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The honey insertion cladding to improve the sensitivity of temperature polymer optical fiber sensor

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Abstract. The sensitivity of temperature polymer optical fiber (POF) sensor has been studied. Part of cladding (9 cm) was substituted with honey. Polymer cladding was stripped mechanically and the honey inserted into the tube. Plastic gel closed the two end sides of the tubes. The optical power output was detected by Optical Power Meter (OPM). Honey cladding and temperature changing effect to the internal reflection and optical fiber output intensity. Highest output intensity changing at 20°C was shown by optical fiber coated by longan honey as cladding. The range of 10-50° C, as the rise of surroundings temperature, the attenuation was getting smaller. Best sensitivity was fiber with sensing part coated by *Longan* honey. Best linearity was sensing fiber with sensing part coated by *Pracimantoro* honey.

Keywords: honey cladding, sensor, POF

1. Introduction

The optical fiber is a kind of wire that made from thin and smooth silica glass or polymer. It is different from copper wires which are conducting electrical current; the optical fiber transmitted an optical signal from one to another end of the wire. A kind of sensor that using optical fiber as an active component or only as an optical waveguide in sensing mechanism is known as optical fiber sensor [1].

The total internal reflection occurs when the incident light is reflected from an interface at a higher angle than the critical angle. However, its intensity does not abruptly decay to zero at the interface, and a small portion of light penetrates into the reflecting medium. This penetrated electromagnetic field is called the evanescent wave [2]. No energy is lost by the evanescent wave unless there is absorption in the medium in which it is traveling [3] This penetration depth of evanescent wave could be determined by Equation 1.

$$d_p = \frac{\lambda}{2\pi \left[\frac{\sin^2 \theta}{n^2} - 1 \right]^{\frac{1}{2}}} \quad (1)$$

Honey is composed primarily of the sugars glucose and fructose, and third highest of honey's component is water. The viscosity of honey is affected by temperature, moisture content and floral source. Table 1 shows how the viscosity changes the temperature, moisture content, and floral source



change. The viscosity of honey decreases rapidly when the temperature rises. 1% moisture is equivalent to 3.5°C and affects viscosity [2].

Table 1. (a) Viscosity changes as temperature change. (b) Viscosity changes as water content change [3].

(a)		(b)	
Temperature (°C)	Viscosity (P)	Water Content (%)	Viscosity at 25°C (P)
13.7	600.0	15.5	138.0
29.0	68.4	17.1	69.0
39.4	21.4	18.2	48.1
48.1	10.7	19.1	34.9
71.1	2.6	20.2	20.4

This particular research examined the influences of honey cladding and surrounding temperature changing toward the output intensity of optical fiber. Best kind of honey that has highest intensity changes, best sensitivity and linearity also has determined by the data result.

As light source entering the fiber core, it will keep traveling until reach the surface field between core and cladding medium (Figure. 1).

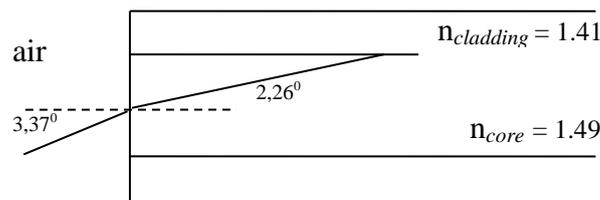


Figure 1. Laser light after entering the fiber core

The light will be reflected back to core only if the angle comes to surface of two medium (θ_i) were greater than critical angle (θ_{crit}). Critical angle (θ_{crit}) of fiber optic was obtained by substituting the core and cladding refractive index to Equation 2.

$$\theta_{crit} = \arcsin\left(\frac{n_2}{n_1}\right) \quad (2)$$

Plastic optical fibers (POF) have flexibility and large core diameter, which enables efficient connection and coupling resulting in a low-cost system for a local area network. These fibers have attention because of their clear technical advantages over glass fibers [4-6]. POF has a higher numerical aperture than glass optical fibers, and the system also has the advantage from a wider acceptance angle which provides a better light collecting conditions [7].

Fiber optic sensor used a modified light waves. The intensity modification can be used as a parameter. Intensity modification is easy to be processed. Intensity changes occurred due to the leakage caused by the optical fiber subjected to physical treatment as pressure, temperature [8-9] changes, bending [10-12].

In this experiment, there was part of a fiber optic which was had removed the cladding and was replaced with honey which affected by the total internal reflection in fiber optic. Fiber optic that was using the fluorinated polymer as cladding has a critical angle at 71.14° will change its magnitude due to of different cladding refractive index.

This particular research examined the influences of honey cladding and surrounding temperature changing toward the output intensity of optical fiber. Best kind of honey that has highest intensity changes, best sensitivity and linearity also has determined by the data result.

2. Methods

The research was started by determining the refractive index of honey using refractometer at a temperature of 20°C. Refractometer was calibrated first using distilled water, and then some drops of honey were put into the prism or sample part of the refractometer. And then, cover the prism was gently closed until honey spreading all over the prism. The next step was reading the scale on refractometer that has been directed toward a light source by peep on it ocular lens. Brix scale that has read before was converted into a refractive index using Brix to refractive index conversion table.

In this research, fiber optic SH-4001-1.3 was cut off 4 m in length, and some cladding part of those wire was removed by 9 cm. Cladding part of fiber was peeled using acetone, and thus only main part of the fiber that remained. The peeled fiber was surrounded by a small tube which then was injected with honey. The part of fiber which had coated by honey was functioned as a probe and placed in a reservoir filled with water. Water in the reservoir had varied its temperature and functioned as surroundings. A tip of fiber was connected with a laser, and the other tip was connected with OPM. The data results were collected by observing the intensity of fiber optic using OPM for increasing temperature of surroundings from 10°C-50°C and decreasing temperature from 50°C-10°C.

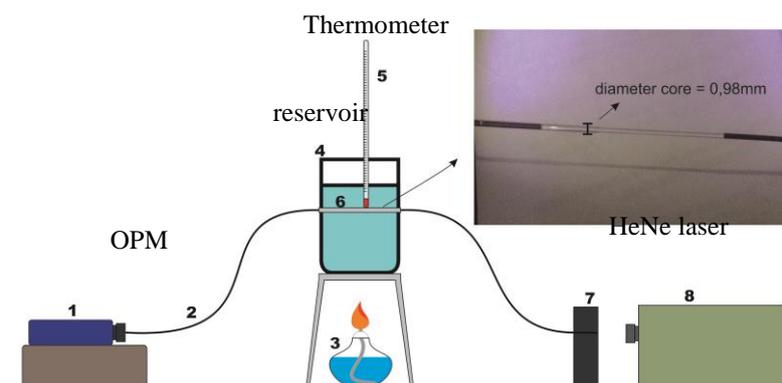


Figure 2. Scheme of experiment set up

3. Result and Discussion

Figure 3 presents the changes in the output intensity of the optical fiber as a function of changes in ambient temperature. Figures 3a, b, c, and d are for sensors with cladding of *madurasa*, *longan*, *madujago* and *pracimantoro* honey respectively. The data are taken at the time of increase and decrease in temperature.

The results show the consistency of the output intensity value when the temperature is raised and lowered. Fig.2 shows that highest attenuation at room temperature of 20°C was shown by fiber optic with *Madurasa* honey as cladding.

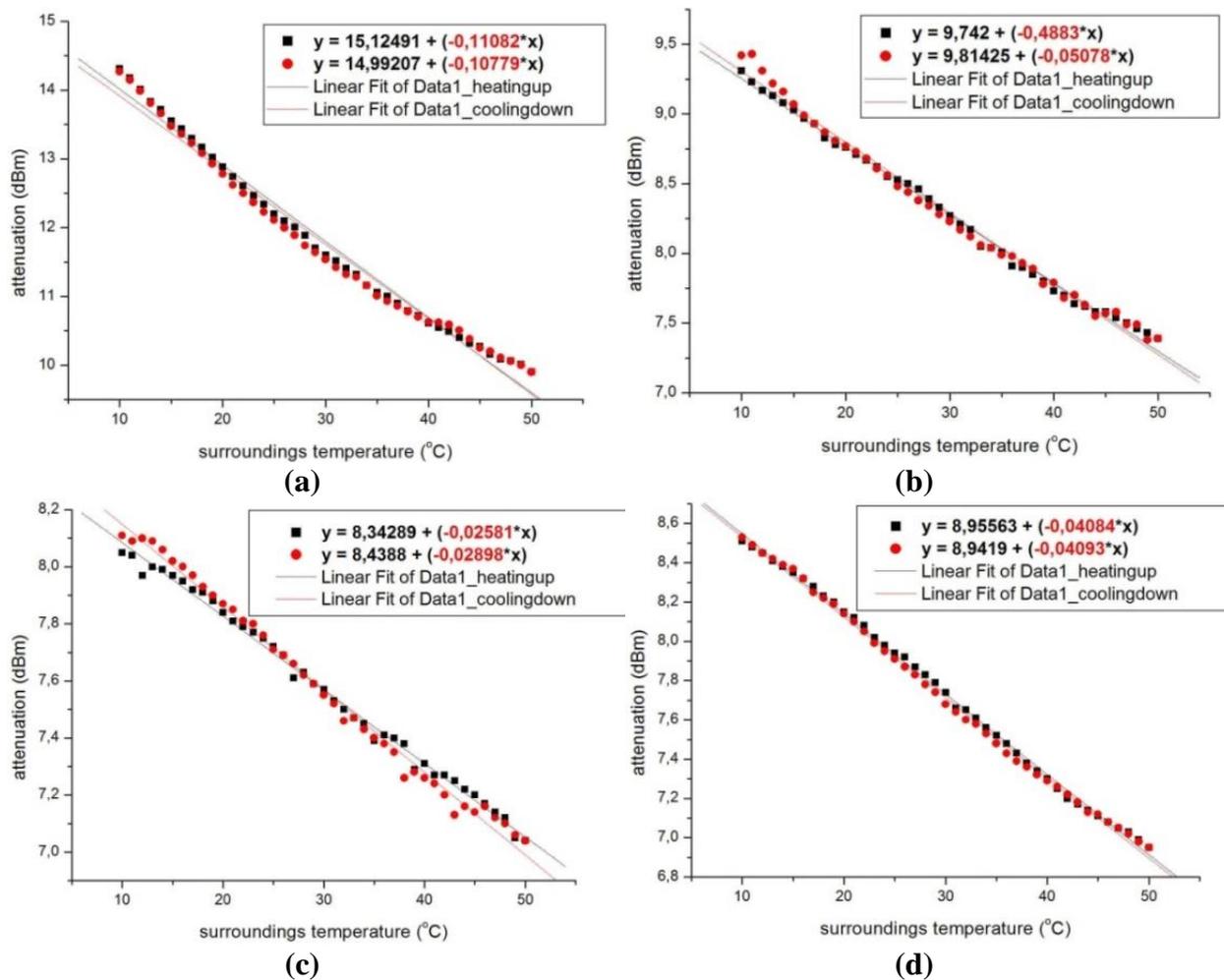


Figure 3. Output power attenuation of fiber optic with various honey cladding at various surroundings temperature. (a) madurasa honey, (b) longan honey, (c) madujago honey, (d) pracimantoro honey

Sensitivity is the changes in the output for every smallest input changes. For any linear element, sensitivity could be determined by its gradient ($\Delta y/\Delta x$). Table 2 showed the gradient value of graph which was obtained by linear fitting of *Origin* software. If the determination coefficient (R) approaching to 1, then both variables have a linear relationship. At Table 2, minus sign (-) show that the graph is decreasing linearly.

Table 2 shows that from all kind of honey in this experiment, the highest sensitivity was shown by madurasa honey with the gradient of $(0,1108 \pm 0,002)$ in the heating process, and $(-0,1078 \pm 0,003)$ of cooling down. However, best linearity was shown by pracimantoro honey with the determination coefficient of $(-0,99909)$ in heating process and $(0,99283)$ of cooling down.

To confirm the effect of this type of honey, we also measured its refractive index. Table 3 showed the refractive index of some honey that was used as cladding. Furthermore, the critical angle of fiber optic was compared to the angle of the incoming ray to know whether the ray through the cladding or reflected back to the core.

Table 2 Sensitivity and linearity of honey as fiber optic cladding

Honey	Sensitivity (dBm/°C)		Linearity	
	Heating	Cooling	Heating	Cooling
<i>Madurasa</i>	- (0.1108 ± 0,002)	- (0.1078 ± 0,0030)	- 0.99283	- 0.98956
<i>Longan</i>	- (0.0488 ± 0,0005)	- (0.0507 ± 0,0009)	- 0.99773	- 0.99455
<i>Madujago</i>	- 0.0258	- 0.0289	- 0.99726	- 0.99625
<i>Pracimantoro</i>	- (0.0408 ± 0,0003)	- (0.0409 ± 0,0003)	- 0.99909	- 0.99877

Table 3. Refractive index of some medium and critical angle when it was used as cladding

Medium	n_{core}	$n_{cladding}$	θ_i (°)	NA	θ_{crit} (°)
Fluorinated Polymer	1.49	1.4100	87.4	0.48	71.14
<i>Madurasa</i> honey	1.49	1.4901	87.4	-	-
<i>Longan</i> honey	1.49	1.4849	87.4	0.12	85.26
<i>Madujago</i> honey	1.49	1.4765	87.4	0.20	82.28
<i>Pracimantoro</i> honey	1.49	1.4821	87.4	0.15	84.10

In fiber optic with honey cladding, even the laser rays were reflected back to the core; however, still, there is attenuation of the output. This is because the rays which are traveled through fiber optic interact with honey cladding by the evanescent wave. Evanescent wave was penetrated the cladding medium and traveled along fiber optic. Moreover, with the changes of cladding refractive index, it will affect the penetration depth of evanescent wave through the cladding medium (d_p). Table 4 shows the penetration depth of evanescent wave through varied honey cladding

Table 4. Penetration depth of evanescent wave

Cladding	λ (nm)	$\sin^2\theta$	n	Penetration depth (nm)
Fluorinated Polymer	632.8	0.998	0.946	297.77
Longan honey	632.8	0.998	0.997	1452.31
Madujago honey	632.8	0.998	0.991	789.46
Pracimantoro honey	632.8	0.998	0.995	1085.44

4. Conclusion

Honey cladding and temperature changes affect the internal reflection and optical fiber output intensity. Greatest output intensity changes at 20°C was shown by optical fiber coated by *Longan* honey as cladding. The range of 10-50° C, as the rise of surroundings temperature, the attenuation is getting smaller. Best sensitivity was fiber with sensing part coated by *Longan* honey. Best linearity was sensing fiber with sensing part coated by *Pracimantoro* honey.

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