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Detection of liver Cancer using Lab-On-Chip Based Optical Biosensor by Nano Cavity Sensing Hole

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Abstract: ***The paper includes the Nano cavity Implementation of the biosensor in the two stages of the cancer including the primary and the secondary. The key challenge in the work is to provide the accuracy with the sensors and the results by communicating the medical reports to the doctors or patient. By imposing the requirement to the modern development in challenging the medical aspects with the Nano Plasmon execution. The Photonic Crystal model simulation is done in the 2D model of Holes-In-Slab with change in the refractive index in selected sensing hole. The refractive index material of the normal cancer by combining the refractive index of the primary and secondary stage in order to know the tissue is cancerous or non-cancerous. Six different sensing holes are considered with six different RI Sensitivity and Quality factors for different sensing holes for different cancerous tissues are investigated. The overall quality factor obtained is 123400 μm/RIU for 1550 nm of wavelength. High quality factor is obtained from the H4 holes in the slab of nearly of 2250 and sensitivity of 0.95nm/RIU.***

Keywords : Quality factor, Biosensors, Refractive Index, Photonic Crystal, Early stage Diagnosis.

I. INTRODUCTION

The Cancer is most extensively increasing and spreading very rapidly. It is found that nearly more than 200 out of 400 men and women suffer from cancer. The normal tissue in the human body also consist of a cancerous and non-cancerous tissue. The lung cancer consists of the normal and abnormal tissue, but the abnormal tissue is of two types the primary stage and the secondary stage[1]. The primary consists of Hepato cellular carcinoma which again has a cancer or non-cancer tissue mostly these cancer starts effecting from the lungs.

The lungs usually have the cancer occurring due to smoking or inhaling some gases. The secondary stage is the Liver Metastasis these is the malignant type of the affected cancer caused from other organs of the body they also have the special factor of affected and non-affected tissue these tumour spreads on the lung and also called as the secondary lung cancer. The rate of surviving is very less nearly 4 years and the death rate are high, in this case, it can be cured only in the early stage. Diseases like Cholera & Tuberculosis occurs in the Cancer due to lungs, these diseases form in the lungs which cause bleeding from mouth. Primary stage is little different when compared to the secondary stage. Malignant tumour can be classified into two separate types viz. Primary and Secondary. Primary liver tumour originates in the liver. Secondary liver tumour originates somewhere else in the body and spreads to the liver. There is a need to differentiate between Primary and Secondary Cancer. In secondary Liver Cancer, the Cancer must be treated according to the treatment options for the primary Cancer[2]. For example, if a person is diagnosed with primary cancer that has spread to the liver, the treatment plan should focus on treating primary colon cancer rather than primary liver cancer. There are four stages of cancer, stage I II III IV, stage I and II are the early stage and cancer can be cured but the stage from III and IV cannot be cured they are almost the last stage and are so harmful that the patient can also die. The radiology, MRIL, city scan, X-ray tests are done to exactly validate weather the cancer which effected lungs is spread on the other parts of the body or not. These tests take longer time and very dangerous to the suffering person. The detection has to be done at the early stage with minimum time so that person can undergo treatment.

II. PROPOSED STRUCTURE

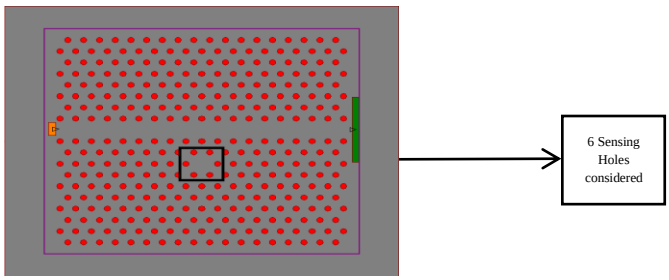

Figure 1. Sensing holes considered during the analysis in Photonic crystal biosensor.

Nano cavity Photonic Crystal Biosensor for different cancerous tissue is analyzed in different sensing holes. Figure 1 shows one hole in slab configuration with a hole is omitted to create Nano cavity in Photonic crystal biosensor. In this sensor waveguide is created by eliminating rows of hole for Optical pulse[3]. Sensitivity and Quality factor for different sensing hole for different cancerous tissues are investigated here.

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Figure 1 shows Nano cavity holes which are considered during the analysis. Six holes are considered during the analysis are H1, H2, H3, H4, H5, H6. Each sensing holes are investigated for different cancerous tissue stages like Cancerous (Hepato cellular carcinoma), Non-cancerous (Hepato cellular carcinoma), Cancerous (Liver metastases), Non-Cancerous (Liver metastases). All the infected tissues are compared with normal tissue. Figure 2(a), (b), (c), (d), (e), (f) shows index profile distribution for different sensing hole in blue colour.

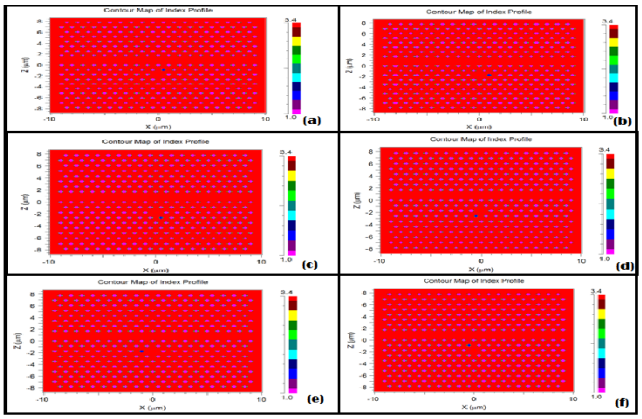

Figure 2. Material profile of sensing holes H1,H2,H3,H4,H5,H6

The Figure 2 (a)(b)(c)(d)(e)(f) depicting the six different holes where in each if the hole the refractive index with exact value and thickness is also mentioned [4]. The H1,H2,H3,H4,H5,H6 are following with normal cancerous and normal non-cancerous, Non-cancerous, cancerous (Hepato cellular carcinoma) Primary Stage, Non-cancerous, cancerous (Liver Metastasis) Secondary stage.

Table 1: Parameters considered during the analysis

Radius of Holes	0.2µm
Lattice constant	1µm
Sensing holes considered in holes	H1,H2,H3,H4,H5,H6
Cancer stages	Normal tissue, Non-cancerous, cancerous (Hepato cellular carcinoma) Primary Stage, Non-cancerous, cancerous (Liver Metastasis) Secondary stage

III. DESIGN AND OPTIMISATION PRINCIPLE

The main reason of this biosensing application is to develop a particular sensor that can detect the affected area with a particular set of the tissue and thus to produce the accuracy that is present in the biosensors which is made to be implemented in Lab-On-Chip [5] under the concept of the defect engineering Plasmon based sensors has gained attention of the researchers across the world. PC is characterized by periodic arrangement of rods (for rods in air) or holes (for holes in slab). The benefit of using PC is that by modifying the size and location of the holes/rods in the lattice structure, the output spectrum, can be modulated to reach values which are impossible with traditional optical sensors based devices. PC provide solution for practical applications where monitoring of Refractive Index(RI) changes is important, such as, monitoring of changes in complex structures bio analytes[6].

$K = \sqrt{kx^2 + ky^2 + kz^2}$

$K = n\frac{2\pi}{\lambda} = n\left(\frac{\omega}{c}\right)$

λ and c are the wavelength in vacuum.

Refraction of two wave in a medium 1 & 2

The R.I is n_1 and n_2

$K_2 = 0$ (Now only 2D)

$k_{spp} = k' + ik''$

Where $k' = \frac{\omega}{C}\sqrt{\frac{\varepsilon_m'\varepsilon_d}{\varepsilon_m' + \varepsilon_d}}$

$k'' = \frac{\omega}{C}\sqrt{\frac{\varepsilon_m'\varepsilon_d}{\varepsilon_m' + \varepsilon_d}}\left(\frac{\varepsilon_m''}{2(\varepsilon_m')^2}\right)$

ε_m' - Dielectric constant of the Real part in the metal

ε_m'' - Imaginary part of the dielectric material

k′ - Propagation efficiency

k″ - Imaginary part of propagation constant

V SIMULATION RESULTS

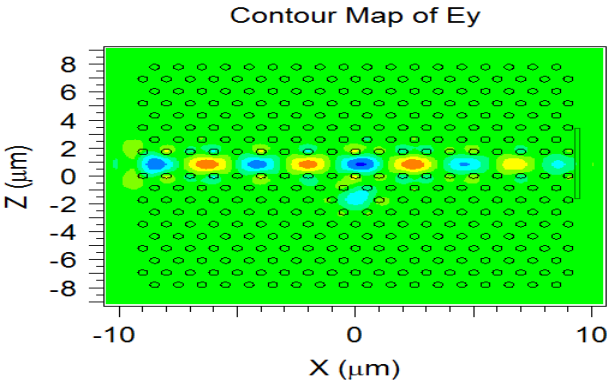

Figure 3. Light confinement in the waveguide and Nano resonator

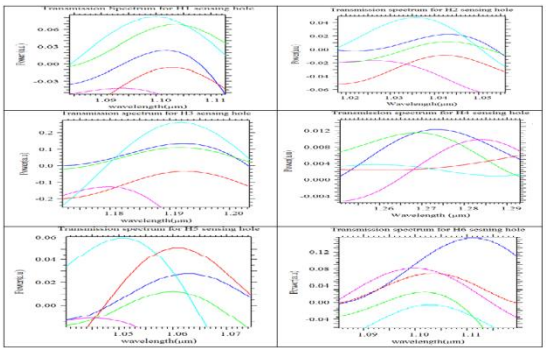

Figure 4.Transmission spectrum for H1, H2, H3, H4, H5, H6 sensing hole.

In the Figure (4), it is observed that the transmission spectrum for different sensing holes having the different indication the dark blue line indicates the cancerous tissue in the Liver metastases [7].

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The green line indicates the non-affected cancerous tissue of the Hepato cellular carcinoma. The red line indicates the non-cancerous tissue in the liver metastases. The blue line depicts the normal tissue that has been affected by the cancer. The cancerous tissue in the magenta line is the Hepato cellular carcinoma.

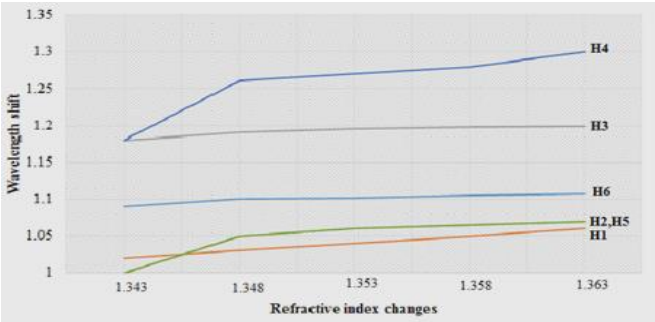

Figure 5.High sensitivity in H4 sensing hole.

From the analysis, it is observed that distinct shift in wavelength is observed different sensing holes. Figure (4) and Figure (5) shows shift in wavelength for different cancer stages in different sensing holes due to changing effective refractive index values for injecting different bio samples in holes in slab configuration [8]. Choosing H4 sensing hole for different sample remarkable shift in wavelength is observed compared to other sensing holes. High quality factor of 2250 and sensitivity of 0.95nm/RIU is obtained for H4 sensing hole.

Table 2: Peak Wavelength and Quality factor for different Sensing hole

Wavelength Range	Normal Tissue (R.I)	Hepato Cellular carcinoma (Primary Stage)		Liver metastasis (Secondary stage)	
		Cancerous (R.I)	Non-Cancerous (R.I)	Cancerous (R.I)	Non-Cancerous (R.I)
1550nm	**1.362**	**1.343**	**1.361**	**1.347**	**1.345**

From the Table 2, the wavelength ranging in 1550 nm is the most suitable for high sensitivity and quality factor. Refractive index of each of the sample is given in the table. Suppose the RI matches falling with its necessary characteristics then the optical meter will show the sensing hole that is not matching the requirements[9]. The normal tissue RI is 1.362 in case the RI is not matching then they are said to be cancer affected. Among the two stages the primary stage is also having the similar kind of the concept the RI of the cancer contained stage is 1.343 if it exceeds 1.361 the primary stage become non-cancer tissue. The Liver metastasis in the secondary stage RI is 1.347 and the non-cancer value is 1.345.

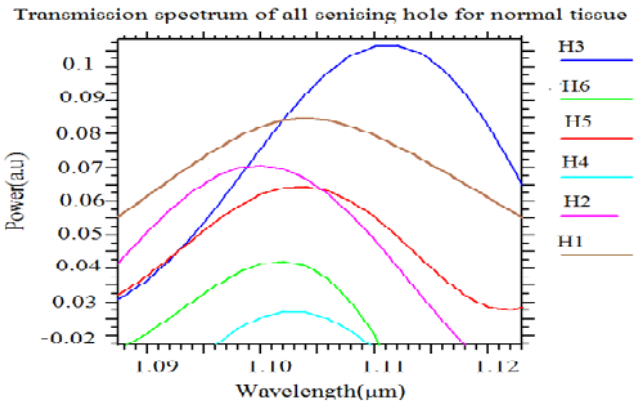

Figure 6.Wavelength shift for H1 sensing hole.

From the Figure 6, the free-space-wavelength of the overlapping graph in which the sensing hole of every shift. It is being observed that the graph depicts all the RI related values in the particular sensors Sensor designed with the plasmonic technology should be able to detect small variation in the R.I. values of the analyte. In the figure 6, we can see that, as we change the refractive index value of the analyte in the sensor we can observe the shift in the wavelength and we can also observe different output power for different R.I. values[10].

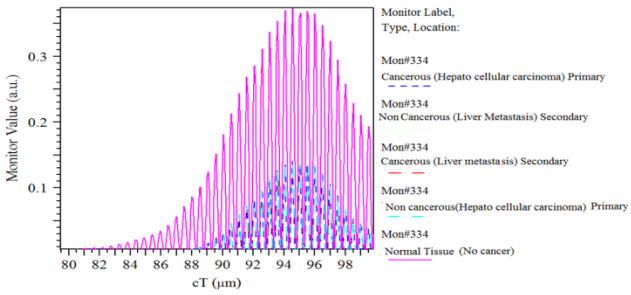

Figure 7. Monitor w.r.t distance travelled by light along waveguide

The Figure 7 depicts the observance of the graph by keeping the monitor at different levels that is being calculated and observed with respect to the light travel in the sensors. The graph shows that as the extinction coefficient of the gold is increased the absorption of light also increases simultaneously up to some extend of applied extinction coefficient. The absorptivity decreases with the increment in the extinction coefficient by thus witnessing the sensitivity towards the RI variation in the sample. The extinction co efficient will also corresponds to the negative refractive index and also called as attenuation constant.

IV. TABLES

Table 3: Wavelength shift for different cancer type in H1 sensing hole

Sensing Hole	Wavelength shift	Quality factor
H1	1.100	550
H2	1.035	1030
H3	1.190	1400

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H4	1.280	2250
H5	1.050	1350
H6	1.120	850

Table 4 : Wavelength shift for different cancer type in H1 sensing hole

Cancer type	Wavelength (nm)	Monitor Power (a.u)
Normal tissue	1.098	0.07
Cancerous (Hepato Cellular carcinoma)	1.090	-0.05
Non-Cancerous (Hepato Cellular carcinoma	1.100	0.06
Cancerous (Liver metastasis)	1.102	0.01
Non-Cancerous (Liver metastasis)	1.104	-0.01

Table 5: Wavelength shift for different cancer type in H2 sensing hole

Cancer type	Wavelength (nm)	Monitor Power (a.u)
Normal tissue	1.030	0.045
Cancerous (Hepato Cellular carcinoma)	1.025	-0.02
Non-Cancerous (Hepato Cellular carcinoma)	1.040	0.01
Cancerous (Liver metastasis)	1.045	0.015
Non-Cancerous (Liver metastasis)	1.043	-0.01

Table 6: Wavelength shift for different cancer type in H3 sensing hole

Cancer type	Wavelength	Monitor Power (a.u)
Normal tissue	1.190	0.30
Cancerous (Hepato Cellular carcinoma)	1.160	-0.15
Non-Cancerous (Hepato Cellular carcinoma	1.192	0.09
Cancerous (Liver metastasis)	1.193	0.11
Non-Cancerous (Liver metastasis)	1.194	-0.095

Table 7: Wavelength shift for different cancer type in H4 sensing hole

Cancer type	Wavelength	Monitor Power (a.u)
Normal tissue	1.250	0.0030
Cancerous (Hepato Cellular carcinoma)	1.285	0.0085
Non-Cancerous (Hepato Cellular carcinoma)	1.265	0.0078
Cancerous (Liver metastasis)	1.275	0.0110
Non-Cancerous (Liver metastasis)	1.290	0.0050

Table 8 : Wavelength shift for different cancer type in H5 sensing hole

Cancer type	Wavelength (nm)	Monitor Power (a.u)
Normal tissue	1.050	0.058
Cancerous (Hepato Cellular carcinoma)	1.045	-0.09
Non-Cancerous (Hepato Cellular carcinoma)	1.060	0.01
Cancerous (Liver metastasis)	1.070	0.025
Non-Cancerous (Liver metastasis)	1.050	0.05

Table 9 : Wavelength shift for different cancer type in H6 sensing hole.

Cancer type	Wavelength	Monitor Power (a.u)
Normal tissue	1.140	-0.02
Cancerous (Hepato Cellular carcinoma)	1.096	0.07
Non-Cancerous (Hepato Cellular carcinoma	1.100	0.01
Cancerous (Liver metastasis)	1.114	0.11
Non-Cancerous (Liver metastasis)	1.104	0.03

CONCLUSION & FUTURE WORK

The Photonic detection of the bio sensing application in the paper is discussing the parameter depends on the quality factor sensitivity and accuracy for the detection limit. The simulation in the paper is done in order to give the analogy on the work focused the observance of the entire simulation is done in a particular sensor using Lab-On-Chip, the result obtained is the actual result keeping the concept of reducing human effort.

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The analogy is made in such a way that single sensor can detect the lung cancer probability. This Biosensor will be very much useful in examining the cancer level in the human body, can be an interim part of the cancer security. The designed sensor is not only a boon for society but can also be immensely helpful in situation of biological warfare. The sensor can be fabricated on implementation of IC (Integrated Chip) as it is minimizing cost effective and even low power consumption no more dissipation can occur. Furthermore, enhancement in the device can also be done under necessary conditions.

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