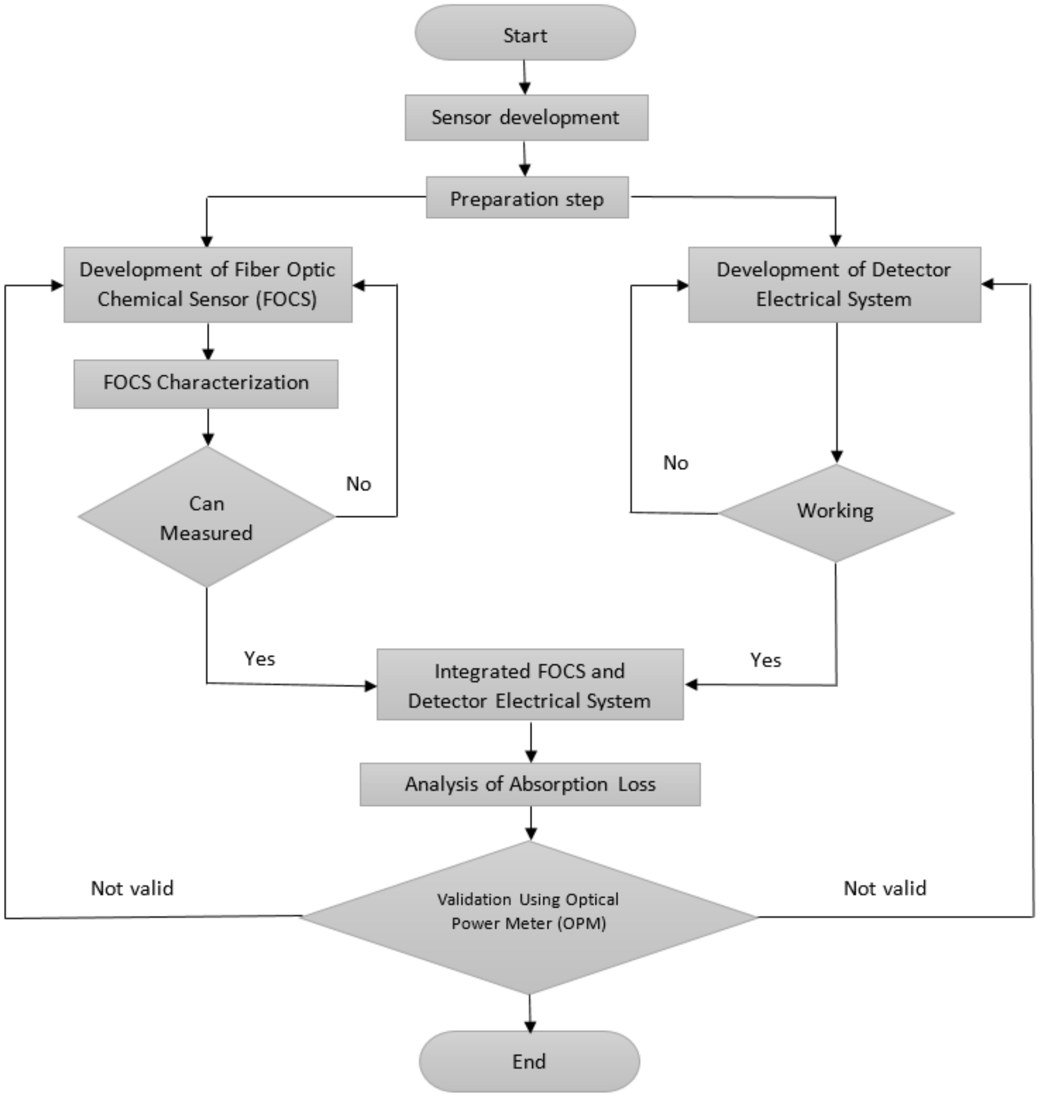

Fig. 3. Flowchart testing process of FOCS with prototype ammonia detector and optical power meter [17].

To obtain the minimum α value of FOCS, the material tested must have been placed between the substrate and sensitive material. In previous studies of chemical optical fiber sensors for the detection of ammonia, mass variations tested were 1 to 5% [17].

Optical fiber as a sensor has also been used as a water vapor detector. Previous study [18] studied fiber optic cables as sensors using ZnO nano-powder as a catalyst for sensing water vapor in optical fibers. The method of making sensors is also not much different from the research on the use of fiber optic cable for sensing ammonia, only that the fiber optic cable cladding is added by ZnO nano-powder. In addition, ZnO nanoparticles give advantages since this type of material can be prepared easily and rapidly from zinc raw materials [19].

Salinity is defined as the mass of salt solids dissolved in 1 kilogram of seawater. If all bromine and iodine are replaced with the same amount of chlorine, all carbonates are converted to oxidation and all organic matter is oxidized. The salinity value is expressed in g / kg which is generally written in ‰ or ppt, which is part of a thousand and one [20].

Salinity has a significant role in many sectors. High concentrations of salinity will greatly affect the sectors that requires water in their production or life process, such as industries, environment, livestock, and plantations. In metal production industries, the level of environmental salinity particularly water salinity can accelerate the process of metal oxidation. As to this, the level of water salinity must be well monitored to avoid metal rusting. Water salinity has also a vital role in the growth of plantations that require water supply [21]. With the importance of detecting water salinity, salinity sensor is thus needed to support the industries, plantations, and environment.

In the process of developing fiber optic chemical sensors for the detection of salinity, Stanley made the cladding of the fiber optic cable removed and this leaves only the fiber optic cable. The condition of the open fiber optic core is utilized by placing saltwater in the exposed part, where some of the light emitted through the optical fiber will be partially absorbed by the liquid [22]. Different salinity concentrations result in changes in light intensity which will be detected by the photodetector. This idea was put forward by Stanley suggesting the measurement of salinity using an optical fiber sensor system.

Salinity sensors are already on the market due to the lack of detectable coverage which results in the need to develop this salinity sensor. Increased salinity detection coverage has been tested also using the Plasmon resonance surface to determine the refractive index so that the accuracy and performance of the detection can be performed well [23]. However, the high cost of making sensors with these methods can burden the farmers or the shrimp pond entrepreneurs. Farmers make an effort to keep the plant growth and produce quality plants and need to detect the salinity level so that the plant can grow [24]. For shrimp farmers, salinity level should also be monitored to get better quality of shrimp [25].

As to this, it is necessary to develop sensors with good performance, appropriate measurement coverage, and affordable price. This study discusses more in the manufacture of fiber optic chemical sensors for the detection of salinity by using standard components and having a fairly good performance.

3. Materials and Method

Optical communication systems are different from microwave systems where the difference lies in the range of carrier wave frequencies used to carry information. , Different from the carrier frequency in the microwave wave which is approximately 1 GHz, the carrier frequency in the optical transmission is usually at 200 THz. The increased capacity of optical communication system information is expected to carry more than 10,000 times greater than the microwave method so that the use of optics can be used for transmission systems for light waves.

Figure 4 explains the generic diagram of an optical communication system consisting of three common elements for all types of communication systems: a transmitter, communication channel, and receiver.

In Fig. 4, a block diagram shows the process of sending and receiving signals. The optical transmitter and optical receiver components are used as in the module. Communication channel is a part of the sensor paired there. In the communication channel we can put salinity from the NaCl solution. Before the signal is received by the optical receiver, the signal will be measured in advance how many signals can be distributed in units of dB.

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Fig. 4. Generic optical communication system.

3.1. Design FOCS module for transfer and receive signal on fiber optic

The fiber optics analog communication module consists of fiber optics analog transmitter module PS-FO-AT and fiber optics analog receiver module PS-FO-AR. It uses to study the fiber optics analog transmission and reception through plastic fiber cable. In transmitter module, onboard function generator is at variable frequency and variable amplitude, supporting external sine signal at certain range and LED driver circuit. In the receiver module, there are photo diode driver section, amplifier and power amplifier circuit (Fig. 5).

As shown in Fig. 5, all connectorization are through BNC connecters, RS232 connecters, patch chords, and un-insulated sockets, in which the connection refers to Fig. 4. The transmitter module uses SFH 756 to transmit signal from source on simplify function generator. The signal form is the sine signal from function generator, and the frequency and amplitude signal can change. Meanwhile, the receiver uses SFH 250 to receive signal from fiber optic sensor. SFH 250 receives the very small signal from sensors, so the amplifier is needed to set signal into high or low.

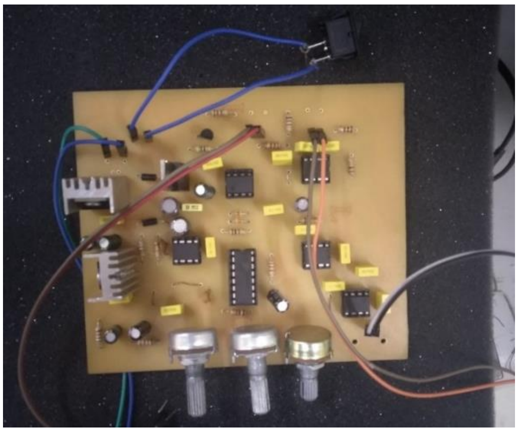

Fig. 5. Simple fiber optic receiver transmitter module.

3.2. Method to produce fiber optic sensor

As in previous studies, the use of cladding areas in fiber optic cable will cause the transmitted light to be absorbed. This is what has been analysed to date and is utilized as the basis for making optical fiber sensors, especially in the chemical field [17, 18, 26]. As a further development, we created the fiber optic chemical sensors for other functions such as to detect water salinity.

The method of producing a fiber optic sensor (Fig. 6) is by opening a bit of cladding on a fiber optic cable so that the signal transmission via fiber optic cable can lose power. The loss of power will be used as a sensor, and the rest of the cladding cable is peeled to give a sensitive liquid to affect the rate of transmission of light in the cable. In addition to using the sensitive liquid, other things that have been proven in [27] using fiber optic plastic, the opened cladding section is given a resin and turmeric as an intermediary to influence the loss of transmitted power.

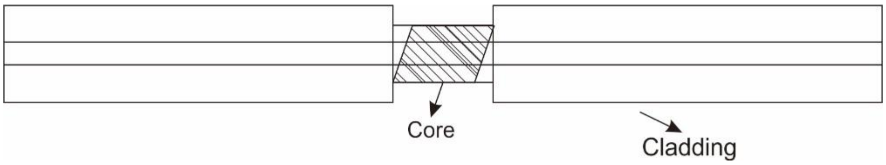

Fig. 6. Fiber optic cable open cladding model.

3.3. Experimental produce for the concentration measurement of NaCl solution

Figure 7 shows a linear graph where each increase in concentration of NaCl can cause the voltage to be transferred even greater [3]. Then, the process of measuring salinity is not far from the data.

The analysis of output voltage measurement is important. Another thing that must be considered is by measuring how far the sensor can transmit the light transferred to it. The measurement can be performed by transmitting signals from the transmitter SFH 756 module to the sensor. Before it is received by the receiver, it will be measured by an optical power meter and calculate how much decibel light is transmitted. To get stable results of the measurements, the power meter was monitored until no significant increases and decreases in measurements occur. Besides, the measurements were performed for 10 times to get the ideal results.

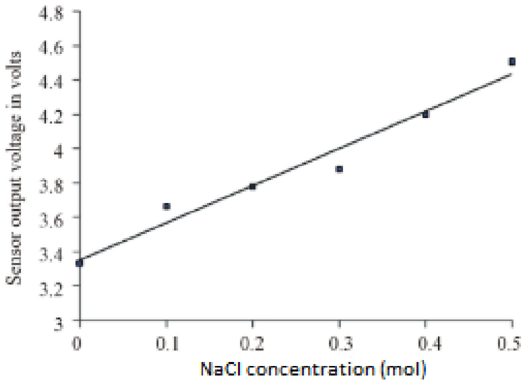

Fig. 7. Response of fiber optic sensor for different concentration of NaCl.

3.4. Method measurement sensor design

As shown in Fig. 1(b), the sensor made for salinity measurement in this experiment used multimode plastic fiber optic cable. The cable was peeled and the visible core was then placed on a glass and peeled on both sides so that it can be connected to the transmitter and receiver (Fig. 8). From Fig. 8, the NaCl solution is placed in the middle of the sensor.

Fig. 8. Sensor Optic from fiber optic cable.

4. Results and Discussion

From the literature about the effect of salt on plants (rice) [25], it was explained that the salinity of salt allowed only at a few levels up to 4000 ppm was very influential on the percentage of plants living for the next few days. In addition to the shrimp culture, the concentration of salinity is good, and the artificial sea water system is at the value of 35 ppt. We had three concentrations for testing to find out the salinity concentration values in the range of 5 - 25 ppt (Fig. 9). The application can thus be used for things that are beneficial to plants and animals and others.

Fig. 9. NaCl Liquid at 5, 15, and 25 ppt.

From the measurement results shown in Tables 1 and 2, the results can be made as a linear graph. From Fig. 10, the increase in the value of power in dB leads to the increases in the concentration of NaCl. There are three sample concentration investigated including 5, 15, and 25 ppt (Fig. 9). Thus, the increase in optical power value in dB is proportional to the increase in the concentration of NaCl solution tested on the sensor corroborating the study [20] where the increase in salt concentration is proportional to the rate the output voltage received by the receiver. This is due to the possible ionic dissociation from NaCl itself [28]. Previous reports explained the changes with voltage, but what we measured in this study is the change in light intensity using optical power meter. Due to unstable voltage measurement and non-patented transfer module and receiver [29], the results influence the difference of conversion of light intensity transmitted to the voltage. However, there is no very far difference delivery of light intensity with voltage because the authors found the fact that the light intensity received by the SFH 250 receiver changes the value of the output voltage that is prepared by module [21]. Thus, with the risk of inaccurate voltage measurement, only the value of light intensity in the decibel is displayed.

Table 1. Optical power meter measurememt at 5, 15, and 25 ppt of NaCl.

Sample	Decibel (dB)									
NaCl 5 ppt	30.78	30.78	30.78	30.78	30.78	30.78	30.78	30.79	30.80	30.79
NaCl 15 ppt	30.88	30.87	30.87	30.88	30.87	30.88	30.87	30.88	30.87	30.88
NaCl 25 ppt	30.96	30.97	30.95	30.94	30.94	30.94	30.94	30.92	30.92	30.92

Table. 2. Intensity by optical power meters (5, 15, and 25 ppt of NaCl).

Sample	$\bar{x}$
NaCl 5 ppt	30.784
NaCl 15 ppt	30.875
NaCl 25 ppt	30.94

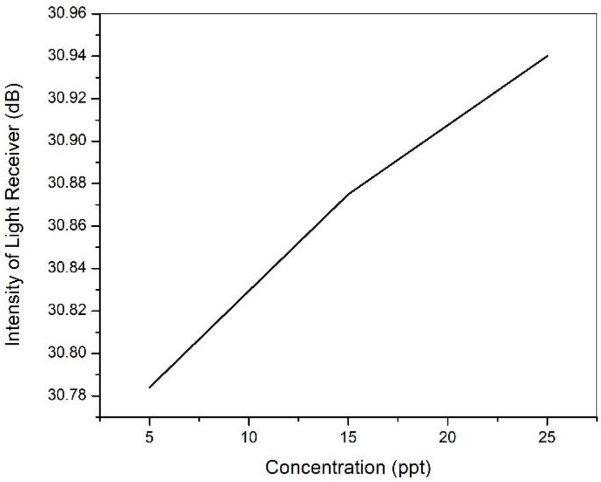

Fig. 10. dB chart according to the value of NaCl salinity concentration.

5. Conclusions

Fiber optic system fabricated can be used to transmit and receive data signal using LED of SFH 756 and SFH 250 as transmitter and receiver, respectively. The signal can be sent via optical fiber cable intermediary that has been made into a sensor by removing the cladding of the fiber optic cable and utilized the influence of placing the liquid on top of the sensor, so that a signal change appears as a result of the liquid. The results of measurements depend on the concentration of salinity placed on the sensor of the fiber optic cable. The signal transmitted can be detected using an optical power meter. The value of each intensity received by an optical power meter depends on the salinity concentration of the NaCl solution. The higher the salinity in the NaCl solution, the higher the intensity receive, with the rate of increase in the salinity of a substance proportional to the rate of intensity of the light sent by the sensor.

Acknowledgments

E.R. thanked to Universitas Pendidikan Indonesia for giving a grant for exchange student in the UPI World Class University Program. We acknowledged the Ministry of Research, Technology and Higher Education of the Republic of Indonesia (Ristekdikti) for research funding and Dr. Goib Wiranto from Research Centre of Electronics and Communication, Lembaga Ilmu Pengetahuan Indonesia (LIPI) for supporting this research activity.

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