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Development of Optical Fiber Sensor Performance as a Tool to Determine Cholesterol Concentration

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Abstract. The purpose of this study was to determine cholesterol concentration by developing the performance of optical sensors. The use of this optical sensor is equipped with an optical fiber bundle to guide the wave in the hope of not reducing the intensity of the wave source. This sensor is simpler and inexpensive to use to determine the concentration of a material. The research method for determining cholesterol levels can be determined through the character of the laser beam to the material through a fiber optic sensor. The optical fiber sensor method is simpler and cheaper to use to determine the concentration of a material. Based on this description, research on fiber optic sensors will be developed as an instrument model to determine cholesterol concentration using a fiber optic bundle type sensor. The method used is the modulation of laser beam intensity. A beam of light that enters the optical fiber of the receiver and is processed by an optical detector into an electrical signal that will be displayed on the computer. The experimental results will obtain a linear relationship between the sensor output peak voltage as a function of variations in cholesterol concentration and parameters and sensor performance will be measured including sensitivity and linearity. The results showed that maximum voltage detection showed a linear decrease with increasing concentration with a sensitivity of 0.15 mV/ppm and a linearity of more than 97%. high sensitivity, simplicity of design, and low cost of promoting the developed sensor results in good performance detecting cholesterol concentration.

1. Introduction

Cholesterol is a fat molecule in cells divided into LDL, HDL, total cholesterol and triglycerides. Cholesterol is one of the nutrients that are needed by the body in addition to other nutrients such as carbohydrates, proteins, vitamins, and minerals. Cholesterol is present in the bloodstream or cells of the body that are needed for the formation of cell walls and as a raw material for several hormones. However, if excessive levels of cholesterol in the blood can cause illness, including coronary heart disease and stroke. Normal cholesterol should be under 200 mg/dl. Cholesterol is also a basic ingredient in the formation of steroid hormones. Excessive cholesterol in the body will be buried in the walls of blood vessels and cause a condition called atherosclerosis, which is narrowing or hardening of the arteries. This condition is the forerunner to the occurrence of heart disease and stroke.



The detection of cholesterol levels has been carried out by researchers such as sensitive and selective electrochemical sensors using silver nanoparticles modified glass carbon electrodes for the determination of cholesterol in serum bovine [1]. Electrochemical sensors are based on molecular film printing on carbon nanoparticles that are modified electrodes for cholesterol determination [2]. The layer of carbon nanotubes and bienzyme biosensor-based gold nanoparticles for cholesterol detection [3]. High-performance electrochemical biosensors for the detection of total cholesterol [4]. Cholesterol detection with amperometry using the electrochemical oxidation method [5]. electrochemical and optical polymers by using biosensors to detect cholesterol [6]. The weaknesses of the sensors are sensor performance optimization such as sensitivity, linear range, and detection limits are still not optimal. Several ways and techniques for calculating solution concentrations such as cholesterol have been carried out. Among them, UV-Vis spectrophotometer is used to determine the blood cholesterol level of patients experiencing hypercholesterolemia. Development of biosensors as analytical instruments for determining cholesterol in traditional foods using UV-Vis spectrophotometer. UV-Vis spectrophotometers require a stable complexing to increase the adsorption sensitivity. Another obstacle is the analysis with UV-Vis spectrophotometer which has a detection limit.

There are many ways to determine the results of cholesterol concentration through laser beam propagation in certain solutions by using sensors through fiber optic waveguides. Sensors using optical fiber are simpler to be used to determine the concentration of a material. Sensors using optical fibers are also used to determine the concentration of the salt solution in a material with high sensitivity measurement results [7]. From this brief description of optical sensors that use fiber developed by researchers to make optical fiber sensors as an instrument to determine cholesterol concentrations by using optical fiber sensor types of optical fiber bundles. This study is to determine the profile of the intensity of the beam output of the receiving optical fiber (RF) detected by the photodetector of the object shift. Besides, to determine the performance of the sensor by using a fiber optic sensor bundle to determine cholesterol concentration. This research expects to get an experimental model (setup) of a fiber optic sensor system bundle to determine cholesterol concentration. Describe the intensity profile of the receiving fiber (RF) beam output which is detected by the photodetector against the object shift. With the final goal of the study is to determine the performance of the session by using two types of optical fibers to determine cholesterol concentrations. The development of this instrument is based on the concept of the interaction of the He-Ne laser beam to a material that takes into account physical quantities.

Laser light includes examples of visible light electromagnetic waves. A laser is a device that emits light through a process called stimulated emission. The laser is a continuation of LASER (Light Amplification by Stimulated Emission of Radiation). Lasers are devices that use quantum mechanical effects, induced or stimulating emissions, to produce coherent light rays. Lasers also have the character of emitting photons in coherent light. Laser light is usually monochromatic, for example has a single wavelength or color, and is emitted in a subtle beam. This is different from ordinary light sources that emit photons that can be seen in all directions, usually encompassing the wavelengths of the broad electromagnetic spectrum. Lasers can be understood through the use of theories of quantum mechanics and thermodynamics.

Laser light is unique and is within the range of the electromagnetic wave spectrum. The light that comes out of the laser with a variety of wavelengths and variations in intensity is applied in various fields, including telecommunications, meteorology, metrology, biology, chemistry, military, cybernetics, industry, and medicine. Laser in this study will propagate using optical fiber. Optical fiber is a kind of cable transmission channel made of glass or plastic that is very smooth and can be used to transmit light signals from one place to another. The light source used is usually a laser. Optical fiber with a diameter of approximately 120 micrometers. The light in the optical fiber does not come out because the refractive index of the glass is greater than the refractive index of the air because the laser has a very narrow spectrum. In principle, optical fiber reflects and refracts the amount of light that propagates in it. The efficiency of optical fibers is determined by the purity of the building blocks of glass. The purer the glass, the less light is absorbed by optical fibers.

2. Method

The principle and method of this research are the basic principle of the properties contained in the He-Ne laser beam which involves a solution. By analyzing the physical quantities of the laser beam through the solution and transmitted through the solution including the intensity and output voltage that is read by the detection device. Detection devices convert wave energy into electrical energy using optical detectors. The tools and materials used in research to determine this cholesterol concentration are Laser Helium-Neon, standard cholesterol, fiber optic type bundle, silicon detector, digital voltmeter. Design of optical fiber sensor design with optical fiber type as shown in Figure 1.

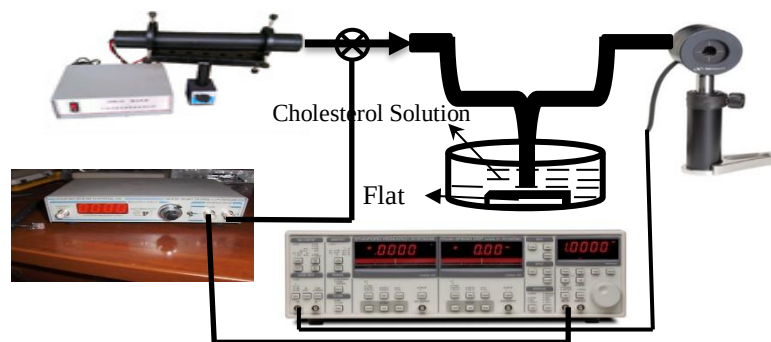


Figure 1. Optical fiber sensors determine the concentration of cholesterol by using a fiber bundle

Research Procedure by characterizing the shift sensor to determine the shifting of the fiber bundle sensing channel to the mirror. Measurement of physical magnitude data when the fiber bundle is placed coincides with a flat and concave mirror i.e. at shift $z = 0$. The optical fiber reflection bundle is placed on the micrometer position by sliding every $50 \mu\text{m}$. At each shift read the measured output voltage so that the data obtained in the form of a detector output voltage as a function of fiber bundle shift. Detection is carried out on several variations of concentration, among others 0 ppm, 50 ppm, 100 ppm, 150 ppm, 200 ppm, 250 ppm, 300 ppm.

Data Analysis in this experiment, research variables can be made including the dependent variable is the peak voltage of the sensor output (in mV units) on optical fiber bundles, the independent variable is the concentration of cholesterol (in units of percent volume). The next step in the experimental test, the data obtained is in the form of the peak voltage value of the sensor output as a function of cholesterol concentration variation. From these functions, it can be determined the front linear region (front slope) and the back linear region (back slope). Linearity test of the front slope and back slope area is used a linear regression test. With the acquisition of peak voltage value data as a function of cholesterol concentration. From these results, sensor performance will be obtained which includes resolution, sensitivity, linearity, dynamic range and linear range of cholesterol sensors from three types of optical fibers.

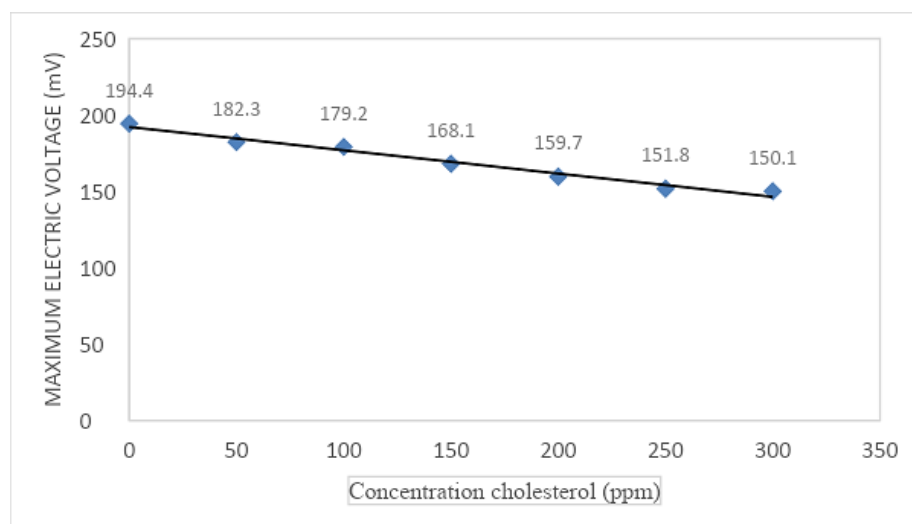
3. Results and Discussion

The amount of electric voltage read on an optical detector as a function of shifting the bundle of fibers for each concentration from 0 ppm to 300 ppm. Experimental data shows that there is a relationship between the variation of cholesterol concentration changes to the maximum output voltage at each concentration. The higher the cholesterol concentration the lower the measured detector output voltage. Detection data of the detector output voltage starts when the bundle fibers placed coincide with a mirror ie at shift $z = 0$. The bundle fibers placed on the micrometer position are shifted every $50 \mu\text{m}$. At each shift position, the detector output voltage is measured to obtain the maximum output voltage from each variation of cholesterol concentration. The maximum output voltage value from the variation of cholesterol concentration as in table 1.

Table 1. Data on maximum electrical voltage for seven cholesterol concentration samples

No	Concentration (ppm)	Electric voltage output (mV)
1	0	194.4
2	50	182.3
3	100	179.2
4	150	168.1
5	200	159.7
6	250	151.8
7	300	150.1

Figure 2. shows that the maximum voltage appears to decrease linearly with increasing concentrations of cholesterol solutions.

**Figure 2.** Maximum voltage for variations in cholesterol concentration

Detection analysis results show that the maximum output voltage shows a linear decrease in the increase in the concentration of cholesterol solution with a sensitivity of 0.15 mV/ppm and linearity of 97.65%. Based on the results of experiments determining cholesterol concentrations using SSO quasi Gaussian beam shows that the optical fiber output power profile will increase with increasing distance of the object shift from the optical fiber bundle, after reaching the peak output power will decrease exponentially with increasing distance in each variation of cholesterol concentration.

The results of peak stress analysis of variations in cholesterol concentration using SSO flat mirror reflecting sensitivity 0.15 mV/ppm and linearity 97.65%. The results of this sensitivity indicate an approach to the value of sensitivity using a quasi Gaussian file and in accordance with the analysis obtained theoretically [8].

4. Conclusion

The conclusion that can be made based on the results and discussion of this study is that the output power profile of the results of experiments using a Gaussian quasi beam shows that the optical power output will increase with increasing object shifts from optical fiber, after reaching the peak the output power will decrease exponentially with increasing distance. The performance of optical fiber sensors to

determine cholesterol concentration reaches high sensitivity, linearity, and accuracy with a sensitivity value of 0.15 mV/ppm, linearity of more than 97.65%, linear range of 0 - 300 ppm.

References

- [1] Nantaphola S, Chailapakul O, and Weena S 2015 Sensitive and selective electrochemical sensor using silver nanoparticles modified glassy carbon electrode for determination of cholesterol in bovine serum *Sensors and Actuators B* **207** pp 193–198
- [2] Ji J, Zhou Z, Zhao X, Sun J, and Sun X 2015 Electrochemical sensor based on the molecularly imprinted film at Au nanoparticles-carbon nanotubes modified electrode for determination of cholesterol *Biosensors and Bioelectronics* **66** pp 590–595
- [3] Cai X, Xia Gaoa L W, and Lin X 2013 A layer-by-layer assembled and carbon nanotubes/gold nanoparticles-based bienzyme biosensor for cholesterol detection *Sensors and Actuators B* **181** pp 575– 583
- [4] Ahmadalinezhad A and Chen A 2011 High-performance electrochemical biosensor for the detection of total cholesterol *Biosensors and Bioelectronics* **26** pp 4508-4513
- [5] Soylemez S, Yesemin A U, Cevher Gundo H, Ergun Y, and Levent T 2015 Electrochemical and optical properties of a conducting polymer and its use in a novel biosensor for the detection of cholesterol *Sensors and Actuators B* **212** pp 425–433
- [6] Faria J B 1998 A theoretical analysis of the bifurcated fiber bundle displacement sensor *IEEE Trans on Inst and Meas* **47** pp 742-747
- [7] Yasin M, Ahmad H, Thambiratnam K, Jasim A A, Phang S W, and Harun S W 2013 Design of Multimode Tapered Fibre Sensor for Glucose Detection *Optoelectronics and Advanced Materials* **7**(5– 6) pp 371-376
- [8] Rahman H A, Harun S W, Saidin N, Yasin M, and Ahmad H 2012 Fiber Optic Displacement Sensor for Temperature Measurement *IEEE Sensors Journal* **12**(5) pp 1361 - 1364