Journal of Ovonic Research Vol. 6, No. 2, April 2010, p. 87 - 92

REFLECTION PROPERTIES OF ONE-DIMENSIONAL MAGNETIC PHOTONIC CRYSTALS

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The reflection properties for one-dimensional magnetic photonic crystals with the different wave impedance and index of refraction have studied by using simple transfer matrix method. The analytical expressions show that no PBGs for both TE- and TM- polarizations exist when Z_1=Z_2 even though there is higher contrast of refractive index for the normal incidence [3]. This occurs because there is no reflection at the interface of two alternating layers in the case. We have observed a larger reflection bands in the magnetic photonic crystals for both modes when the ratio of the impedance (Z_1/Z_2) and index of refraction are high. Such large reflection band of the magnetic photonic crystal can be used as filter for the both modes.

(Received April 2, 2010; accepted April 15, 2010)

Keywords: Photonic crystal, Reflection properties, Magnetic, Polarization, Filter

1. Introduction

Periodic dielectric structures that exhibit electromagnetic stop bands or PBGs, have attracted much attention because of their ability to control the propagation of electromagnetic waves. The understanding of the roles of the dielectric constant and magnetic permeability in PBGs are open the wide possibility of using magnetic materials in various PBG structures. Investigations on the influence of magnetic permeability on PBG effects and the properties of photonic crystals made from magnetic materials have recently been increased [1-2]. Recently Kee et al. [3] have derived the analytical expressions for equiomnidirectional contours of the omnidirectional reflection bands of a one-dimensional magnetic photonic crystal consisting of two alternating layers with different wave impedance and the same index of refraction.

2. Mathedology

One dimensional magnetic photonic crystal that is made of an infinite periodic array of alternating layers with $\varepsilon_1\mu_1$ and $\varepsilon_2\mu_2$, with the thicknesses d_1 and d_2, respectively is considered. In a homogeneous layer with ε and μ is related to the refractive index $n=\sqrt{\mu\varepsilon}$ and the wave impedance $Z=\sqrt{\mu/\varepsilon}$. The Maxwell's equation for homogeneous and isotropic medium, the electric field is given by [4]:

$$\vec{\nabla}^2 \vec{E} - \mu\, \varepsilon \frac{\partial^2 \vec{E}}{\partial t^2} = 0 \tag{1}$$

Using above equation, we have formulated the matrix propagation equations for the each layer in terms of refractive index and impedance. Such matrix is used to calculate the band structure and reflectance of the magnetic photonic crystal containing n and Z.

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3. Results and discussion

We know that the essential parameter in the formation of the PBGs is the wave impedance and the refractive index of the materials. Kee et al.[3] have studied the analytical expressions shows that no PBGs for both modes exist when $Z_1=Z_2$ even though there is higher contrast of refractive index for normal incidence. If the refractive indices of successive layers are the same and the wave impedances are different, then upper and lower frequencies range of the TE-mode are equal to those of the TM-mode for all incidence angles. The omni reflection bands are a universal property of a periodic array of two alternating layers with different wave impedance if both layers have the same index of refraction. But the large reflection bands of the photonic crystal for both modes have also obtained when the contrast of the refractive index is high. They have obtained a larger reflection bands in one-dimensional magnetic photonic crystals for both modes when the ratio of the impedance (Z_1/Z_2) and index of refraction are high.

m=1 (first order band)

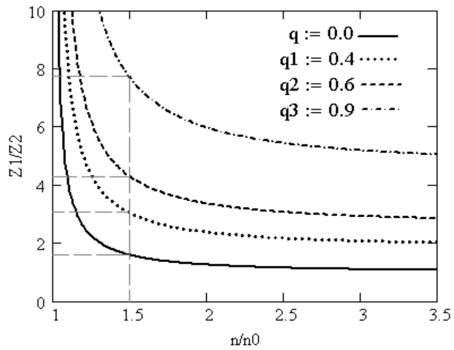
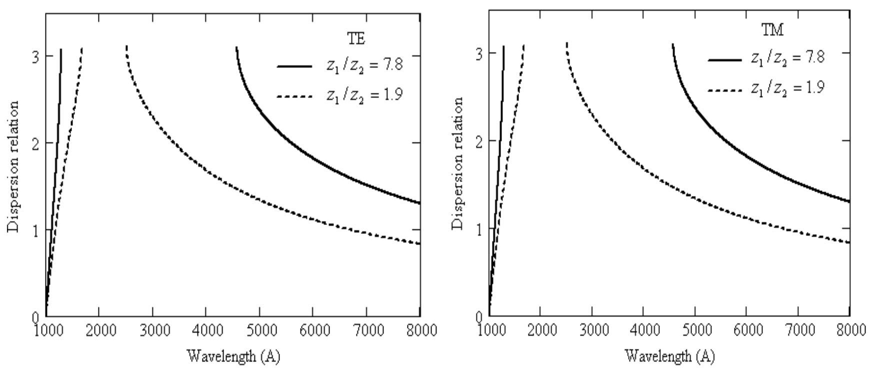


Fig. 1. Contours of the relative size of the ODR

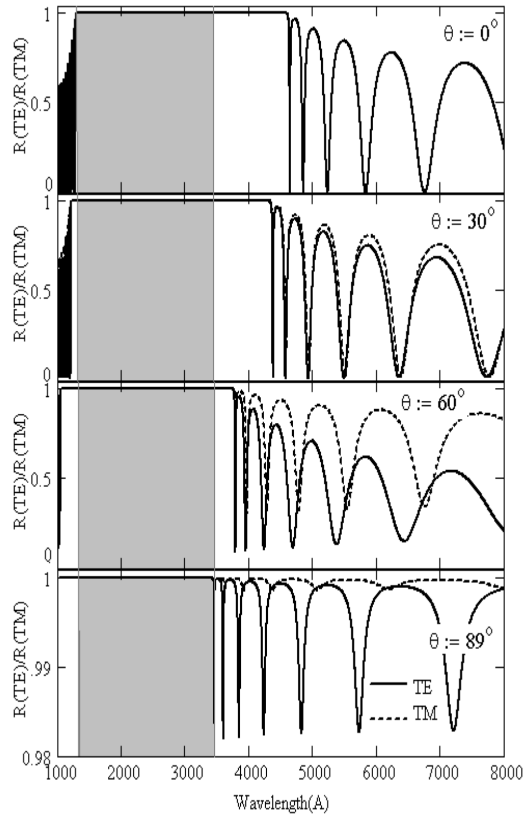
We have done the calculations for the magnetic photonic crystals containing air (n=1.0) and glass (n=1.5) materials with different Z_1/Z_2 ratio for the m=1 and m=2 order of bands. The impedance ratio with relative refractive index is shown in the figure 1.0. The contours of the relative size of the first order band (m=1) shows to its middle frequency for q=0.0, 0.4, 0.6, 0.9. We observe that the large ODR (Omni-Directional Reflection) will observe when the Z_1/Z_2 and the refractive index are large. The reflectance and band structure for both modes are calculated for first order band with impedance ratio (Z_1/Z_2) are 7.8 and 1.9 as shown in figure 2.0. We have observed that the band gap is large for the largest value of the Z_1/Z_2 in the both modes. The reflectance of the structure for both modes are calculated for $Z_1/Z_2=7.8$ as shown in the figure 3.0(a) and corresponding ODR gaps shown in the figure 3(b). The reflectance of the structure for $Z_1/Z_2=7.8$ for both modes are same due to the impedance of the structure are same. But at the large angle of incidence reflectance is highly varied due to large change of the parallel propagation vector. The forbidden band and reflectance of the structure are depending in the impedance of the materials. We have found the large 3000A^0 ODR wavelength gap.



(a) (b)

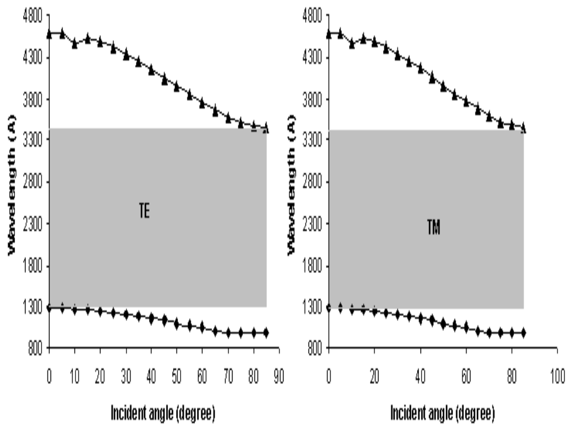
Fig. 2. Band structure for (a) TE-mode and (b) TM-mode.

m=1 and z1/z2=7.8



(a)

m=1 and z1/z2=7.8



(b)

Fig. 3. Omni-directional reflection (ODR) (a) reflectance Vs wavelength for different angle of incidences (b) Omni-PBG.

The same calculations are repeated for the second order band i.e. m=2. We found that the ODR is also varied but this variation is less compared to the first order band. The band structures are calculated for the both modes with Z_1/Z_2=0.38 and 0.22 as shown in the figure 5. In this case the large band gap has observed for Z_1/Z_2=0.22, it may be due to the increase of the Z_1/Z_2 for the glass material inside the structure. The reflectance band for the Z_1/Z_2=0.22 is also found large for the both modes. The ODR gap of 1300A^0 wavelength is obtained.

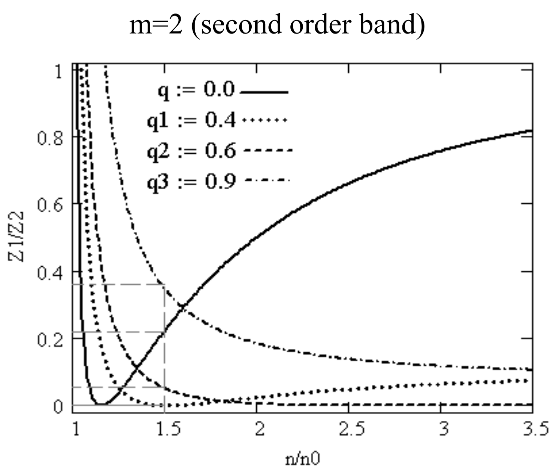
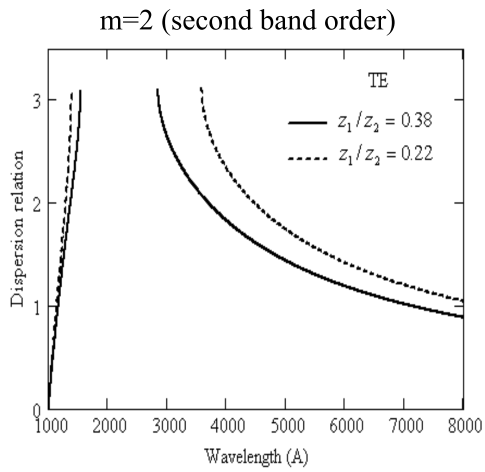
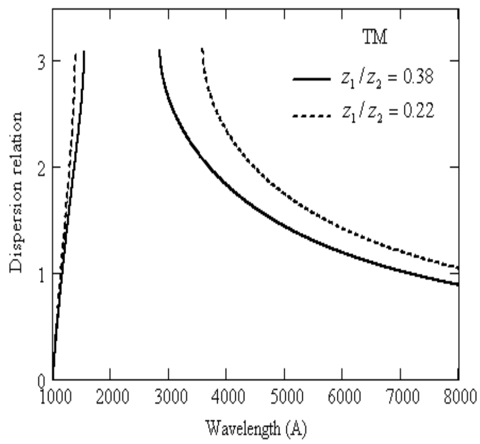


Fig. 4: Contours of the relative size of the ODR



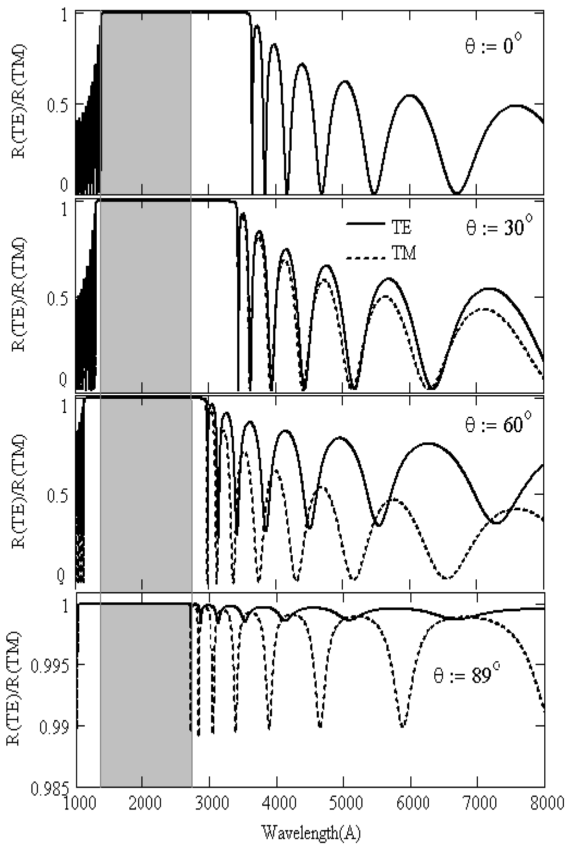
(a)



(b)

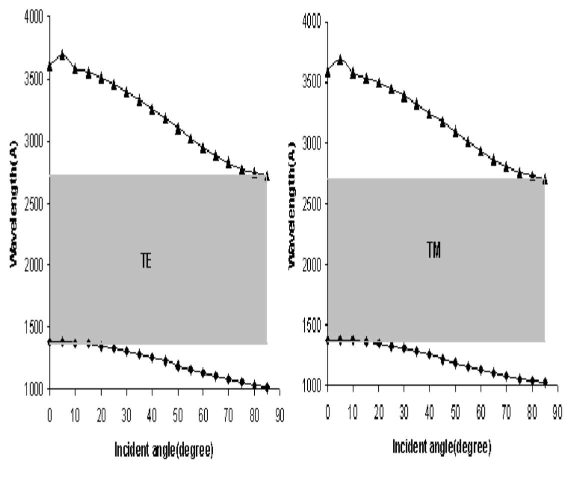
Fig. 5: Band structure for (a) TE-mode and (b) TM-mode

m=2 and z1/z2=0.22



(a)

m=2 and z1/z2=0.22



(b)

Fig. 6. Omni-directional reflection (ODR) (a) reflectance Vs wavelength for different angle of incidences (b) Omni-PBG

From the given result we concluded that the ODR gaps of the magnetic photonic crystal are dependent on the impedance of the materials even though there is higher contrast of refractive index. The large impedance of the materials of the first order band has the large ODR gap due to the large of q but for the second order band the ODR gap is less than the first order band due to small value of q where q is the ODR parameter.

4. Conclusions

We have shown the analytical expressions show that no PBGs for both polarizations exist when $Z_1=Z_2$ even though there is higher contrast of refractive index for normal incidence. This occurs because there is no reflection at the interface of two alternating layers in the case. We have observed a larger reflection bands in the magnetic photonic crystals for both modes when the ratio of the impedance (Z_1/Z_2) and index of refraction are high. The ODR band gaps are totally dependent of the impedance parameters of the materials. The large impedance of the magnetic photonic crystals has the large ODR for the both modes. Such large reflection band of the magnetic photonic crystal can be used as filter for the both modes.

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