**Interplay between ordered multilayer structure and randomly distributed**

**nanospheres and nanopillars in dichromated pullulan increases the width of the photonic bandgap**

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Complex nanostructures with interesting properties for photonic applications received great attention. Initially, highly ordered photonic crystal structures have been manufactured and investigated [1]. Interesting physical phenomena were discovered, such as: complete band gaps, nonlinearities, slow light, negative refraction. Later, attention was drawn to disordered materials [2], random lasing and rediscovering effects like coherent backscattering, Anderson localization [3].

Usually, ordered and disordered photonic structures have been generated and analyzed separately. However, in nature, biological photonic structures are complex and inherently disordered. Here, we present structures having both ordered and disordered components, integrated into novel photonic structure. Ordered Bragg layers are mutually separated and supported by nanopillars, while internal voids are filled with randomly distributed nanospheres. This complex morphology is formed simultaneously by the holographic method and the nonsolvent induced phase separation. Depending on the film thickness, there can be as many as 50 Bragg layers. We show that the interplay between the Bragg regularity and random scattering increases the width of the photonic band-gap significantly, up to a 35% wide band gap, (Δλmax/λmax = 35 %).

Photonic structures are holographically recorded in pullulan , a linear homopolysaccharide produced by micro-organisms (Aureobasidium pullulans), doped with ammonium dichromate. Here we use the dichromated pullulan for volume (Bragg) grating generation using a simple counter- propagating beam configuration.

Our photonic material has both properties of ordered photonic crystals: band gap and high reflectivity; and disordered structures: weak localization [4].

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