Abstract

Photonic crystals (PhCs) are structures with periodic variation of the refractive index in one, two or three dimensions. They exhibit a photonic stop-band (PSB), which is the range of frequencies at which the electromagnetic radiation is not allowed to pass through the structure. The PSB of PhCs is used in many applications involving controlling the light-matter interactions. One-dimensional photonic crystals (1DPhCs) or distributed Bragg reflectors (DBRs) consist of two quarter-wave thick thin films having high and low refractive index stacked in a periodic manner with planar interfaces between them. Introducing a defect layer into otherwise periodic 1DPhCs leads to highly localized defect states within the PSB. Depending on the position of the defect layer, either on the surface or within the 1DPhC structure, they are named as surface states and microcavity modes, respectively. The research work carried out as a part of this thesis aims to establish new ways to improve the sensitivity of microcavity mode, surface states-driven photonic crystal-coupled emission (PCCE), and Tamm state-coupled emission (TSCE) platforms in 1DPhC framework under weak coupling regime with cost effective fabrication methods. Sol-gel technique and dip-coating processing were used for the fabrication of crack-free 1DPhCs. The experimental results have been supported by transfer matrix simulations as well as finite element method based computations for microcavity structures, PCCE and TSCE platforms.

The effect of the number of bilayers on the dispersion characteristics and the electric field intensity distributions of Bloch surface waves (BSWs) and internal optical modes (IOMs) of the 1DPhC were studied using transfer matrix method. The critical role of nano-engineering using graphene oxide (GO) and silver nanowires (AgNWs) on the IOM-driven PCCE platform has been explored to yield an unprecedented >1300-fold increase in fluorescence intensity of rhodamine B (RhB) dye molecules. The PCCE enhancements obtained with the synergism among dielectric plasmons (from 1DPhC), GO plasmons, and localized surface plasmons (from AgNWs) have been utilized to sense cholesterol at the single-molecule limit of detection. In order to eliminate the metal plasmons sustaining losses, nano-engineering using high refractive index $Ba_{0.85}Ca_{0.15}Zr_{0.1}Ti_{0.9}O_3$ (BCZT) nanoparticles (NPs) and GO on the PCCE platform have been explored for significantly augmenting the fluorescence of RhB molecules. While nano-BCZT yielded 100-fold fluorescence enhancement in the lossy surface plasmon coupled emission (SPCE) platform, >1000-fold enhancement is demonstrated in lossless PCCE platform due to the generation of multi-fold nanocavities with copious hotspots. On the other hand, TSCE was explored in super-Tamm structure which exhibited Fano resonances. Threshold characteristics of the TSCE was investigated for their lasing-like behaviour, making it a promising candidate for the development of directional light-emitting devices and sensors. Finally, 1DPhC waveguide designs are proposed based on the strong confinement of leaky modes in the low refractive index core. This has been experimentally validated by waveguided transmission measurements and finite difference time domain (FDTD) computations. The polarization dependent studies on the leaky modes of the femtosecond micromachining fabricated 1DPhC channel waveguides highlighted the polarization maintaining behaviour of the waveguides which is of immense interest for communication related applications.

Keywords: *One-dimensional photonic crystals, Surface states, Tamm states, Microcavity modes, Photonic-crystal-coupled emission platform, Tamm state-coupled emission platform.*