Modified Photonic Band Gap Via Thermal Shrinkage of Two-photon Polymerized Distributed Bragg Reflectors

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One-dimensional (1D) polymer-based photonic crystals (PhCs) in the 1.55 μm wavelength range can be easily created using a two-photon direct laser writing system. To achieve shorter period structures, we report the use of thermal shrinkage [1-3] of two-photon polymerized structures at elevated temperatures to eliminate unpolymerized material, leading to the uniform shrinkage of distributed Bragg reflector (DBR) structures [4] by a ratio of 2.5 to 5. Our Finite difference time domain (FDTD) simulation and the angle-resolved light scattering characterisation technique using Fourier image spectroscopy (FIS) [5-7] show that the photonic bandgap (PBG) of DBRs blue-shift in the visible region (650 nm to 500 nm).

The samples were thermally annealed as follows: the oven raises the temperature at a ramp rate of 10 ℃/min to the target temperature, which is 450 ℃ and remains at that temperature for a time Δt. Then, the chamber is cooled to room temperature for approximately 5 minutes. Figure 1 shows the resulting shrinkage for Δt=0, 4, 8 and 12 minutes as well as the corresponding optical image. Figure 2 shows the resulting angular-resolved FIS measurements, including the measurement of the original structure before shrinkage.

This technique could allow achieving an omnidirectional bandgap in the visible range for 3D PhCs using lower-resolution fabrication. Furthermore, the DBR templates could be used as a sacrifice or buffer layer to shrink different 3D PhC templates, thanks to their flat surface.

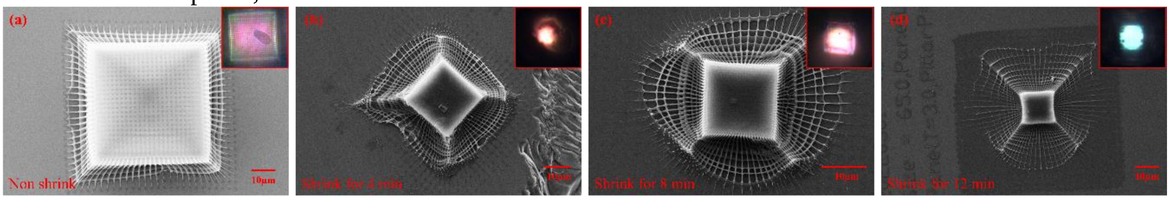

Fig. 1 The pillar-supported DBR after different shrinkage recipes in SEM image, from left to right, is Δt=0, 4, 8 and 12 minutes, respectively.

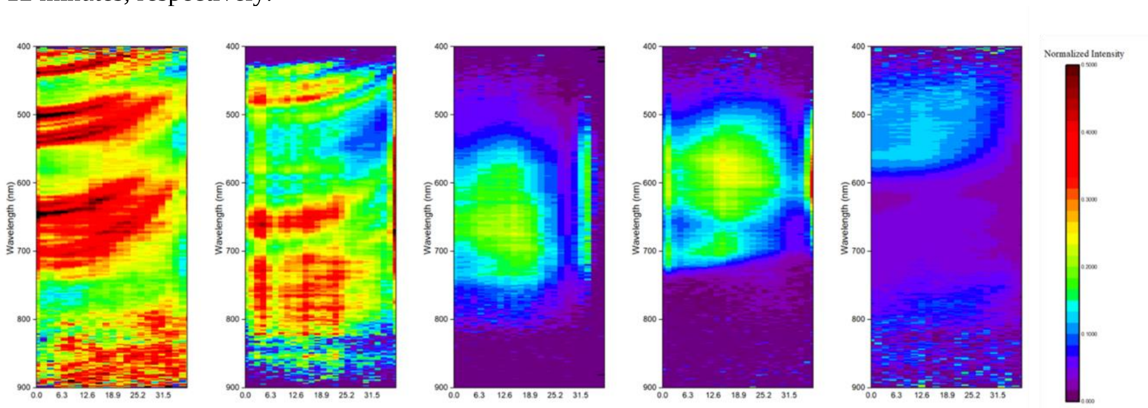

Fig. 2 Measured angular reflection spectrum from 0° to 37.5°. Following the sequence from the original, and the annealed samples for Δt=0, 4, 8 and 12 minutes. The band structures are noisy in the infrared due to Fabry-Perot oscillations from the quartz substrate.

References

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