CHAPTER – 6

SUMMARY AND FUTURE PROSPECTS

6.1 Summary of the thesis research work

The present thesis is focused on the study of photonic band gap (PBG) properties in 1-D PC structures composed of graded index materials, semiconductor and negative index materials with periodic and quasi-periodic arrangements. The influences of geometrical and material parameters on the tunability of photonic and omnidirectional band gaps have been investigated. Initially, the effect of graded index materials on the photonic and omnidirectional band gap and defect mode properties in 1-D PC structures composed of graded index materials have been demonstrated. The number of PBGs increases with the thickness of graded materials layers. The bandwidths of PBGs are modulated with the values of grading parameters of the graded index materials. The gradation profiles have also a substantial influenced on the PBG, reflection phase shift and electric field distribution in the structures. Bandwidth and band region of PBGs can be changed with different grading profiles. Omnidirectional band gaps (OBGs) also exist when the relative refractive index of the constituted homogeneous layers of the proposed structures greater than 1.0. Thus, 1-D GPC structures with the relative refractive index of the constituted homogeneous layer greater than 1.0 are suitable to design the widespread OBG devices. 1-D GPC structures with the refractive index of the constituted homogeneous layer equal to 1.0 have wide common reflection band for TE-polarised electromagnetic waves. Therefore, these structures can be utilized especially for the configuration of TE-polarized devices. Moreover, the tunability of photonic defect modes in 1-D PC structures containing a defect layer of the graded index materials has investigated. The generation, position and intensity of defect modes can be modulated with structural parameters, gradation profile, grading parameters and the thickness of defect layer, angle of incidence and polarization. The position of defect modes and their intensity also change with grading parameters and using different graded index materials as a defect. Thus, the desired photonic and omnidirectional band gaps and defect modes can be achieved by selecting suitable structural parameters, gradation parameters and profiles, angles of incidence and polarization in the considered structures.

Further, the PBG properties of 1-D PC structures composed of exponential graded index material and metamaterials have been investigated. The formation, band region and bandwidth of PBGs can be controlled by the thickness of meta-materials layers. Generation of the photonic and omnidirectional band gaps and their band width strongly depend on the structural parameters and types of meta-materials. The number of PBGs and their bandwidth and band range can be tuned by changing the layer thickness and types of meta-material. The thickness of the graded material layers only influenced on the bandwidth of photonic and omnidirectional band gaps. The bandwidth and band range of band gaps can be controlled by the layer thicknesses, grading profile and parameters, and types of meta-materials. In the case of the 1-D PC structures composed of semiconductor with graded index materials, the number of PBGs also increases with the thickness of the constituent graded index materials and semiconductor layers and temperature. The band frequency range and bandwidth of PBGs can be tuned by controlling the temperature, grading parameters and profiles, and structural parameters. Thus, the tunable PBGs can achieve by selecting appropriate structural parameters, grading parameters and profiles, and temperature in the considered structures. Such photonic crystals can be utilized to design tunable filters, reflectors, sensors and other optical devices in the terahertz range.

Finally, the effects of graded index materials and semiconductor on the PBG properties in 1-D quasi-periodic (Fibonacci, Thue-Morse and Double-Periodic) PC structures have been investigated. In this case, the number of PBGs increases with layers thickness. More and more PBGs and photonic localization modes appear with the generation of quasi-periodic sequences. The position of localization modes and PBGs affect with the change of grading profiles while refractive index at the initial and final boundary of the graded layer are same. Broader PBGs are obtained for maximum contrast of the refractive index of the constituted layers in the PC structures. Hetero-structures of the different quasi-periodic structures may also provide very large PBG, and their frequency range and purity can be changed with different materials and quasi-periodic structures. In the case of the quasi-periodic structures with semiconductors, photonic and omnidirectional band gaps can be tuned with temperature. Moreover, the frequency band region and bandwidth of PBs affect with Fibonacci, Thue-Morse and Double-Periodic sequences. Total photonic and omnidirectional bandwidths can be modulated through the change of temperature, quasi-periodic generations and sequences. Thus, photonic and omnidirectional band gaps of the proposed structures can be tuned through the temperature, lattice parameters, grading parameters and profiles, generation of quasi-periodic sequences and different types of quasi-periodic systems.

Accordingly, the proposed 1-D PC structures composed of graded and dispersive materials with periodic and quasi-periodic arrangements can be used to design various photonic devices such as mirrors, multi-channel filters, reflectors and optical sensors and other optical devices. This work further opens the idea of understanding the effect of graded index materials, meta-materials and semiconductors on the photonic and omnidirectional band gaps and localization mode phenomena in 1-D PC structures with periodic and quasi-periodic structures.

6.2 Future plan

The possible extensions to the work in this thesis and also some other possible avenues of research along the same themes have been presented in this section. It was found that the proposed 1-D PC structures can support desired tunability of photonic and omnidirectional band gaps using graded index materials, meta-materials and semiconductor. The effects of disorder on the photonic and omnidirectional band gaps and localization modes in the quasi-periodic structures with graded materials and semiconductor have also studied. Due to the distinctive photonic band gap properties and numerous possible applications in optoelectronics and optical communications of the considered PC structures, one possible extension would be to study the optical properties of higher order PCs such as 2-D and 3-D PCs composed of different materials in periodic or quasi-periodic arrangements. Such studies would be performed using concepts of graded index optics in PC structures based on periodic and aperiodic arrangements. Moreover, the computational models of PC structures would be demonstrated which could enhance the light harvesting efficiency and power conversion efficiency for the sensors, LEDs and solar cells applications. Studies would also be extended to develop PCs using different thin film techniques and self-organize colloidal particle suspension on the substrate and synthesis of high refractive index materials by different chemical routes such as such as sol-gel, citrate method, hydrothermal and auto-combustion method for various photonic applications.

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