Three-dimensional photonic crystals fabricated in polymer

Min Gu
Centre for Micro-Photonics and CUDOS, School of Biophysical Sciences and Electrical Engineering,
Hawthorn, Victoria 312, Australia
mgu@swin.edu.au

Abstract: We report on our recent achievement in fabricating three-dimensional photonic crystals in polymer based on the concept of the void or viod-channel generation. This method is a one-step approach and results in photonic crystals with a high degree of perfection. Three-dimensional photonic crystals with woodpile, face-centred-cubic and diamond lattice structures have been successfully produced, exhibiting a near-infrared transmission suppression of 70-90%.

OCIS codes: 130.0250, 190.4180, 190.4360, 220.4000.

1. Introduction

Photonic crystals are artificial periodic dielectric structures that can control the behaviours of light in a manner analogous to the way in which semiconductor crystals control the behaviours of electrons. Three-dimensional (3-D) photonic crystals hold a key to the successful development of all-optical devices [1]. The ability to generate voids inside transparent materials using ultra-short pulsed laser light has provide a useful tool for fabricating 3-D photonic crystals. The physical mechanism for this process is the micro-explosion under multi-photon absorption [2]. Here we present a novel approach to generate submicron-size voids and void channel-based 3-D photonic crystals by direct femtosecond-laser writing into a solid polymer material [3-5].

2. 3-D photonic crystals with a face-centred-cubic lattice structure

Figs. 1 (a)-(c) show the baseline-corrected transmission spectra of 28-layer 3-D face-centred-cubic void photonic crystals stacked in the [100] direction with a lattice constant of 3.4 μm, 4.0 μm and 4.96 μm, respectively. The suppression of transmission of the 1st order gaps is as large as 74% [5]. The 2nd order gaps which locate at the half of the wavelengths of the first gaps were also observed. But the suppression rate is much lower than that of the first gaps (~20%). The mid-gap wavelengths of both the 1st and the 2nd order gaps as a function of the lattice constants were shown in Fig. 1 (d), implying a linear relationship between the mid-gap wavelengths and the lattice constants.

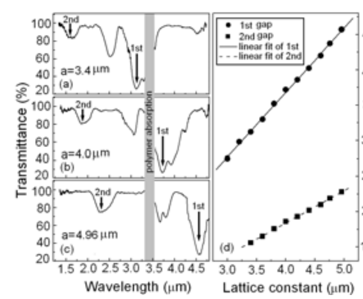

Fig. 1

3. 3-D photonic crystals with a woodpile lattice structure

If a laser beam is scanning, void channels can be fabricated and stacked as a woodpile structure [3]. Fig. 2 shows the transmission spectra in the stacking direction for eight woodpile structures with the layer spacing increasing from 1.5 μm to 3 μm. Arrows denote the photonic bandgaps. Both the main gap (hollow arrow) and the second-order gap (solid arrow) shift to shorter wavelengths upon reduction of the layer spacing. Because of the high degree of perfection in the fabrication process, noticeable third and fourth-order gaps have also been observed [4].

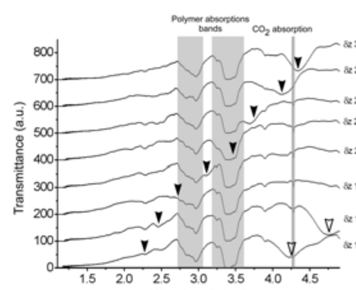

Fig. 2

References

[1] M. Straub and M. Gu, "Near infrared photonic crystals with higher-order bandgaps generated by two-photon photopolymerization," *Opt. Lett.* **27**, 1824-1826 (2002).

[2] D. Day and M. Gu, "Formation of voids in a doped polymethylmethacrylate polymer,"*Appl. Phys. Lett.*, **80** 2404-2406 (2002).

[3] M. Ventura, M. Straub and M. Gu, "Void-channel microstructures in resin solids as an efficient way to photonic crystals," *Appl. Phys. Lett*., **82**, 1649-1651 (2003).

[4] M. Straub, M. Ventura and M. Gu, "Multiple higher-order stop gaps in infrared polymer photonic crystals," *Phys. Rev. Lett*., **91**, 043901 (2003).

[5] G. Zhou, M. Ventura, M. Vanner and M. Gu, fabrication and optical characterization of three-dimensional face-centred-cubic photonic crystals in a solid polymer material, to be submitted (2004).