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Original research article

A new-fangled proposal for 4th optical communication windows using 3-D silicon photonics: Future structure for future application

G. Palai

Gandhi Institute for Technological Advancement (GITA), Bhubaneswar, Odisha, India

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ABSTRACT

Present contribution proposes a future application of 3D photonic crystal structure in the field of optical communication, where communication deals with the wavelength of 1625 nm to 1675 nm which is represented as 4th optical communication windows. Plane wave expansion method is used to optimize above said silicon structure and the optimization result divulges that aside nature and configuration of the structure, lattice spacing and radius of air holes play vital role to realize the same. For example, lattice spacing of 848 nm and 725 nm of diameter of air holes bestows the complete band gap for 4th optical windows (1625 nm to 1675 nm) regime.

1. Introduction

Research on one and two dimensional photonic crystal structure is burgeoning in hasty manner owing to feasible fabrication. However the exploration of 3D photonic structure is going on sluggish way because of the manufacturing constrain. But researchers believe that this structure shall provide excellent properties which are not exhibited by one and two dimensional photonic structure. For example; the notion of optical computer can be envisaged if we able to design and develop the said structure [1]. Apart from this the real time application of 3D photonic crystal structure could able to stop the scarcity of electrical power, if the trapping of photon particles would be possible [2]. The above incredible application of 3D photonic structure is due to the realization of complete photonic bad gap of the same structure. Photonic band gap is a basic parameter of photonic crystal, which is represented as the amount of signal is reflected from it. Recently some works related to sensing and communications have been carried out using 3D photonic crystal structure, which can be accomplished in future[3–8]. Since 3D photonic structure has not come to real picture pertaining to fabrication now-a-days, it is signified as future structure. Moreover since this structure deals with the 1625 nm–1675 nm regime which is a non operational mode with respect to recent research. So this is represented as future application. So far as different operational communication windows are concerned, the wavelengths around 850 nm, 1310 nm and 1550 nm stand for first, second and third optical communication windows. The first one (850 nm) is not suitable for fiber optic communication application due to absorption loss. Nevertheless 3rd communication window (1550 nm) bestows better recital as compared to 2nd (1310 nm) window owing to absorption factor in optical fiber. But almost no real works have been reflected in literature with respect to above said 4th communication windows. Nonetheless few works have been proposed with respect the above signal regime [9]. So pertaining to academic interest for future application, this communication attempt to correlate 3D silicon photonic crystal

E-mail address: gpalai28@gmail.com

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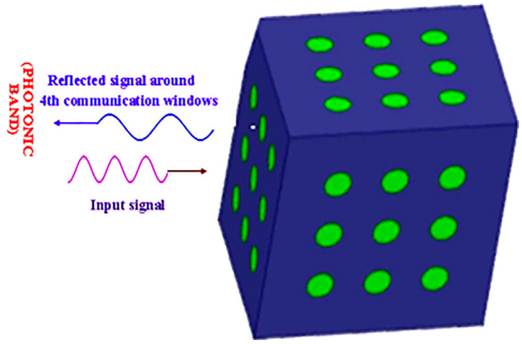

Fig. 1. 3-D silicon photonic structure.

Table 1
simulation output for wavelength of lower and upper band.

Lattice spacing (a) in nm	Wavelength ranges (nm) corresponding to photonic band gap	
	Upper Band (lower wavelength)	Lower band (Higher wavelength)
800	1545	1540
840	1618	1650
843	1625	1658
844	1626	1644
845	1625	1664
846	1624	1669
847	1629	1673
848	1625	1676
849	1635	1682
850	1637	1686
860	1704	1724
900	1789	1877
1000	1909	2214

structure with aforementioned wavelength regime. The proposed structure is not new for photonic application because Palai et.al. have also chosen similar type of structure for sensing application.

2. Result and discussion

Prior to discussion the band analysis of 3D photonic crystal structure, let us discuss 3D silicon crystal structure shown in Fig. 1.

This structure is similar to reference [3–8], where sensing application is made. Here silicon material is backbone of this structure such that 3×3 air holes are etched on it. Aside background material, structure parameter including diameter of air holes and lattice spacing are two key elements to realize the complete band gap of said photonic structure. Utilizing above 3D silicon structure, this article divulges the possible uses of photonic crystal structure for application at the wavelength of 1625 nm–1675 nm regime. To accomplish such application, this paper optimizes 3D structure with varying the lattice spacing and diameter of air holes such that background material remains invariable. Again to fetch the same, lattice spacing is amending from 0.8 μm to 1.0 μm, where the radius of air holes is taken of $\frac{\sqrt{3}}{4} \times$ lattice spacing (a) to execute band of silicon structure owing to silicon as tetrahedral structure. Though simulation is made using plane wave expansion method corresponding to different lattice spacing, photonic band gap for three lattice spacing (a = 800 nm, 848 nm and 900 nm) is shown in Fig. 2(a)–(c) respectively [2]. The reason for choosing such parameters is to optimize and realize the band gap of said structure at 4th optical communication windows.

In Fig. 2, wave vector ((k)) and normalized frequency ($\frac{\omega a}{2\pi c}$) is chosen along horizontal and vertical axis respectively. Analyzing Fig. 2(a), no gap is found in 3D silicon photonic crystal structure having lattice spacing of 800 nm, which infers no signal is reflected pertaining to same. However in Fig. 2(b) and (c) a definite gap is exhibited between consecutive allowed bands which are represented as photonic band gap. Moreover the wavelength ranges from 1625 nm to 1676 nm and 1789 nm to 1877 nm is computed corresponding to Fig. 2(b) and (c) respectively. Since 1789 nm–1877 nm of wavelength is the beyond of 4th optical communication windows, structure corresponding to lattice spacing of 900 nm is the out of the scope for investigation here. But the structure having lattice spacing of 848 nm confirms that the operation of 4th windows can be possible using dimensional photonic crystal structure. Apart from these result, this paper also made simulation using different values of lattice spacing, the same result is suitably placed in Table 1;

Table 1 conveys the simulation output for observing reflected wavelength corresponding to each lattice spacing of 3D silicon structure. The observation indicates no band gap is envisaged at 800 nm of lattice spacing because lower wavelength