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IMPERFECTION METHOD BASED ON OPTICAL FIBER FOR ALCOHOL CONTENT DETECTION SENSOR

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Abstract: Testing of optical fiber-based sensors using the imperfection method to detect alcohol contents. The sample results from mixing alcohol and distilled water to produce eight samples with an alcohol content level from 0% to 70%. The greater alcohol content causes the output power of the sensor to decrease due to the increase in the refractive index of alcohol content around the sensor. An increase in the refractive index of alcohol content causes power losses to increase, resulting in lost light intensity being transmitted in optical fiber-based sensors. Power losses are increasing to produce the best characteristics of the sensor. The best sensor is shown in the Gamma configuration at imperfection 3 with a sensitivity value of 0.346 µW/%. The imperfection method is suitable for determining the characteristics of optical fiber-based alcohol detection sensors because it has a high sensitivity.

Keywords: *Alcohol, Sensor, Optical Fiber*

INTRODUCTION

The development of optical fiber technology as a data transmission medium in communication can now be applied to sensor systems. Optical fiber-based sensors have a wide wavelength and detection range. In addition, using optical fiber as a sensor has the advantages of simple sensor fabrication, resistance to electromagnetic (EM) wave interference, small size, and high sensitivity [1–4]. The optical fiber sensor component comprises Single-Mode Fiber (SMF) and Fiber Bragg Grating (FBG). These sensors can measure physical changes such as refractive index, temperature, glucose, pH, heart rate, crack, electric current, force, strain, displacement, and pressure. Developing sensors with simple, reliable, and low-cost modifications has attracted many researchers to propose innovations in measurement systems, especially in measuring alcohol content [5–11].

Alcohol is an organic chemical that dissolves easily in water and is colorless. These chemicals can be used as anti-bacterial, preservatives, and ingredients in alcoholic beverages [12][13]. Research on the detection of the quality of alcoholic beverages has been reported using optical fiber sensors [14–16], and PCF-SPR sensors to detect alcohol concentrations at low temperatures [1]. Fabry-Perot (FP) optical fibers and double-D-shaped optical fibers as sensitive materials are coated with ethanol [17][18]. The phenomenon of Snell's Law in implementing sensors for detecting the evaporation of alcohol concentrations in alcohol-water mixtures is based on plastic optical fiber (POF) [19][20]. Measurement of alcohol content using macro bending U and Gamma configurations on optical fiber sensors without cladding has low sensitivity [21].

This research will be innovative in developing sensors for detecting alcohol content using macro bending U and Gamma configurations on optical fiber imperfection. This method takes advantage of the power losses in fiber optic sensors. Imperfection in optical fiber will cause large power losses resulting in high sensitivity. The advantages of this method are simple fabrication and low cost.

RESEARCH METHOD

This study uses POF from polymethyl methacrylate (PMMA). POF has elastic properties, so it is not easily broken. POF has a jacket, cladding, and core structure. The refractive index of the fiber optic core is 1.492, the cladding is 1.402, and the numerical aperture is 0.5. The light source is an infrared light emitting diode (LED) type IF-E91A and a photodetector type S120C. The photodetector as a light receiver will be measured on the Thorlabs PM100D Optical Power Meter (OPM). Light intensity measurements are displayed on a computer as sensor output power. This study used samples from mixing concentrations of alcohol and distilled water to produce eight samples with alcohol contents ranging from 0% to 70%. The level of alcohol content is measured using an alcoholmeter.

The testing method for the alcohol content detection sensor based on POF uses U and Gamma configurations. This research method was developed by making defects on the optical fiber, namely, imperfection 1, imperfection 2, and imperfection 3. The fiber optic jacket is peeled off with a constant length of 3 cm. The optical fiber is dipped into each alcohol sample. The circuit schematic and design of the alcohol content detection sensor are shown in Figure 1 and Figure 2.

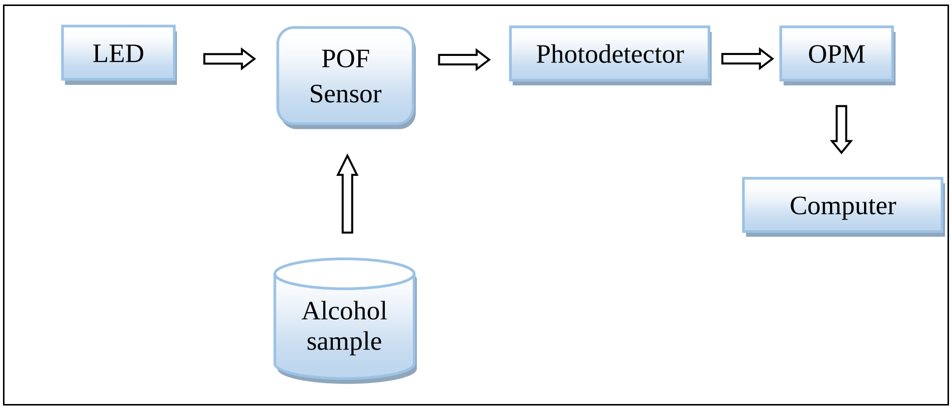

Figure 1. Circuit schematic of the alcohol content detection sensor

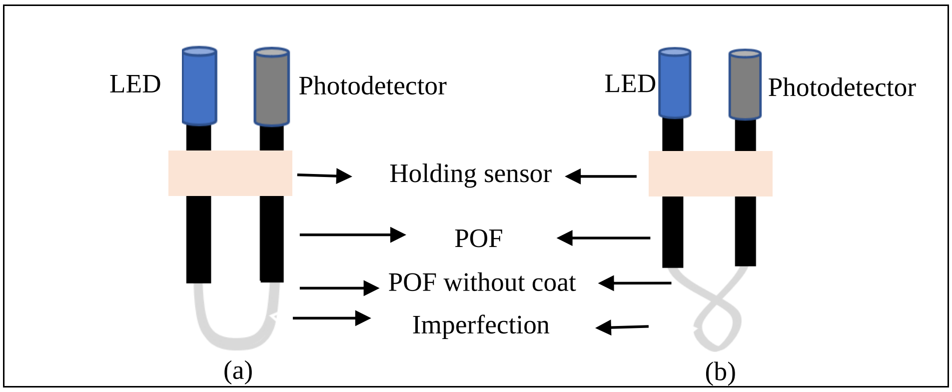

Figure 2. Design of POF alcohol content detection sensor (a) U configuration and (b) Gamma configuration

RESULT AND DISCUSSION

As a light transmission medium, POF is used as a sensor to detect alcohol contents. The alcohol content sensor is made into two configurations, U and gamma, each without a jacket. The sensor is dipped in the alcohol content using a variation of imperfection 1, imperfection 2, and imperfection 3. The test results for sensors based on fiber optics to detect alcohol content using the U-configuration vary in the number of imperfections seen in Figure 3.

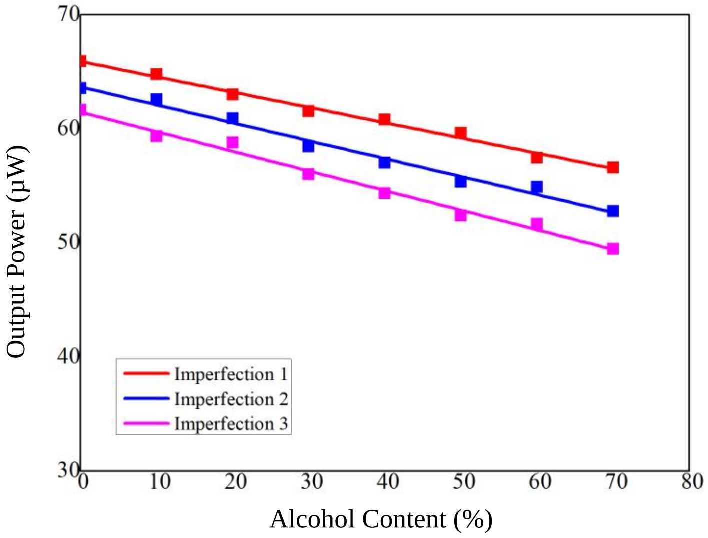

Figure 3. Testing sensors for detecting alcohol content in the U configuration with variations in the number of optical fiber imperfections.

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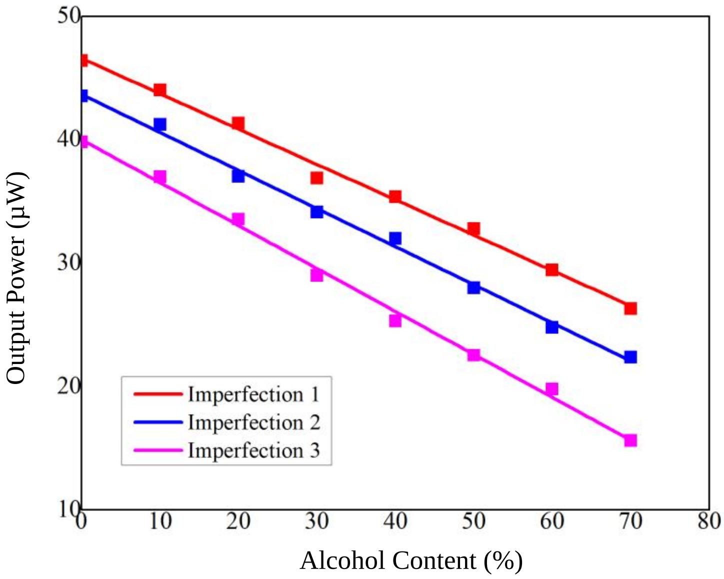

Figure 4. Testing of sensors for detecting alcohol contents in Gamma configuration, variations in the number of optical fiber imperfections.

Figure 3 displays the response of the sensor output power to the level of alcohol content. The greater the alcohol content, the lower the output power of the sensor [21]. The number of imperfections also greatly affects the output power of the sensor. The more imperfections in the fiber optic sensor, the sensor's output power also decrease.

Furthermore, testing fiber optic-based sensors to detect alcohol contents using a Gamma configuration for variations in the number of imperfections is shown in Figure 4.

Based on Figure 4 shows the response of the sensor output power to the level of alcohol content. This graph is similar to Figure 3. The sensor output power decreases as the alcohol content increases. Likewise, the number of imperfections greatly affects the output power of the sensor. The more imperfections in the fiber optic sensor, the sensor's output power also decreases. The sensor output power decreases due to the missing light intensity, resulting in power losses in the optical fiber [22]. Power losses occur due to the influence of the refractive index of optical fiber and the refractive index of alcohol content. Power losses increase along with the increase in the refractive index of alcohol content around the sensor so that the output power decreases.

Furthermore, the sensor output power data is used to determine the sensor characteristics. The parameters used to determine the characteristics of the sensor are its range, sensitivity, and resolution. Range (*P*) is the difference between the maximum and minimum output power, using the equation $\Delta P = P_{max}-P_{min}$. Sensitivity (*S*) is the sensitivity level of the sensor to the measured amount of solution, namely $S = (P_{max}-P_{min})/(K_{max}-K_{min})$. At the same time, Resolution (*R*) is the smallest value that can be measured by the sensor, namely $R = N/S$ [22–24]. Where N is the smallest OPM scale value of 0.001 µW, the calculation of sensor characteristics values can be seen in Table 1.

Table 1. Characteristics of sensors detecting alcohol content in the U and Gamma configurations for variations in the number of imperfections in optical fiber.

Characteristics of Sensor	U-configuration			Gamma-configuration		
	Imperf-1	Imperf-2	Imperf-3	Imperf-1	Imperf-2	Imperf-3
Range (µW)	9.310	10.780	12.180	20.090	21.140	24.220
Sensitivity (µW/%)	0.133	0.154	0.174	0.287	0.302	0.346
Resolution (%)	0.007	0.006	0.005	0.003	0.003	0.002

Table 1 shows the characteristic values of the alcohol detection sensors for variations in the number of imperfections. The number of defects increases resulting in a greater range of output power. The greater the output power range, the more sensor sensitivity increases, and the resolution decrease. The best sensor in the U configuration is shown at imperfection 3 with a sensitivity of 0.174 µW/%. Likewise, with the Gamma configuration, the best sensor is shown at

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imperfection 3 with a sensitivity of 0.346 µW/%. The best sensor sensitivity comparison results can be seen in Figure 5. The graph in Figure 5 shows that the Gamma configuration has a greater sensitivity value than the U configuration. It is because the Gamma configuration occurs macro bending compared to the U configuration, resulting in greater power losses. The greater the power losses that occur, the better the sensor characteristics [21,23-24]. Optical fiber-based sensors using the imperfection method are suitable for detecting alcohol contents because they have high sensitivity.

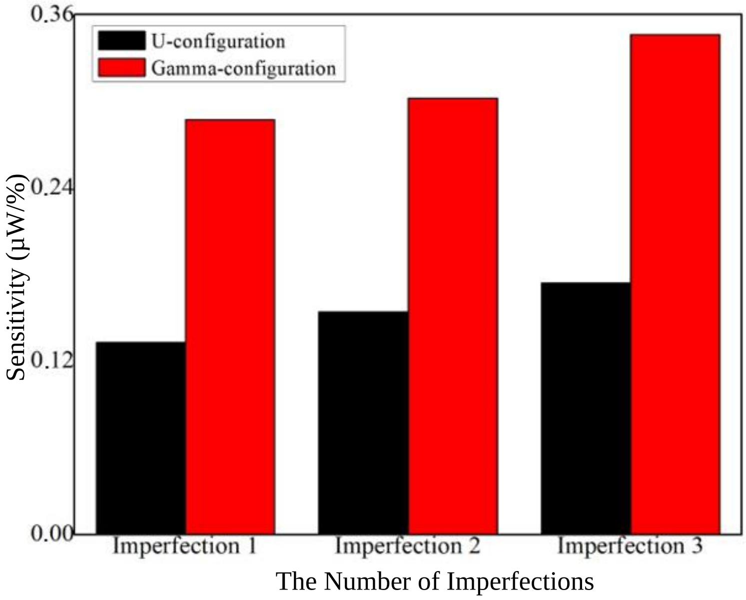

Figure 5. Comparison of the best sensor sensitivities.

CONCLUSION

The test results for the alcohol content detection sensor show the response to changes in the sensor output power to the level of alcohol content. The greater alcohol content causes the output power of the sensor to decrease due to the increase in the refractive index of alcohol content around the sensor. An increase in the refractive index of alcohol content causes power losses to increase, resulting in lost light intensity being transmitted in optical fiber-based sensors. Likewise, with variations in the number of imperfections, the greater the number of imperfections, the better the sensor's sensitivity. The best sensor is shown in the Gamma configuration at imperfection 3 with a sensitivity value of 0.346 µW/%. The imperfection method is suitable for determining the characteristics of optical fiber-based alcohol detection sensors because it has a high sensitivity.

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