Label-free Biosensor Based on Photonic Crystal Microcavity for MalariaDetection with High Sensitivity

Bounaas Faiza*, Labbani Amel

Laboratory of Hyperfrequency and Semiconductors, Department of Electronics Faculty of Science and Technology, University of Frères Mentouri Constantine1, Constantine Algeria

*Corresponding Author

INTRODUCTION

The majority of deaths occur in tropical countries is due to Malaria disease. The people infected by this malady caused by a parasite will have severe complications like anemia, cerebral Malaria, organ failure, etc. Several technologies have been developed for detecting Malaria. Label-free optical biosensors have received considerable attention due to their contribution to significant advances in medical diagnostics and chemical and biochemical applications. One-dimensional photonic crystal (1D PC) optical biosensors have attracted the most interest of many researchers because they open the possibility of controlling and manipulating light in confined space. In addition, they have received significant attention owing to their high sensitivity, reliability, and short detection time. For this reason, we have investigated a highly sensitive biosensor based on a 1D PC platform for detecting Malaria disease at an early stage. The proposed device comprises an endlessly repeating stack of silicon (Si) and water layers with one defect cell containing the sample to be monitored. The obtained structure has the following sequence (Si) $(water/Si)^N$ $D(Si/water)^N$(Si), where D and N are the cavity layer and the period number, respectively. The sensing principle is based on varying the refractive index of the analyte. When the blood sample is infiltrated into the cavity, the spectral position of the wavelength peak shifts to the shorter wavelength.

THEORETICAL STUDY

We have theoretically analyzed the defect mode transmission properties of the suggested biosensor design using the transfer matrix method (TMM). The TMM of a single layer is expressed as:

$$M_i = \begin{bmatrix} \cos d_i \varrho_i & -\left(\frac{i}{P_i}\right) \sin d_i \varrho_i \\ -i\, P_i \sin d_i \varrho_i & \cos d_i \varrho_i \end{bmatrix} \quad (1)$$

where *i* represents the Si layer, water layer and D microcavity cell. The matrix of the entire structure is the product of such matrices $M_{Si}(M_{water}/M_{Si})^N\, M_D(M_{water}/M_{Si})^N M_{Si}$

The transmittance coefficient t can be given as:

$$t = \left|\frac{2P_0}{(Q_{11}+Q_{12}P_0)P_0+Q_{21}+Q_{22}P_0}\right|^2 \quad (2)$$

RESULTS AND DISCUSSION

In this section, we present the numerical results of our biosensor design. The structure is expressed as $M_{Si}(M_{water}/M_{Si})^N\, M_D\, (M_{water}/M_{Si})^N M_{Si}$. The refractive indices of Si and water are 3.4 and 1.33, respectively. The thicknesses of all the layers are given to be quarter-wavelength ($\lambda_0/4$), which λ_0 is

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equal to 1550nm. In our model, the defect layer's thickness is assumed to be 550 nm. Such defect is filled with blood samples with a different refractive index of the healthy and infected person corresponding to different stages of malaria infection. Fig. 1 depicts the transmission spectra for normal and infected cells at different stages of Malaria. From this figure, we noticed that as the refractive index (RI) decreases, the resonant peak shifts towards a shorter wavelength. The refractive index and the resonant peak position calculated by TMM are shown in Table 1.

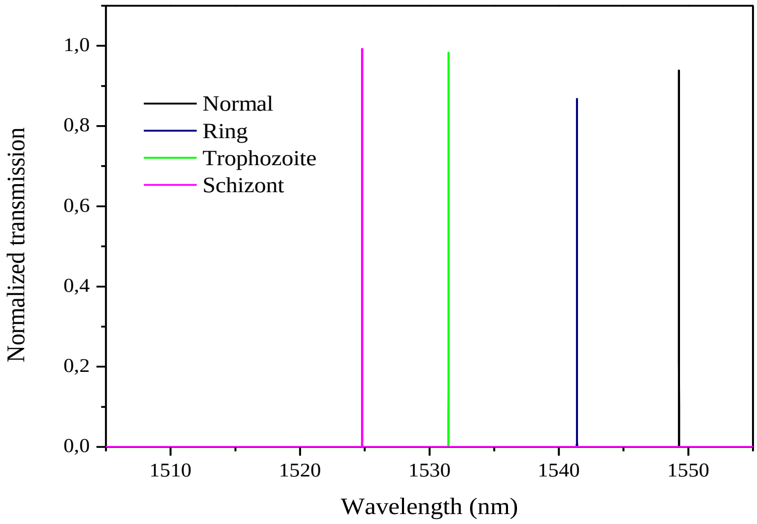

Fig. 1 transmission spectra at different stages of Malaria

Table 1. The refractive index of Malaria stage and the resonant wavelength

Malaria stage	RI	Wavelength(nm)
Normal stage	1.408	1549.283
Ring stage	1.396	1541.398
Trophozoite stage	1.381	1531.466
Schizont stage	1.371	1524.8

CONCLUSION

This paper investigates a highly sensitive refractive index for Malaria diagnosis based on the 1D-PC platform. TMM method is used to demonstrate the performance of the presented device. From the result of the numerical simulations, it is found that the variation of the analyte's refractive index leads to the shift of the resonant mode. The shift in the transmittance peaks varies from 1549.283 nm to 1524.8 nm. Therefore, the proposed biosensor offers a high sensitivity of 657.083 nm/RIU, the quality factor of $7.17\times10^{5}$and detection limit of 2.72×10^{-7}. The obtained results are much better than similar devices[1]. Therefore, they can be used to design highly sensitive PC biosensors. In addition, the suggested device is easy to fabricate with low operating costs.

REFERENCES

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