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Height controllable two-dimensional photonic crystal structures fabricated with two-photon photopolymerisation

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Abstract – *In this paper photonic crystal structures were fabricated with a shot by shot method. By utilizing two-photon photopolymerisation feature size can be decreased to less than 300 nm. Feature height can be accurately controlled by using different sized obstructions.*

Nowadays integrated optics is the main trend of optics. One of the most important aims of this cutting edge field is to make small-scale all optical signal-processing devices. Photonic crystals (PCs) are a promising candidate for achieving such an aim because of its excellent optical properties [1]. Owing to the difficulties associated with the fabrication of three-dimensional (3D) photonic crystals, planar PCs have attracted significant research attention. Basically two-dimensional (2D) PCs consist of periodic lattice of holes or rods. The geometry of the lattice as well as the feature of the holes or rods plays a crucial role in determining the properties of the PCs. By changing the rod diameter and lattice spacing, the bandgap can be adjusted. Therefore, much effort has been made to decrease the lateral size of rods [2,3]. Although controlling the size in vertical direction is equally important concerning achieving a full bandgap, reports in such an aspect have seldom been seen.

In this paper, a novel confocal system with high NA (NA=1.2 and 1.65) objectives is used to photopolymerize a threshold material- Norland Optical adhesive 63. The nonlinear nature of two-photon excitation can shrink the focal spot in transverse direction, which enables rods of less than 300 nm in lateral size and less than 1 μm in lattice spacing. A shot by shot fabrication process is applied instead of using the multibeam interference method, which makes arbitrary structures possible. By changing exposure power and time, rods of different size are developed. Measuring the rod diameter and height as a function of exposure time and power helped us to accurately determine the two-photon photopolymerisation damage threshold, therefore fully controlling the fabrication process (Fig1). Both grating structures and photonic crystal waveguide structures are fabricated (Fig3).

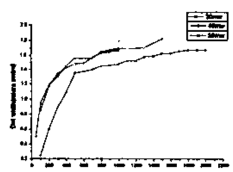

Fig 1 Rod width versus exposure time

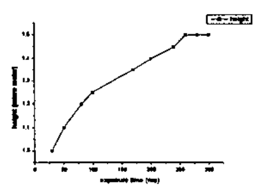

Fig 2 Rod height versus exposure time

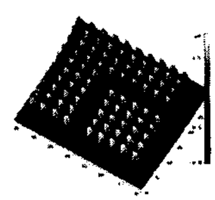

Fig 3 AFM image of a PC structure

In order to control the vertical size of rod, we introduce obstructions at the back aperture of the objectives. It is well known that an annular beam can elongate the focal spot in the axial direction and shrink spot size in transverse direction [4]. Therefore by using annular beam illumination, one can adjust the rod height and control the PC structure in the vertical direction. An improvement in height/width aspect ratio is demonstrated in this paper by applying $\varepsilon = 0.65$ (ε is the radius of the central obstruction normalized by the radius of the back aperture of the objective) annular beam illumination.

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