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Realization of structural color via direct laser writing in photoresists

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1. Introduction

Structural color arises in periodic materials due to multiple internal reflections, interference and diffraction of light waves as well as random scattering. Bright, angle-independent colors of some natural systems, such as wings of butterflies and bugs, scales of fish, etc., originate from the structural factors rather than light absorption or emission [1]. There is a considerable interest in realizing structural color in artificial systems to achieve pigment-free, non-fading, bright colors[2], but this is a challenging task because 3D patterning sub-micron resolution is required to achieve structural color in the visible spectral range. Here, we describe realization of controllable structural color using 3D woodpile architecture photonic crystals (PhC) fabricated in photoresist by femtosecond Direct Laser Write (DLW) technique.

2. Experimental details and main results

The DLW fabrication is explained schematically in Fig. 1(a). Woodpile PhC structures were written using beam of a femtosecond Ti:Sapphire oscillator (λ=800 nm, Δt=80 fs, f=80 MHz) tightly focused by an NA=1.35 oil-immersion lens into organic-inorganic sol-gel based photoresist film deposited on glass substrate, using precisely controlled 3D translation of the sample. The 3D woodpile PhC samples were composed of photoresist rods having lateral/axial diameters of about 0.2/0.5μm arranged laterally into layers with rod-to-rod spacing of 1.0μm, and the layers were stacked axially with layer-to-layer distance of 0.35 μm to realize 3D woodpile photonic crystal architecture with an fcc lattice symmetry. The structures had a footprint of about (40x40) μm^2

Figure 1(b) shows optical microscopy images of several samples under observation in reflection geometry using NA=0.3 microscope lens, illustrating bright structural colors of the fabricated structures. Furthermore, gradual change of the dominant color from red to green is observed when power of the writing laser beam (and diameter of dielectric rods) is decreased.

The observed colors cannot be associated with high reflectance bands due to fundamental photonic stop gaps of the PhCs, since for these samples fundamental stop gaps occur outside the optical range, at near-infrared wavelengths (~1.5 μm). Hence, the origin of color is attributed to several factors, such as high reflectance due to higher-order photonic stop gaps as well as diffraction and random scattering on structure imperfections and rough surface. These results indicate that DLW technique in photoresists allows fast prototyping of porous dielectrics exhibiting structural colors. Owing to fast development of DLW technique, especially increase of writing speed, in the future, this approach might lead to realization of structural color in larger areas.

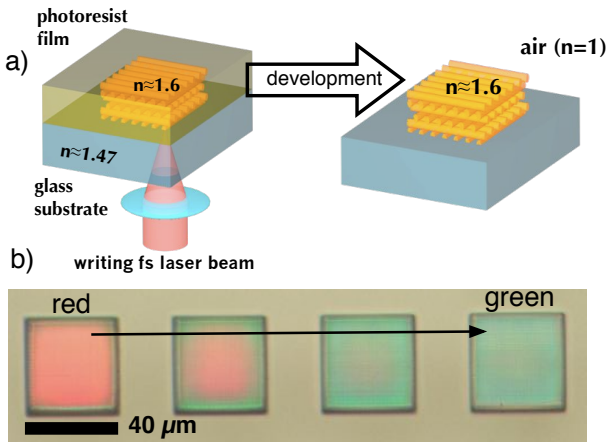

Fig. 1 Fabrication of 3D woodpile structures by DLW technique in photoresist. (b) Optical images of the fabricated samples illustrating gradual change of structural color from red to green with decreasing power of the writing laser beam.

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