Design of a Fiber Optic Biosensor for Cholesterol Detection in Human Blood

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Abstract. A fiber optic sensor is to detect the cholesterol content in blood serum-based biosensor using plastic optical fiber that has been designed. The fiber optic sensor designed with sensing area was a fiber optic grated by 5 scratches then given bending treatment by 5 cm. The first test was by UV-Vis spectrometer with linearity of 0.96. The second test was by light spectrometer with linearity in white LED of 0.94. Optical fiber sensors were made to work well on a range of blood serum concentration of 140 mg/dL to 250 mg/dL.

1. Introduction
The importance of knowing the content of the concentration of cholesterol in the body is because high cholesterol in the body does not show any symptoms, it is important to check the content of cholesterol in the body on a regular basis. Diseases due to high cholesterol that exceeds the normal threshold may increase the risk of atherosclerosis (disease on the arteries or blood vessels that spread blood to the body) and cardiovascular disease (a disease caused by malfunctioning of heart and blood vessels, such as heart disease, hypertension and stroke), hypercholesterolemia (high cholesterol levels) and heart disease \cite{1}. Therefore, a biosensor is developed to determine the content of cholesterol using blood serum that can be done in real-time. In the field of optics, to determine the concentration of cholesterol in human blood, it can be done by using optical fiber of Long Period Gratings (LPG) \cite{2}.

Research on enzyme-based biosensor, what is used to detect the cholesterol level in the blood is an electrochemical biosensor designed and fabricated by screen printing technique or thick film technology \cite{3}. In addition, it is by the amperometric biosensors with the base of titanium oxide nanoparticles by accelerating the Reduced Instruction Set Computing (RISC) \cite{4}. And to detect the use of cholesterol, amperometric enzyme which uses polymer-based amperometric enzyme electrodes (Pt/popd/Chox) \cite{5} is used.

2. Experimental
In this study, to determine the concentration of cholesterol in human blood serum, it could be performed using the optical fiber sensor of Plastic Optical Fiber (POF) type scratched by 5 scratches. It was performed by examining the content of cholesterol in human blood serum using optical fiber scratched at the center of the optical fiber as the sensing area. Then the optical fiber was given bending treatment. On the sensing area, the interactions with blood serum occurred. Optical fiber connected on
the light source at one of the end of optical fiber and the other end of the optical fiber were connected to the detector, then from the detector to the interface. The measurement results would then be read and displayed on the PC. In this study, utilizing the change in the intensity of light which passed through the optical fiber sensor was the result from changes of the optical property, that was a refractive index or absorption spectrum of the medium surrounding the core optical fibers [6].

The design of the spectrometer was divided in two main parts: the manufacture of hardware and software. The hardware consisted of a convex lens, grating, light source, propulsion systems, and control system. This tool was designed to measure light spectrum using fiber optics, and then for the place of optical fiber was micropositioner. In this study, the sensing area was the optical fibers scratched by 5 scratches and then given bending treatment by 5 cm.

3. Result and Discussion

Light spectrometer calibration is using monochromatic light in the form of He-Ne laser which wavelength has been known, that is 632.80 nm. From the results of calibration, it is obtained the peak result by (631.18 ± 0.71) nm with the accuracy of 99.89% as showed at Figure 1.

![Figure 1. The resulting graph calibration using laser HeNe](image)

The sample used in this research is blood serum obtained from Budi Sehat Clinic, Surakarta, Central Java, Indonesia. The blood serum has had information such as the different content of cholesterol concentrations, this becomes a variation in a study conducted, in which the data is presented in Table 1.

| Number of Blood’s data | Cholesterol concentration (mg/dL) |
|------------------------|-----------------------------------|
| 1                      | 140.8                             |
| 2                      | 191.3                             |
| 3                      | 232.1                             |
| 4                      | 234.2                             |
| 5                      | 243.5                             |

The blood is serum measured using light spectrometer, each sample is measured with different LEDs. LED variation used is a white LED, a green LED, blue LED and yellow LED. The purpose of the LED
color variation is due to the wavelength range of each LED is different, meaning that it will produce a different absorption as well. Figure 2 shows the results of the linearity from testing blood serum with white LED, green LED and blue LED. In the yellow LED, it is not obtained the linear graph because in the yellow LED there is no specific absorption at certain wavelengths as the light is passed. The light is passed since the blood serum samples have clear yellow color.

![Graph](image)

**Figure 2.** Results of the linearity from testing blood serum with (a) white, (b) green and (c) blue LED

Typical uptake results on white LED is at a wavelength of 514.20 nm with linearity of 0.94, on green LED at a wavelength of 527.90 nm with linearity of 0.87 and on blue LED at a wavelength of 475.70 nm with linearity of 0.88. Meanwhile, in the test using a UV-Vis spectrometer, it has a wavelength of 577.00 nm with linearity of 0.96. Figure 3 shows the results of blood serum test using a UV-Vis spectrometer and the light spectrometer graph of absorbance as the concentration function of (a) white LED (b) green LED (c) yellow LED.
In this study, the blood serum is not mixed with other substances such as enzymes and reagents on the cholesterol test in the health field. Diagnostic study used for cholesterol with absorption wavelength of the best reagent kit is at a wavelength of 505 nm, then what is used in the estimation of cholesterol diagnostic study is at a wavelength of 505 nm [7]. Measurement of cholesterol levels purely measured using a scratched optical fiber as the sensing area which is given bending treatment using a spectrometer light tool. Before the testing using a spectrometer light, the blood serum is measured using a UV-Vis spectrometer. The results of measurements of UV-Vis spectrometer and the light spectrometer are then compared.

4. Conclusion
The study of cholesterol content uses optical fiber sensors-based biosensor using scratched optical fibers. Light source is passed in the optical fiber that has been scratched, in which the light is absorbed by the blood serum in accordance with the principles of light propagation. The first test is by UV-Vis spectrometer with linearity of 0.96. The second test is by light spectrometer with linearity in white LEDs of 0.94. Optical fiber sensors are made to work well on a range of blood serum concentration of 140 mg/dL to 250 mg/dL.
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