Protein Content Sensor based on Plastic Optical Fiber

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Abstract. Plastic optical fiber (POF) content protein sensor has been developed. This sensor is made with a gamma and spiral configuration, with a cladding peel length of 5 cm. POF sensor is dipped into the container containing Bovine Serum Albumin (BSA) solution with different concentrations of 0.1-1 mg/ml. Both ends of the sensor are connected by Light Emitting Diode (LED) and Phototransistor. The LED light will propagate through the POF and it is received by the phototransistor. Light that propagates will be interfenced due to increasing of protein concentration around the sensor, so that the output voltage will be affected. The output voltage will be forwarded to Arduino Uno and read by the computer. The best results were obtained in a spiral configuration with 3 bending with a sensitivity of 0.007 V/ml/mg and a resolution of 0.142 mg/ml. This method has advantages that are easy fabrication, simple measurement process, and low cost.

1. Introduction

Optical fiber is a type of transparent and flexible fiber made of glass or plastic. Generally, optical fibers function as optical waveguides in optical communication. But as technology develops, optical fiber is not only applied to optical communication systems but also in various other fields such as sensing or sensor systems. The developments of optical fiber sensor have been widely used to measure various physical quantities, such as viscosity [1], temperature [2] and, pressure [3]. In the field of chemistry including, PH [4] and salinity [5]. In the field of biology including, glucose [6], DNA [7], protein [8], etc.

The uniqueness of this optical fiber sensor has a small and light size, the ability to measure long distances up to several kilometers, safe (not affected by electromagnetic waves), high sensitivity in measurement. Optical fiber sensors in detecting proteins have been developed among others, Jiang et al (2017) detected protein molecules using tilted brag grating fiber (TFBG) combined toward surface plasmon resonance (SPR) effects, where the optical fiber used was coated with a thin gold [9]. Guo et al (2016) detected protein in urine using tilted fiber brag grating (TFBG), sensors coated with silver [10]. Several of these studies have the weakness such as elaborate measurement and fabrication processes and require a long time.

In this study, a measurement of protein fiber sensor based on POF will be developed using bending methods. Light waves propagating in POF will be isolated if the fiber is bent. As a result of the bend, the light will come out from the core towards the cladding. The greater light coming out from the core will cause the greater power loss that occurs, so it resulting light intensity decreases [11]. This method is expected to be able to produce high sensitivity in the simple measurement systems, simple fabrication, and low cost.
2. Method
In this study, we using step index type of POF made of polymethyl metacrylate (PMMA), with refractive index of cladding is 1.402 and core is 1.492. Diameters of $d_{\text{core}} = 2.2$ mm, $d_{\text{cladding}} = 1.0$ mm, and $d_{\text{core}} = 0.98$ mm, with the numerical aperture (NA) value is 0.5. This sensor uses an infrared LED with IFE91A type with light wavelength is 950 nm. Light emitted through optical fibers will be received by phototransistor IFD92 type which converts light information into electricity. The sample used is BSA. It is dissolved in aquades and divided into 10 parts with different concentrations namely 0.1 mg/ml to 1.0 mg/ml with a range of 0.1 mg/ml. BSA solution measured by using Lowry method to determine protein content. The Lowry method is one of method that can use to determine protein content. In this study, we compare our method (using optical fiber) with Lowry method.

![LED](image)

**Figure 1.** The flow diagram of protein content sensor based on POF

![LED](image)

**Figure 2.** Configuration of (a) Gamma (b) Spiral

The flow diagram of protein content sensor based on POF is shown in Figure 1. The LED light will be transmitted through the POF and received by the phototransistor. The phototransistor function as a transducer that converts light information into electricity information become output voltage (Volt). Output voltage result is smaller, it will be amplified by an optrational amplifier (Op-Amp). The voltage coming out from the Op-Amp will be forwarded to Arduino Uno which function to convert the analog to digital voltage and then read on the computer. Changes in the concentration of the BSA solution around the sensor affect the light intensity as well as the power loss, so that the output voltage also changes.

The sensor is made with gamma and spiral configurations, it can be seen in Figure 2. The length of each optical fiber sensor used constant is 15 cm, with the peel length of cladding is 5 cm. Gamma configuration are made with different diameters consists of 0.2 cm, 0.3 cm and 0.4 cm. While spiral configuration is made with different number of bending consists of 1, 2, and 3 bends.
3. Result and Discussion

In this study, protein level sensors based on POF, measurements of BSA protein levels were carried out at different concentrations. BSA is dissolved in distilled water with a volume of 50 ml. The dissolved BSA mass is 5-50 mg. Furthermore, the BSA solution protein level is measured using the Lowry method. The measurement results in Figure 3.

![Figure 3](image)

**Figure 3** Graph of measurement results of protein contents using the Lowry method

Measurements of protein based on plastic optical fiber have been done using a gamma without cladding configuration with a diameter variation and spiral configuration without cladding with the number of bends that are varied. The sensor is dipped into the BSA solution sample which has been changed in concentration. Sensor output voltage changes in response to changes in BSA concentration on the gamma configuration and spiral configuration shown in Figure 4.

![Figure 4](image)

**Figure 4** Graph of output voltage changes toward protein concentration configurations (a) Gamma and (b) Spiral

In Figure 3 shows that the BSA is proportional to the increase in output voltage on the computer. Changes in output voltage are caused by increasing the BSA concentration which results change the sensor refractive index and it causes the power loss increases. This case causes the light intensity
decreases. The smaller the intensity of light passing through the sensor causes the greater the output voltage. This statement has suitability by Guo et al (2016) detected protein content in urine that the refractive index of urine would increase when protein content of urine increased [10].

There are several characteristics of sensor. They are range, sensitivity and resolution. The range is obtained from the difference between the maximum output voltage (Vmax) and the minimum output voltage (Vmin) and it can be seen in the following equation (1) below [12,13]:

$$\Delta V = V_{\text{max}} - V_{\text{min}}$$

(1)

The sensitivity value can be seen in equation (2) below:

$$S = \frac{V_{\text{max}} - V_{\text{min}}}{K_{\text{max}} - K_{\text{min}}}$$

(2)

Where, \(K_{\text{max}}\) is the maximum BSA concentration dan \(K_{\text{min}}\) is the minimum BSA concentration. The greater the sensitivity value, the better the sensor.

Furthermore, calculating resolution of the sensor to measure the smallest value by the sensor. The resolution value can be seen in equation (3) below [11,12]:

$$R = \frac{N}{S}$$

(3)

Where, \(R\) is the sensor resolution, \(N\) is smallest scale value of Arduino (\(N_{\text{arduino}} = 0.001\) V) and \(S\) is the sensitivity of the sensor. Characteristics of protein content sensor using POF can be seen in table 1.

**Table 1**: Characteristics of sensor protein content based on POF in Gamma and Spiral configurations

| Characteristics of Sensor | Gamma Configuration | Spiral Configuration |
|---------------------------|---------------------|---------------------|
|                           | 0.2 cm | 0.3 cm | 0.4 cm | 1 bend | 2 bends | 3 bends |
| Range (V)                 | 0.0032 | 0.0026 | 0.0016 | 0.0027 | 0.0036 | 0.005    |
| Sensitivity (VmL/mg)      | 0.0036 | 0.0029 | 0.0018 | 0.0030 | 0.0040 | 0.007    |
| Resolution (mg/mL)        | 0.2778 | 0.3448 | 0.5556 | 0.3333 | 0.2500 | 0.142    |

Based on characteristics of the sensor in Table 1 is show that the good sensor has a large range, high sensitivity and a small resolution values. The sensitivity of the gamma configuration is smaller than spiral configuration. The sensitivity of the gamma configuration sensor be affected by the diameter of gamma. Based on Table 1, the best sensor characteristics were obtained in the Spiral configuration at 3 bends with range, sensitivity and resolution 0.005 mg/mL, 0.007 VmL/mg, and 0.142 mg/mL respectively. Based on these results, the sensitivity of the spiral configuration sensor is influenced by the number of bending in POF. The more number of bending, the more light intensity produced in POF. These statements have a suitability with previous studies that the number of bending affects the light intensity decreases so that the power loss is greater [1,14]. POF as sensor can be used in measuring protein contents because it has good sensitivity.

**4. Conclusion**

Conclusion of this research is the greater concentration of protein solution, the greater the change in sensor output voltage. The more number of bends and the smaller diameter of the curve, characteristics of the sensor are better. The best measurement results were obtained in a spiral configuration at 3 bends, with a range of 0.005 mg/mL, sensitivity 0.007 VmL/mg, and resolution of 0.142 mg/mL.

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References

[1] Yunus M and A. Arifin 2018 Design of oil viscosity sensor based on plastic optical fiber. *IOP Conference Series Journal of Physics* **979** 1-7

[2] Lv R, Zheng H, Zhao Y, and Gu Y 2018 An optical fiber sensor for simultaneous measurement of flow rate and temperature in the pipeline *Optical Fiber Technology* **45** 313-318

[3] Zhao Q, Zheng H K, Lva R K, Gu Y F, Zhao Z, and Yang Y 2018 Novel integrated optical fiber sensor for temperature, pressure and flow measurement *Sensors and Actuators A* **280** 68-75

[4] Jeon D, Yoo WJ, Seo JK, Shin SH, Han KT, Kim SG, Park JY, and Lee B 2013 Fiber-Optic PH Sensor Based On Sol-Gel Film Immobilized with Neutral Red *Optical Review* **20** 209-213

[5] Irwin S, Wall V, and Davenport J 2006 Measurement of temperature and salinity effects on oxygen consumption of Artemia franciscana K measured using fibre-optic oxygen microsensors *Hydrobiologia* **575** 109115

[6] Li W, Sun C, Yu S, Pu Z, Zhang P, Xu K, Song Z, Li D. (2018). Flattened fiber-optic atr sensor enhanced by silver nanoparticles for glucose measurement *Biomedical Microdevices*, 21(1).

[7] Xiao S B, 2009, Detection of transgenic maize using surface plasmon resonance (SPR) DNA biosensor *Journal of Maize Sciences*, 2: 38–43.

[8] Anderson G P, Jacoby M A, Ligler F S, and King K D 1996 Effectiveness of protein A for antibody immobilization for a fiber optic biosensor *Biosensors & Bioelectronics* **12** 329-336

[9] Jiang Q, Xue M, Liang P, Zhang C, Lin J, and Ouyang J 2017 Principle and experiment of protein detection based on optical fiber sensing *Photonic Sensors* **7** 317-32

[10] Guo T, Liu F, Liang X, Qiu X, Huang Y, Xie C, Xu P, Mao W, Guan B O, and Albert J 2016 Highly sensitive detection of urinary protein variations using tilted fiber grating sensors with plasmonic nanocoatings *Biosensors and Bioelectronics* **78** 221-228

[11] Cheng L, Li Y, Ma Y, Li M, and Tong F 2018 The sensing principle of a new type of crack sensor based on linear macro-bending loss of an optical fiber and its experimental investigation *Sensors and Actuators A Physical* **272** 53-61

[12] Arifin A, Yusrar, Miftahuddin, Bualkar A, and Dahlang T 2017 Comparison of sensitivity and resolution load sensor at various configuration polymer optical fiber *The 6th ICTAP* **1801** 1-6

[13] Arifin A, Hatta A M, Sekartedjo, Muntini M S, and Rubianto A 2015 Long-Range Displacement Sensor Based on SMS Fiber Structure and OTDR *Photonic Sensors* **5** 166-171

[14] Arifin A, Lebang A K, Yunus M, Dewang S, Idris I and Tahir D, 2019, Measurement Heart Rate Based On Plastic Optical Fiber Sensor, *IOP Conf. Journal of Physics: IOP Conf. Journal of Physics* **1170** 1-7