Simulation of Self-assembled Photonic Crystals with Embedded Waveguide Using FDTD Method

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Photonic crystals (PCs) with three-dimensionally periodic structures and omnidirectional photonic bandgaps (PBGs) within certain wavelength ranges have attracted extensive interest in their various potential applications in integrated photonics and optics. Artificial planar, line, or point defects embedded in the PCs, which allow propagating or localizing light, are required for the applications. One of the 3-D PBG structures, self-assembled PCs (inverse opals) with embedded defects has been investigated widely due to its simple and low-cost fabrication process. Ordered templates with close-packed face centered cubic structure may be built by the colloidal spheres, and is selectively removed after infiltrating a semiconductor material with high-refractive index into the interstitials of spheres.

A complete numerical characterization of the self-assembled PCs with a defect is essential for guiding the design process and obtaining a deeper insight into the physics of PCs. One of the numerical techniques, the Finite Difference Time Domain (FDTD) method for simulating the interaction of electromagnetic fields with material structures has become a well-established tool for the analysis of PCs. For predicting the PC behaviors and designing proper applications, we need to accurately model the PCs and their applications using the FDTD method.

In this paper, the numerical analysis using FDTD method for 3-D self-assembled inverse opal structures with embedded line defects is discussed. No previous results of such investigation have been reported. To confirm the existence of specific PBGs of self-assembled PCs, we calculated photonic band structures and transmittance spectrum using the MIT Photonic-Bands program based on Plane-Wave method and the Rsoft Fullwave FDTD codes, respectively. The simulation results for the 3-D PCs with close-packed air spheres surrounded by silicon suggest that the air spheres with diameter of 870 nm are required for a PBG at wavelength of 1550 nm, and the band structure of 3-D inverse opal shows an omnidirectional PBG exists. A line defect, Si_3N_4 rectangular channel waveguide embedded in the 3-D self-assembled PCs was used for the propagation simulations of light at wavelength of 1550 nm and the transmission spectrums of the waveguides were measured using the FDTD codes. We confirmed that guided wave propagation occurred along the Si_3N_4 guide within the PBG. Simulation results on both the 2-D and 3-D inverse opals with embedded waveguides will be presented at meeting.