

Surrounding refractive index and liquid based sensors using fibre bragg grating

Nurul Shuhada Tan Halid¹, Suzairi Daud^{1,2}, Siti Nur Aizatti Rohizad¹, Esmafatinsyafiq Multar¹ and Abdull Rahim Mohd Yusoff³

¹ Department of Physics, Faculty of Science, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.

² Laser Center, Ibnu Sina Institute for Scientific & Industrial Research, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.

³ Department of Chemistry, Faculty of Science, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.

Abstract. Fiber Bragg grating (FBG) becomes one of the favourable sensing elements in current technology. In this study, FBG was chosen as the temperature sensor to validate the performance in different liquid samples and surrounding refractive index (SRI). FBG was chosen for the purpose due to its super sensitive sensor, low in cost, minimal of data loss, and other outstanding advantages. The experiment was done in difference sample of liquids, SRI, and condition. The sensitivity of FBG in air, water, and stingless bee honey were recorded at 10.6892 nm/°C, 10.6247 nm/°C, and 13.3985 nm/°C respectively. It shows that FBG is suit as a temperature sensor in different medium and SRI.

1. Introduction

The surface temperature measurement is very any important for monitoring devices and apparatus. This parameter allows us to monitor the condition from time to time. Some devices do not give any warning if they have problem for example CT scan in the hospitals. When the temperature is monitored, the user safety will be taken care of. It is included in the various field for example factory, medical and laboratory where big and high risk machine where used. Methods for surface temperature measurement are divided into two categories: non-contact measurement methods for example infrared radiation thermometer, while for contact measurement methods are thermocouple and thermal resistor. When the temperature rises, the fuse will burn out and produce smoke or bad smell that can be easily detected and can alarm the people. When the system is not working and not gives any warning then the problem is not detectable. Machine will warn through temperature where the temperature will rise when there is damage to the system, some of them was installed with radiator to cool the system. The temperature of the water coolant system determines the “health” of a system. If the coolant system is not working the temperature will rise and affect the performance quality. Temperature is one of the vectors which the differences cannot be measured by observation. It must have standard medium to see the changes or device to measure the temperature.

The purpose of this study is to provide a stable system that can measure the temperature in the surrounding and water by using fiber Bragg grating (FBG) sensor. The FBGs is selected because this fiber optic has low attenuation and very sensitive to temperature changes [1]. It can give accurate



measurement of temperature by measuring its wavelength shift. The temperature monitoring might be different depend on the surrounding. The sample use in this study was air, water and stingless bees honey. In the case of stingless bees honey, the temperature monitoring system is use to determine the quality after expose to high temperature. The stingless bees honey is known as one of the additional health supplement. This research can determine the maximum temperature that will cause the quality to drop. It is important to know the optimum temperature for storing honey and which temperature can reduce the quality of honey.

2. Theory

FBG use light as a medium to transfer the information [2]. It is chosen because due to its high heat resistant, immune to electromagnetic wave, more safe (compare to other devices) and has high accuracy when measure temperature [3]. FBG work by transmit and reflect the spectra to send information to the detector [4].

FBGs are a kind of tool made from fiber optic, where a small portion of FBG is exposed to UV light. Only certain wavelength can be transmitting from the original source of wavelength. The rest of the wavelength will be reflected back. This specific wavelength is called Bragg wavelength.

Bragg wavelength is expressed as

$$\lambda_B = 2n\Lambda \quad (1)$$

where λ_B the Bragg wavelength, n is the refractive index of materials and Λ is the period of index modulation. Temperature is measured by using the expression

$$\Delta\lambda_B = \lambda_B(1 + \xi) \Delta T \quad (2)$$

where ΔT is the temperature changes, $\Delta\lambda_B$ is Bragg wavelength shift, and ξ is the thermo-optic coefficient [5,6].

3. Methodology

The experiment set up shown in Figure 1 is to characterize the FBGs grating. It is use to measure its behaviour in air and water. The refractive index of air, water, and stingless bees honey at STP are 1.00029, water is 1.3333 and stingless bee honey is 1.4649 respectively. The same FBGs will be use to determine the wavelength shift in air, water, and stingless bees honey. The thermocouple is use to measure the temperature of the surrounding and solutions. The solution is used as the medium to transfer heat to FBGs. FBG is exposed in the hot surfaces and the heater is turned on until reach 100 °C. The Bragg wavelength is recorded. The experiment is repeated by using water as medium. Thermocouple is use as a comparison after the temperature calculation by the FBG sensors. After the wavelength shift recorded for surrounding air, the experiment is repeated by using water.

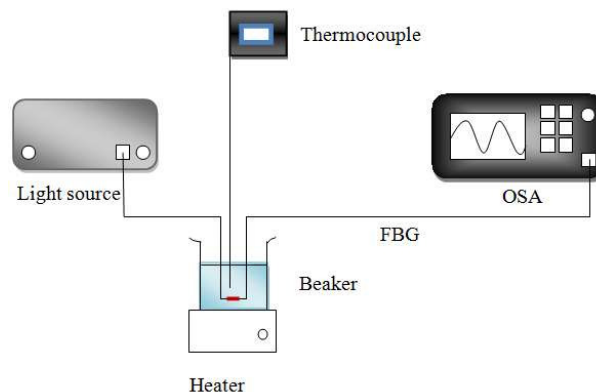


Figure 1. The experimental set up.

4. Results and Discussion

FBG is exposed and immersed together with the temperature sensor or thermocouple so that the temperature can be measured more accurately. The Bragg wavelength is recorded to obtain the center wavelength. The linear graphs formed prove that the theory as the temperature increase, the Bragg wavelength will continue to shift to the right. The Bragg wavelength will continue to shift when the higher temperature is applied.

Table 1. The comparison of the tabulated data for the FBG in air, water and stingless bee honey.

No.	Temperature (± 0.1) $^{\circ}\text{C}$	Bragg wavelength, in air (± 0.01) nm	Bragg wavelength, in water (± 0.01) nm	Bragg wavelength, in honey (± 0.01) nm
1	23	1540.88	1540.88	1529.96
2	25	1541.08	1540.92	1529.96
3	30	1541.56	1540.96	1530.04
4	40	1541.82	1541.04	1530.16
5	50	1542.32	1541.16	1530.28
6	60	1542.10	1541.28	1530.44
7	70	1542.48	1541.36	1530.56
8	80	1542.88	1541.48	1530.72
9	90	1543.04	1541.60	1530.84
10	100	1543.28	1541.68	1530.96

Figure 2 shows that the graph for all medium is linear. It shows that the FBG that expose in the hot air in different temperature cause the different measurement in Bragg wavelength. The sensitivity of the FBG in air, water and stingless bees honey is 10.6892 pm/ $^{\circ}\text{C}$, 10.6247 pm/ $^{\circ}\text{C}$ and 13.3985 pm/ $^{\circ}\text{C}$ respectively. The sensitivity is changes when the refractive index is different. This is due to the different in the refractive index of the medium.

Figure 3, 4 and 5 shows the waveform of FBG in varies temperature. The temperature varied from 23 $^{\circ}\text{C}$ until 100 $^{\circ}\text{C}$. The graph shows the waveform shift to the right when the temperature increases, indicates that the shifting occurs on the Bragg grating of the FBG when the temperature is applied on it. With this measurement, the research can be carried out to produce FBG as a temperature sensor or optical fiber thermometer.

When the FBG is heated, the central will experience a red shift but will return to its original wavelength when the temperature returns to room temperature. The shifting of the Bragg wavelength from left to right proves the Fresnel reflection [7,8]. When the refractive index or physical dimension of wave guiding core is vary, the different periodic modulation of the refractive index can be obtained. The shifting is showing that the sensitivity is high even low increment of temperature [9,10].

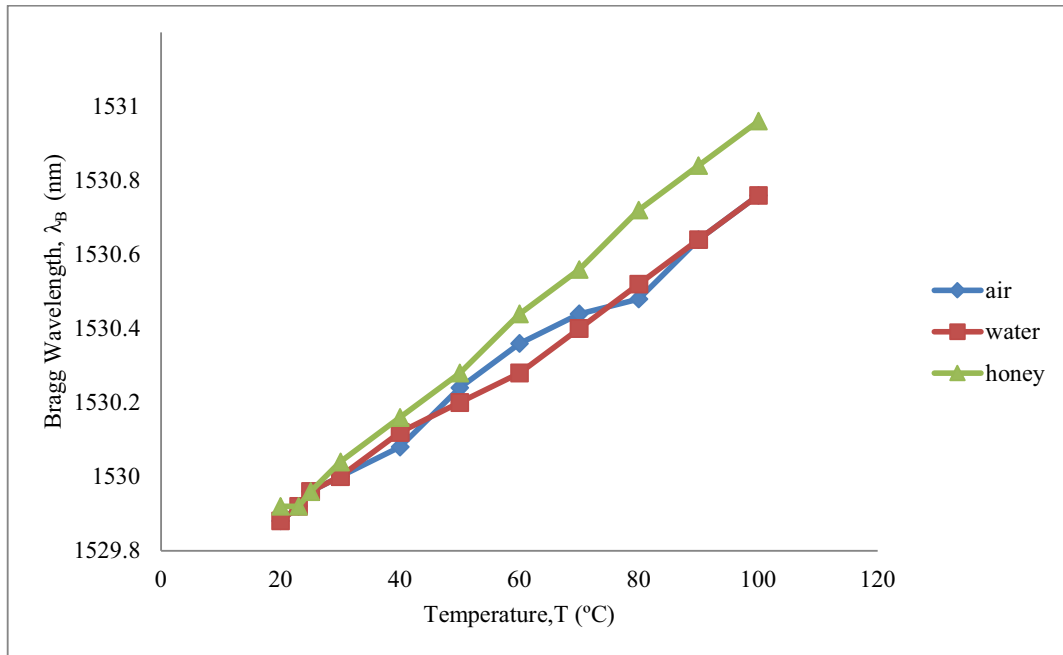


Figure 2. Graph of temperature versus Bragg wavelength.

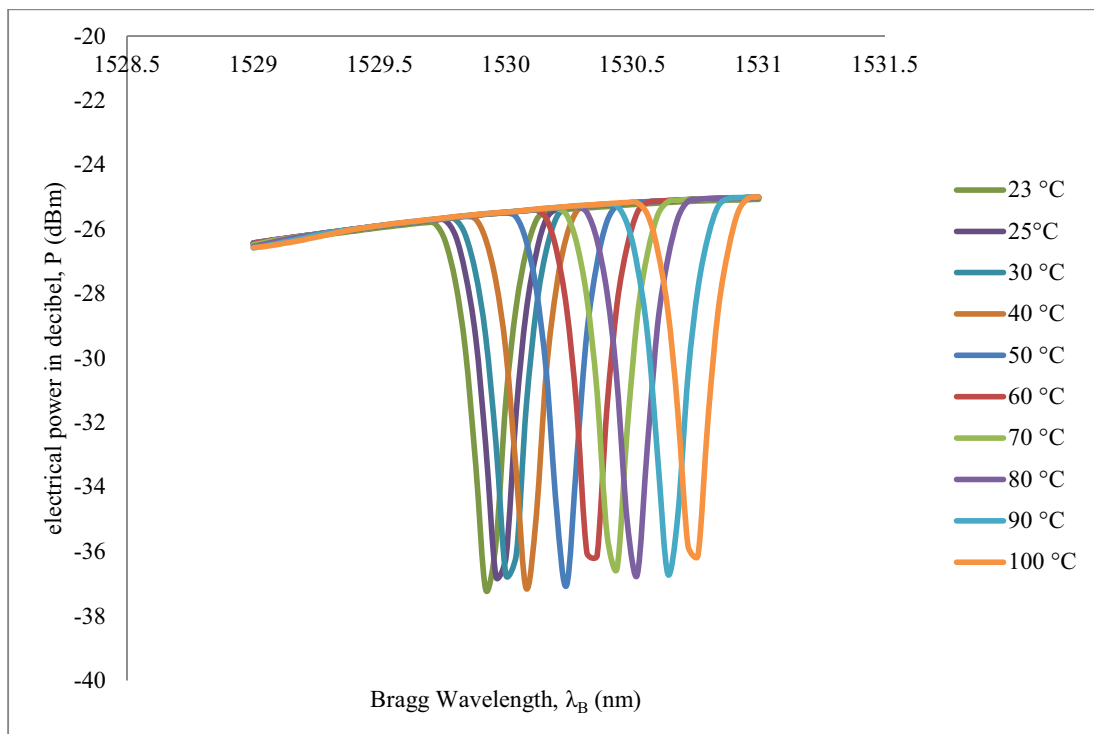


Figure 3. The waveform for FBG in air.

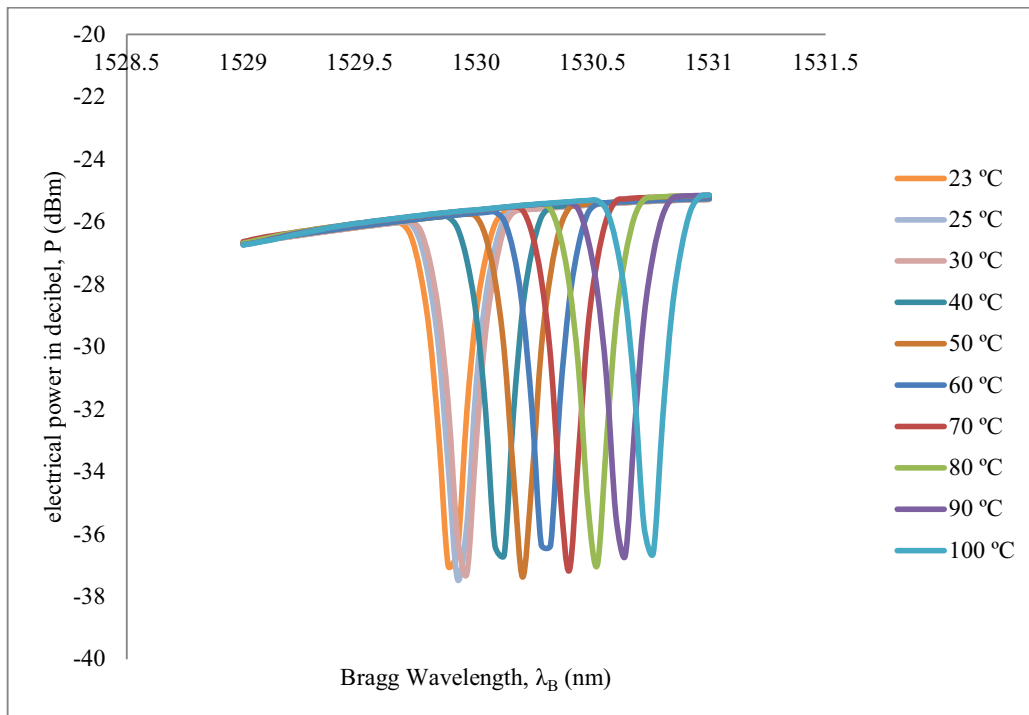


Figure 4. The waveform of FBG in water.

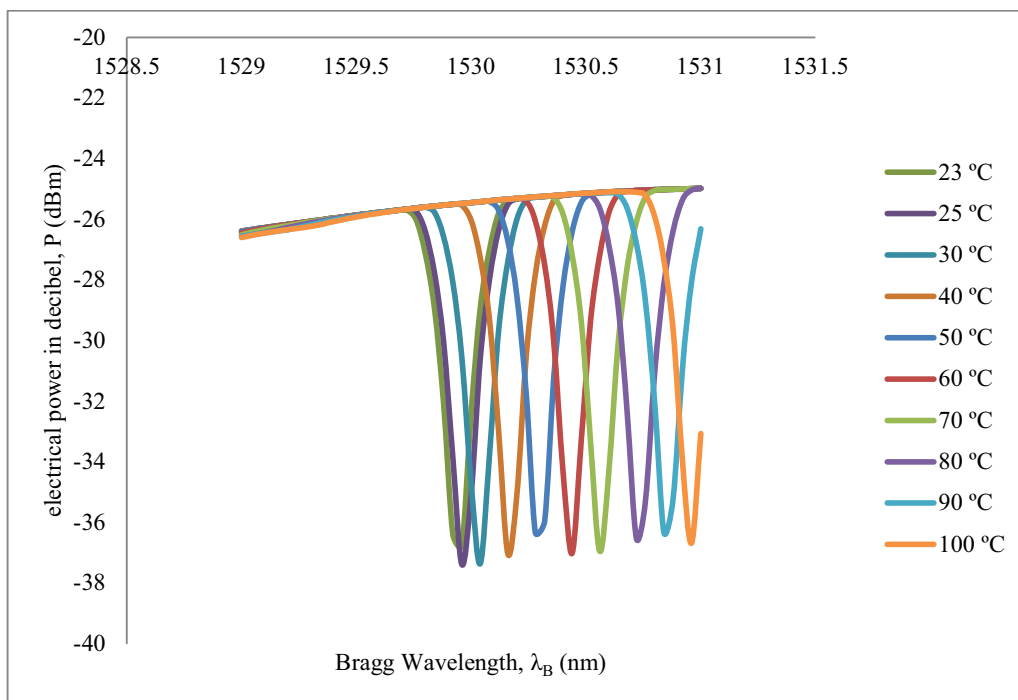


Figure 5. The waveform of FBG in stingless bee honey.

5. Conclusions

Results show that there is a linear relationship of the Bragg wavelength shift when the different temperature is applied on the FBG. This results shows that the FBG is suitable as a temperature sensor in any condition, medium or solution. The wavelength shift to the temperature changing make the FBG as a suitable device/ sensor to monitor the temperature because of the accuracy when the temperature changes.

FBG also suitable to replaced the electrical devices and use to as the surface monitoring. It gives a lot of benefit since it can be use in various environments. The thermal expansion also stable compare to the other instrument. The future research can be included for the FBG as a multisensor in any environment.

Acknowledgement

Authors like to acknowledge Universiti Teknologi Malaysia for supporting this research via TDR grant vot. no. 07G29.

References

- [1] Zheng X, Bremer K, and Roth B 2018 *Sensor (Basel)* **18** 1436
- [2] Rosli E and Mohd Noor U 2018 *Materials Science and Engineering* **340** 012020
- [3] Hirayama N and Yasukazu S 2000 *ISA Transaction* **39** 169-73
- [4] Daud S, Abd Aziz M S, Chaudhary K, Bahadorana M and Ali J 2016 **78** 277–80
- [5] Kadhim S A, Taha S A A, and Resen D A 2015 *Int J Innov Res Sci Eng Technol* **4** 8038-43
- [6] Daud S, Noorden D A, Aziz M S, Chaudhary K, Bahadoran M and Ali J 2015 *J. Comput. Theor. Nanosci.* **12** 5778–80
- [7] Werneck M M, Allil R C S B, Ribeiro B A and de Nazaré F V B 2013 *Current Trends in Short- and Long-Period Fiber Gratings*, ed C Cuadrado-Laborde (Rijeka: InTech) 1-24
- [8] Yuan J, Zhao C, Ye M, Kang J, Zhang Z, and Jin S 2014 *Photonic Sensors* **4** 48–52
- [9] Campanella C E, Cuccovillo A, Campanella C, Yurt A K and Passaro V M N 2018 *Sensors* **18** 3115
- [10] Kim B G and Garmire E 1992 *Appl. Opt.* **31** 5099-101