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Effect of Defect Layer on the Localized States in 1-D Photonic Crystal

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Abstract

In the present work, defect modes developed as a result of defect states in one dimensional photonic crystal has been studied. The transmission spectrum has been obtained using transfer matrix method . The study has been extended to investigate the effect refractive index dependence on transmission for 1D photonic crystal.

Keywords: 1-D Photonic Crystal , Refractive Index , Transmission Spectrum , Optical Communication

INTRODUCTION

Photonic crystals (PCs) attracted much scientific interest in the last decade due to their electromagnetic properties and their potential applications as optical limiter, switch, filters, sensors, actuators, optical diode etc.[1]. When the periodicity is broken by introducing a defect into a photonic crystal (PC), a localized defect mode will appear inside the photonic band gap (PBG) due to change of the interference behavior of light The defect modes lead to the selective transmission in the 1D PCs and they can be utilized as filters, sensors, splitters etc. in optical communication[2-4]. In this paper, we have presented the results obtained by introducing a defect layer of Si in the symmetrical multilayered Si/air photonic crystal by changing the thickness photonic crystals and analyzing the frequencies of confined states which can be tuned properly.

THEORETICAL MODEL

The Structural configuration used in this work may be expressed as $(AB)^mD(BA)^m$, where A and B stand for the different layers with high and low refractive indices n_A and n_B, respectively, D defect layer with refractive index n_D and m is the number of layers. We have chosen Si and air representing $n_A=3.45$ and $n_B=1$ and $d_A=0.2a$, $d_B=0.8a$ respectively, where the parameter a is the lattice constant. The thickness of defect layer d = 0.4a. Here D is taken to be Si with refractive index n_D varying between 2.0 and 4.0 at wavelength of 1550nm [5]. Consider a monochromatic light of wavelength λ incident normally on the crystal surface. The transmittance of the structure was obtained by the well known transfer matrix method using the standard codes [6].

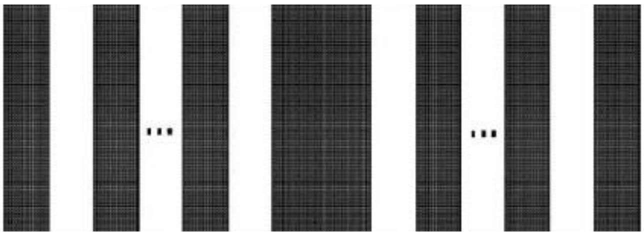

Figure 1. Schematic diagram of 1-D Defect Photonic crystal.

RESULTS AND DISCUSSION

We first calculate the transmission spectrum for the perfect truncated $(AB)^mA$ PC with m=5 as shown in Fig.2. Transmission depends on many parameter such as thickness of defect layer, filling fraction, angle of incidence and refractive index of layer [7.]. Fig.3 shows the transmission with different refractive indexes of defect layer n_D are taken as 2,3,4 respectively keeping the thickness of the defect layer 0.4a. The change in refractive index can be obtained through changes in pressure, temperature or concentration of impurities in Si.

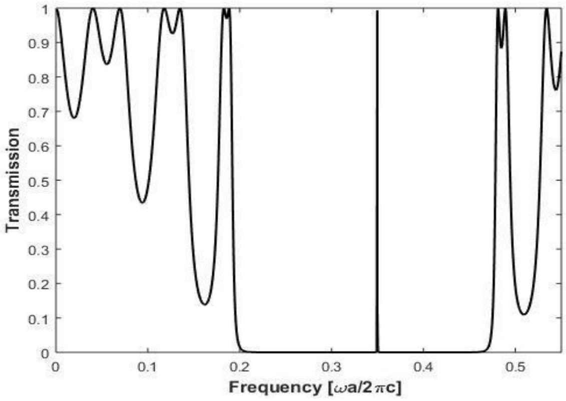

Figure 2 Transmission Spectrum of 1-D Photonic Crystal with Defect Layer as Structure $(AB)^5C(BA)^5$

A defect in the otherwise regular lattice permit creation of localized modes with frequency inside the PBG. As the mode has a frequency in the PBG, then it must exponentially decay once it enters the crystal. The number of defect modes and their locations can be controlled by changing either thickness of the defect layer or refractive index of the defect layer [8]. In the present work, the total volume of the defect layer is not changed, it is anticipated that the localized states corresponding to these defect modes are spread out so as to allow fields to be concentrated more and more in the high-ε defect layer. The localized states thus generated cause the shifting of frequency to lower values, as has been displayed in Fig. 3[1]..

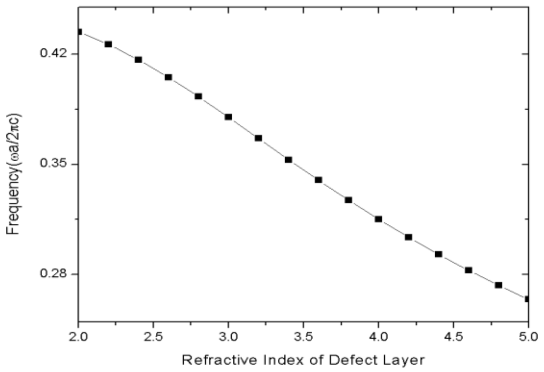

Figure 3: Variation of normalized frequency with refractive index

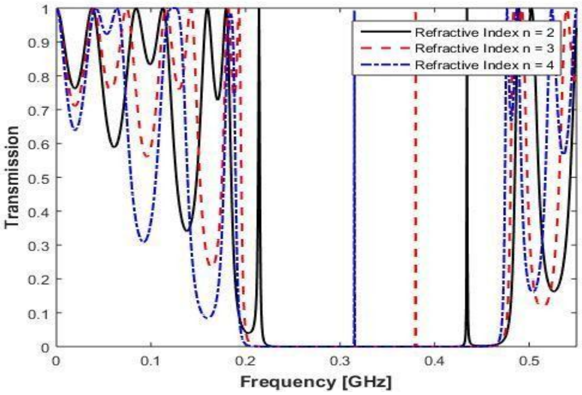

Figure 4: Refractive index dependence of defect layer

The number of defect mode frequencies in the bandgap increases with refractive index as shown in Fig. 4. Thus, photonic single quantum well (QW) is generated around the defect due to quantum confinement effects [9]. The sharp peaks are seen inside the PBG. These sharp peaks can be termed as ‘‘confined states’’, which can be used as high-frequency carriers one-to-one for optical communication systems [10]. The confined states can completely transmit through the quantum well owing to the fact that they pass through the structure by resonant tunneling. When the energy of the incident photons is matched with the confined state of the defect layer, the signal can be transmitted, while if both of them do not match, the transmission does not occur. These peaks can be termed as “resonant peaks”. The confined state shifts to lower values with increasing refractive index of Si. It provides opportunity to control the optical confined modes [11]. The defect mode can also work as a guided mode for waveguide application in narrow band region. This is extremely useful as a filter device [12].

CONCLUSIONS

In the research work it is found that the transmission spectrum of 1-D Si/air photonic crystal can be modified by varying the refractive index of the defect material. The resulting structure gives rise to localized states which generate confined states within the photonic band gap . The normalized frequencies shits towards lower values with increasing refractive index. The work can be useful for the design and development of the optical communication systems.

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