Research Paper PHYSICS

Effects of Transmission Spectra of the Dielectric Photonic Crystals

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ABSTRACT

The study of optical transmission properties of photonic crystals using the transfer matrix method shows that photonic crystals have different transmission spectra. The spectra of dielectric photonic crystal begin with transmission band at lower frequencies.

KEYWORDS | Transmission; Photonic Crystals; Photonic Band Gap.

1. Introduction

Photonic crystals (PCs) are macroscopic media which arranged periodically with different refractive indices and their periodicities are in the range of the incident light [1]. In such structures the permittivity is a periodic function in space. In this case, the dielectric permittivity function repeats itself in one dimension (1D) the structure called one dimensional photonic crystal (1D-PC), if it repeats itself in 2D or 3D the structure called 2D or 3D PC. The one dimensional photonic crystal (**Figure 1**) is a multilayered media. It is worthy to mention that, the propagation of photons in the PCs is similar to the propagation of electrons in the semiconductor crystals, where the effect of the periodic dielectric function on the propagating photon in PCs is much like the effect of the periodic potential function on the propagating electron in semiconductor crystal. Consequently, a photonic band is created in PCs similar to the electronic bad gap in semi-conductor crystal [2].

On the other hand, when electromagnetic waves (EM) incident on the PCs Bloch states create in the crystal, if the Bloch wave falls in the so called forbidden bands (photonic band gap) such a wave is evanescent and can't propagate in the crystal. Thus the light energy is expected to be totally reflected, and the crystal acts as a high reflectance reflector for the incident wave. The photonic band gap of the photonic crystal makes us able to control the light even the spontaneous emission [3]. In this paper, we are going to do comparative study between the 1D-DPCs and -MPCs pointing to the general applications of each kind according to its characteristics.

2. Results and Discussion:

Dielectric Photonic Crystals (DPCs)

In the last decades dielectric photonic crystals have attracted much research interest due to their various applications for example, optical filters, waveguides, and optical fibres [4]. In this section, we restrict our communications on the characteristics of the 1D-DPC showing its various applications. The reflection of the EM waves through DPCs exhibit resonance reflection very much like the diffraction of x-rays by crystal lattice planes, therefore it's called Bragg reflector.

We have designed 1D- DPC composed of a low index material (Cryolite = 1.34) and a high index material (Silicon = 3.4) stacked alternatively on a glass substrate. The number of periods, lattice constant, effective refractive index, and the filling factors of the low and the high index materials are taken to be 10, 250, 2.389, 0.6, and 0.4 nm, respectively. The filling factor (*f*) of a material in a 1D-PC can be given by [6];

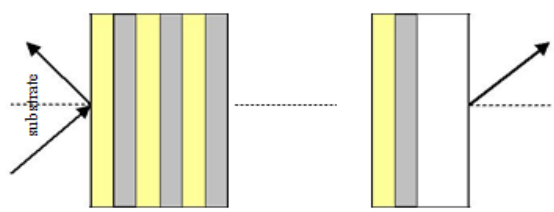


Figure: 1: Schematic diagram shows a one dimensional photonic crystal.

f=d Λ

where d and Λ are the material layer thickness in the

unit cell of the PC and the lattice constant (spatially pe

respectively. The transmission spectra

of the DPC are displayed in Figure 2. The figure shows

that the DPC presents a transmission band for the low

frequencies (long wavelengths), and the first band gap is

associated with the Bragg condition [2];

λ =2nΛ

where λ is the centre wavelength of the first band gap, Λ is the lattice constant, and n is the effective refractive

index. The effective refractive index can be given by [2];

and εeff = fl εl + fh εh

It's known that, in a specified frequency range the band gap width depends on the difference in the refrac- tive indices of the two constituent materials (Dn). So to show effect of Dn we have designed DPC from Cryo-lite/Silicon dioxide (n =1.46). The transmission spectra are displayed in Figure 2, it is obvious that, when the number of periods is equal to ten, Dn of Cryolite/Sili- con dioxide is small not enough to open deep gap, but when the number of periods become equal to fifty, a narrow deep gap can be open. We have observed that the (3)

number of periods doesn't effect on the position or the width of the band gap. But increasing number of periods enhances

the reflectivity of the bad gap and makes the band gap edges steeper.

In **Figure 3**, the number of the resonance transmission peaks (RTPs) for the PC of fifty periods is larger than number of RTPs for the PC of ten periods. It is noticed that, the RTPs of the DPC is directly proportional to the number of periods, and the RTPs have become closer to each other and sharper as the wavelength decreases and vice versa.

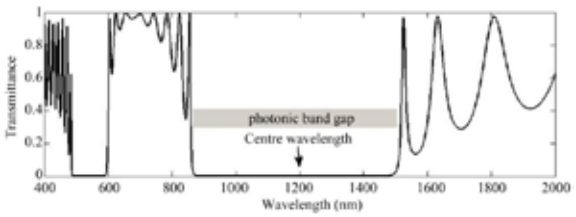


Figure :2. Calculated transmission spectra of a dielectric photonic crystal with n1 = 1.34, n2 = 3.4, d1 = 150 nm, d2 = 100 nm, number of periods = 10, and $\theta = 0^{\circ}$.

The term fl el represents the filling factor of the low index material multiplied by its permittivity, and the term fh eh represents the filling factor of the high index material multiplied by its permittivity [5]. The centre wavelength of the first stop band determined by Bragg condition is approximately equal to 1194 nm which is consistent with the value deduced from the transfer matrix method that shown in Figure 2. The photonic band gap of the DPC can be tunable by varying n or Λ, and the band gap

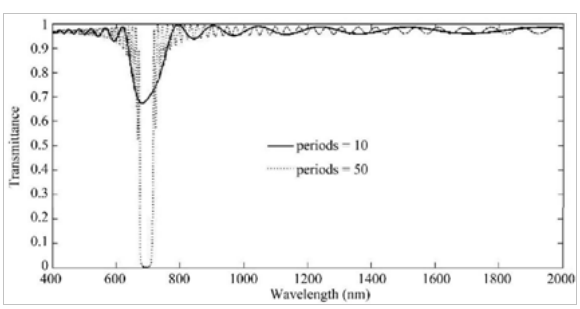


Figure: 3. Calculated transmission spectra of a dielectric PC with n1 = 1.34, n2 = 1.46, d1 = 150 nm, d2 = 100 nm, period = 10, and $\theta = 0^{\circ}$.

Conclusion

The DPC has only Structural band gaps that produce from EM waves interferences. The spectra of dielectric photonic crystal begins with transmission band at lower frequencies,. In the DPC the ***P***-Polarized waves is more sensitive to the incident angle than the ***S***-Polarized waves.

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