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Realization of accurate blood glucose sensor using photonics based metamaterial

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ABSTRACT

A new method is proposed in present communication to investigate the concentration of glucose in human blood using photonic metamaterial structure at 2 GHz frequency. Here 3 × 3 air holes are etched on 2D photonic structure containing blood sample manipulates with the high frequency structure simulator software, where two types of structures such as silicon and polymer metamaterial are considered for the sake of validations. 2D finite element simulation method divulges that linear variation of S11 parameter and feeble absorption bestows an accurate measurement of glucose in human blood using aforementioned photonic structure.

1. Introduction

Prior to focus on technical content of present article, let us concentrate on world's most silent cancer disease called as diabetes. Diabetes a disease that occurs when your blood glucose and also called blood sugar is too high. It might be one of the most talked about diseases across the world and especially in India. As far as estimation of diabetic patient is concerned, International Diabetes Federation (IDF) estimates the total number of adult diabetics (aged between 20 to 79 years) all over the world at around 425 million. Further medical experts are anticipating that 9.9% of world population would be suffered from such dangerous disease by 2045 [1]. The amount of glucose presence in the blood plays vital role to realize either hypo or hyperglycaemia disease. Further various contemporary techniques are being employed now-a-days to estimate the amount of sugar in human blood. However the accurate estimation of different parameter related to human blood is a matter of concerned for today's research. Moreover several methods are being used to investigate the concentration of glucose.The current communication discloses a novel method to estimate the same using photonic metamaterial structure. As far as literature survey on similar type of investigation is concerned, reference [2] measures the concentration sugar, salt and alcohol in their aqueous solution using 2D photonic crystal structure. Further concentration of PAM hydrogel in their aqueous solution is estimated in reference [3] using similar type of structure. Further the amount of haemoglobin in human blood is obtained with the help of triangular photonic crystal structure and 3D structure in reference [4] and [5] respectively. Though the above said references deals with the computation of bio-medical parameters, absorption losses have not been considered in reference [2] and [3]. Though the accuracy of investigation is found satisfactory in these references, plane wave expansion method is widely used in all cases. Furthermore, plane wave expansion method manipulates with different

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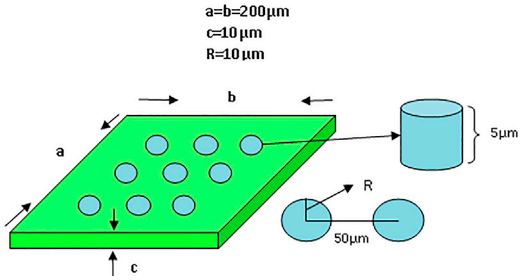

Fig. 1. Schematic diagram of 2D metamaterial structure.

structures in reference [6] to measure different blood related parameters. Even though plane wave expansion method is an apt technique for sensing application, no good agreement is fetched pertaining to complex structure. Nonetheless finite element method is pertinent method for both simple and complex structure as FEM deals with entire region for simulation. Keeping in view of accurate measurement of glucose in human blood, this paper employs a metamaterial structure to investigate the glucose concentration with the help of finite element method based HFSS (High Frequency Structure Simulator) software. To validate the output upshot corresponding to each concentration of glucose, we examines the same result by choosing two types of background materials of silicon and polymer material pertaining to 2 GHz signal.

2. Proposed structure and principle of operation

3×3 cylindrical air holes are etched on silicon and polymer substrate in such way that blood sample with different percentages of glucose shall be infiltrated inside the holes. The reason for choosing such background material is to realize an accurate investigation of glucose in blood sample. The proposed structure for same is shown in Fig. 1.

In above figure lattice spacing (α), radius and height of air holes is taken of 50 µm and 10 µm respectively. The reason for selecting such dimension is that accurate investigation is seen for both silicon and polymer background structure for estimating the glucose concentration. The principle of measurement is based on the linear variation of S_{11} and transmittance parameter with respect to different percentage of glucose in human blood. Further this paper also deals with the computation of absorption loss of silicon and polymer photonic structure pertaining to the input signal of 2 GHz frequency.

3. Result and analysis of simulation work

In this work, 2D photonic structure with having 3×3 air holes containing different percentage of glucose concentration deal with 2Dfinite element method to obtain S_{11} parameter of above said metamaterial structure with silicon and polymer as back ground material. S_{11} parameter is a well-known parameter and frequently employed in microwave region for solving the problems related to different frequencies. Moreover 1, 1 represents as signal is incident at port 1 and received at same port. Further extend to optical region; it is represented as reflectance parameter with respect to photonic structure at selected signal.

Recalling Section 2; S_{11} parameter is computed using high frequency structure simulator software (HFSS) for both Silicon and Polymer based metamaterial structure at frequency of 2 GHz signal. To obtain S11 parameter (reflectance), we set same input parameter to get an accurate result with respect to the same. The proposed input parameters are mentioned in tabular forms as follows [7]:

Aside nature of material, structure, dimension and manipulating signal including the parameters reflected in the Table 1 plays vital role to compute the reflected signal and absorption loss, which is indispensable to control the transmitted signal emerging from above mentioned structure. Again analysing the Table 1, first column represents the concentration of glucose

Table 1
Input Parameters for making simulation.

BGC (mg/dl)	Relative Permittivity $[\varepsilon_{r}]$	Equivalent Conductivity σ_e[S/m]
0	69.4325	1.4895
25	67.2436	1.4895
50	65.0547	1.4895
75	62.8658	1.4895
100	60.6768	1.4895
125	58.4879	1.4895
150	56.2990	1.4895
175	54.1101	1.4895
200	51.9211	1.4895
225	49.7322	1.4895
250	47.5433	1.4895