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Early detection of acute dehydration using one dimensional photonic device

Chittaranjan Nayak, Ardhendu Saha*

Department of Electrical Engineering, National Institute of Technology Agartala, Barjala, Jirania, PO-Tripura En, Agartala 799046, Tripura, India

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ABSTRACT

The present work has been focused on precise measurement technique of osmolality, total dissolved solids and specific gravity of human urine using diamond based one-dimensional photonic crystal structure. The photonic bandgap of the proposed structure has been computed using finite difference time domain method. Result showed that the linear relationship between key parameters with respect to output energy. During measurement of various samples using proposed biosensor, the sensitivity was found to be 0.09 which was comparably larger than the earlier report.

1. Introduction

One-third of the human body weight is due to body fluids [1]. Loss of body fluids, mostly water when it exceeds the amount that is taken in, causes dehydration. It has been reported that the death may be the one of the reason for acute dehydration. Therefore the early detection of dehydration is almost important in medical science. Dehydration leads to decrease in osmolality, specific gravity (SG) and total dissolved solids (TDS) contained in human urine [2]. The determination of above such parameters may be used as key parameters for early detection of dehydration. As refractive index varies with dissolve content of liquid, therefore the change refractive index (RI) can be used as tool for early detection of acute dehydration. The change in RI of any liquid sample can be measured by optical procedure using different optical devices such as fiber optic sensor [3], refractometer (prism based) [4], and photonic crystal structure sensor [5].

Photonic crystal structure (PCs) is the periodic variation of the RI which prevents some of the electromagnetic waves to pass through it. Depending on the dimension of the variation of RI of the PCs, these are categorized as one, two and three dimensional PCs [6]. Recently there are several repots using one dimensional PCs (ODPCs) such as reflectors [7,8], filters [9–11], sensors [12,13] etc. for wide range of applications.

There are various methods employed such as transfer matrix method (TMM) [14,15], plane wave expansion (PWE) method [11], finite difference time domain (FDTD) method [16–18], finite element method (FEM) [19], boundary element method (BEM) [20] etc. to compute the solution of electromagnetic waves of one dimensional photonic crystal. Though there are several methods used for computation purpose, however FDTD method is frequently used to avoid empirical calculation which is advantageous than others [21].

Recently silicon based two dimensional photonic crystal had proposed to measure the concentration of sugar, salt and alcohol in solutions [5]. The crystal used in this study was a lattice constant of 1 μm with minimum separation width of 0.2 μm between the two adjacent holes. In this study, PWE method was used for computation purpose. Since ODPCs is more compact than other dimensional, therefore a theoretical investigation of early detection of acute dehydration is carried out using diamond based one dimensional photonic crystal structure (D-ODPCs) having least separation width of 0.6 μm by FDTD method to avoid structural collapse. Diamond is used in the presence study due to stable in acidic and alkali media [22]. In addition, D-ODPCs was already reported, however in presence study the theoretical investigation is carried out using D-ODPCs with varying lattice constant[23].

2. Subject and methodology

The computation of osmolality, SG and TDS of the human urine has been manipulated by the interaction of light with D-ODPCs. The schematic diagram of D-ODPCs considered for the early detection of acute dehydration is shown in Fig. 1.

* Corresponding author. Tel.: +91 9436540988; fax: +91 9436540988.
E-mail address: arsagtwave@gmail.com (A. Saha).

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Fig. 1. D-ODPCs consisting of round end slot type air hole.

D-ODPCs which was need for the experiment consist of a round end slot type air hole of width 400 nm and lattice constant of 1 μm considered for measuring the energy of transmittance. In the above experiment laser light from a source of wavelength 589.3 was incident on the D-ODPCs. It was considered that light has partially reflected and transmitted by desired structure inflated with different TDS content of human urine. FTDT method has been used to compute the photonic bandgap (PB) which is basically measured the reflected energy of D-ODPCs inflated with different TDS content of human urine. It is obvious that FDTD method is also friendly. The variation of PB in ODPCs has considered due to variation with width of the layers, RI of the layers or both.

The variations of RI of human urine with respect to different values of osmolality, SG and TDS were obtained from the previous

Table 1
Change of refractive indices with variation in osmolality, specific gravity and total dissolved solids of human urine sample [2].

Samples sl. no.	Osmolality [Os/kg]	Total dissolved solid [g/100 g]	Specific gravity [20/20]	Refractive index
S-1	1.46	10	1.040	1.3489
S-2	1.24	8.4	1.034	1.3464
S-3	0.8	5.4	1.022	1.3415
S-4	0.6	4.1	1.017	1.3396
S-5	0.4	2.8	1.012	1.3374

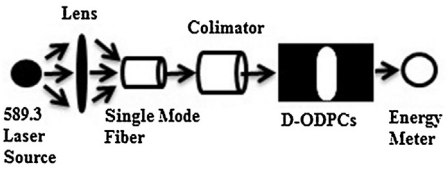

Fig. 2. Schematic diagram of the experimental setup for measurements of different parameters in the human urine.

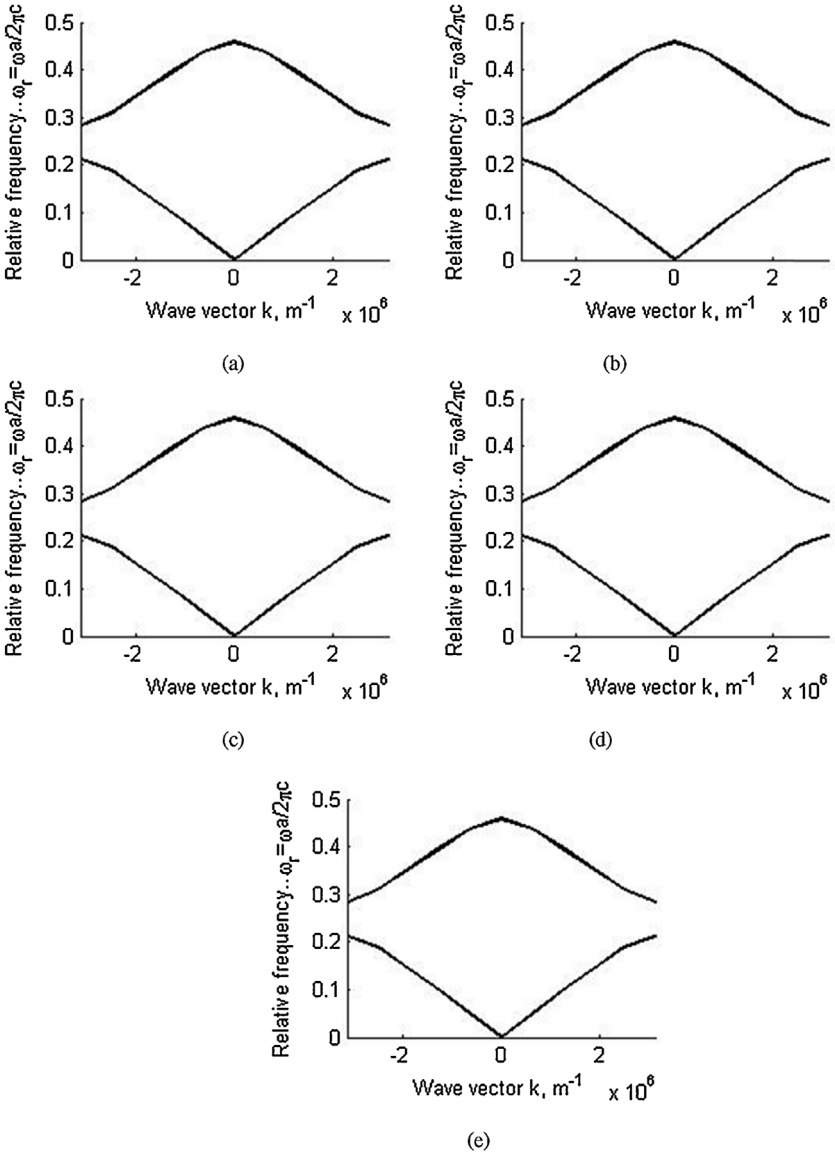

Fig. 3. PB of D-ODPCs inflated with different samples of human urine in the hair hole. (a) S-1, (b) S-2, (c) S-3, (d) S-4 and (e) S-5.