INTERPLAY BETWEEN ORDERED MULTILAYER STRUCTURE AND RANDOMLY DISTRIBUTED NANOSPHERES AND NANOPILLARS IN DICHROMATED PULLULAN INCREASES THE WIDTH 0F THE PHOTONIC BAND GAP

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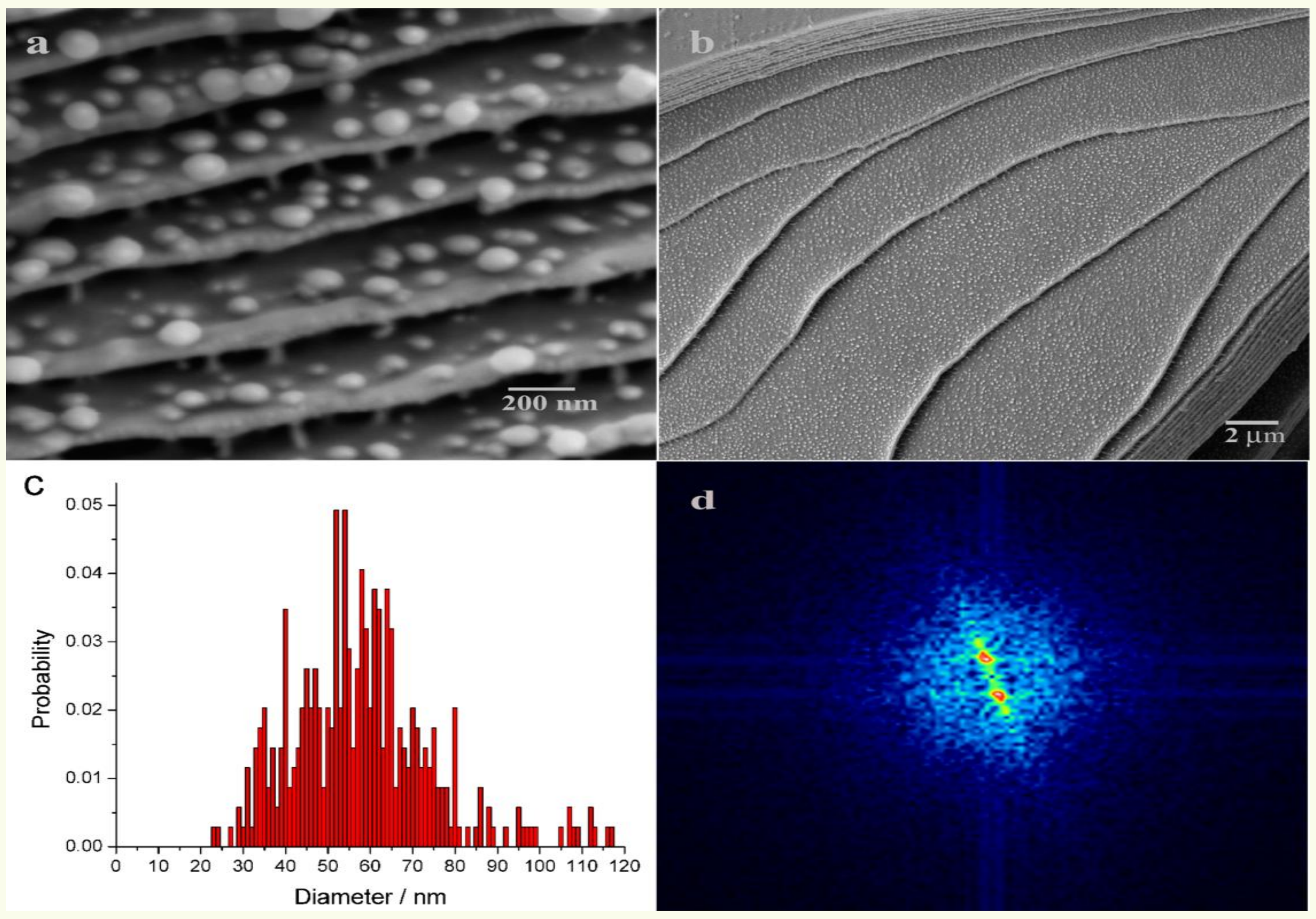
Complex nanostructures with interesting properties for photonic applications have received great attention. Initially, highly ordered photonic crystal structures have been manufactured and investigated [1]. Interesting physical phenomena were discovered, such as: complete band gaps, nonlinearities, slow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

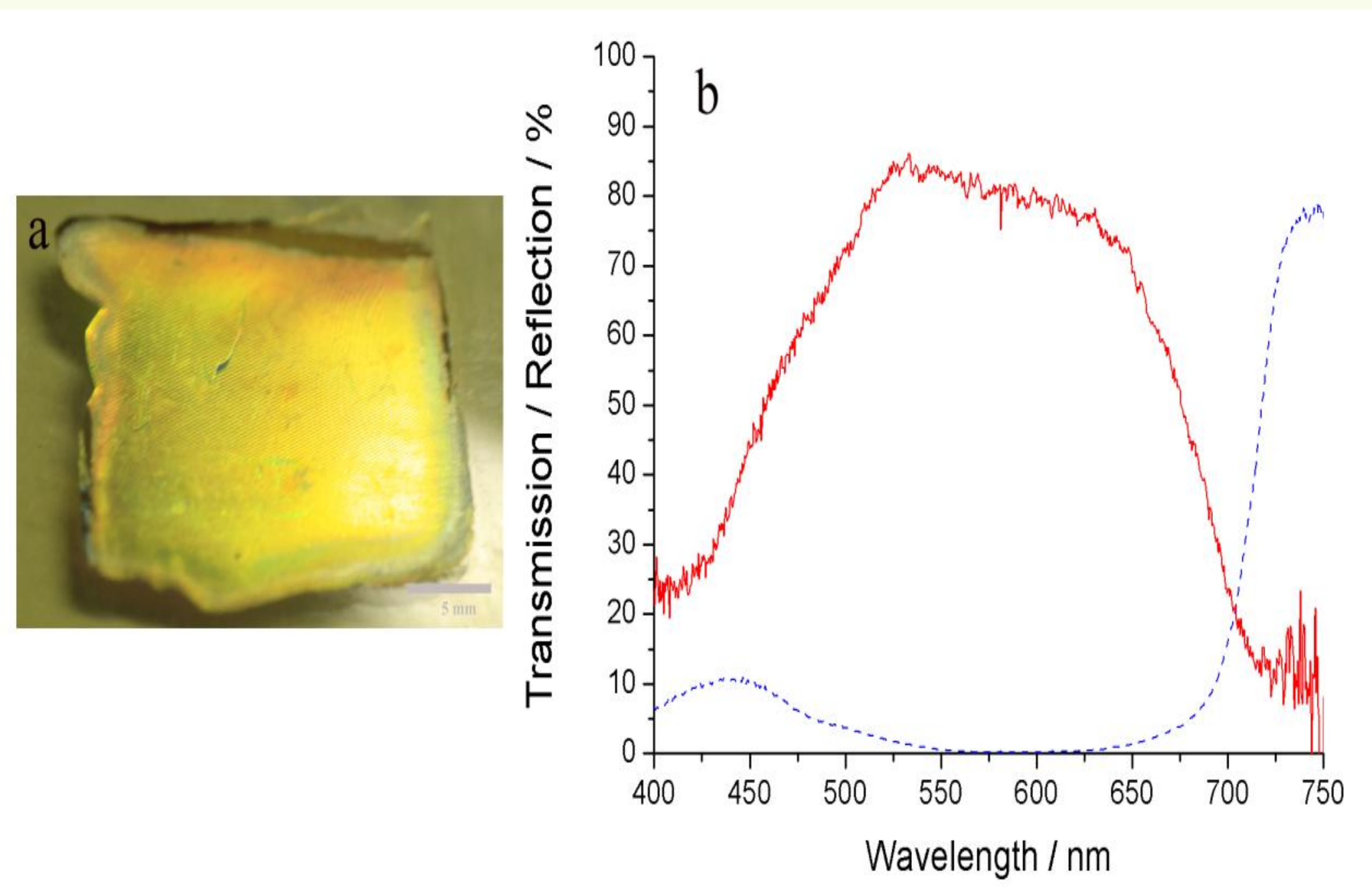
Usually, ordered and disordered photonic structures have been generated and analyzed separately. However, in nature, biological photonic structures are complex and inherently disordered. Here, we present structures having both ordered and disordered components, integrated into novel photonic structure. 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.

Photonic structures are holographically recorded in pullulan , a linear homopolysaccharide produced by micro-organisms (Aureobasidium pullulans), doped with ammonium dichromate (DCP). Here we use the dichromated pullulan for volume (Bragg) grating generation using a simple counter- propagating beam configuration. Laser at 532 nm was used as a light source. After exposure, DCP grating is chemically processed using a mixture of water and isopropyl alcohol as a developer.

The experimentally obtained band gap can be compared to theoretical estimate of the band gap for a perfect multilayer photonic crystal. We predict the 40 nm width of band gap, which is five times less than the experimentally obtained value, $\Delta\lambda exp \simeq 200$ nm. We attribute increased band gap to coherent light scattering on randomly distributed nanospheres and nanopillars inside the Bragg layers [4].



a) FEGSEM image of cross-section DCP photonic structure; b) FEGSEM image of internal structure of DCP grating; c) normalized distribution of nanosphere diameters, d) 2D FFT of FEGSEM image a.



a) Reflection image of a DCP sample; b) Reflection and transmission spectra of the DCP photonic structure.

In conclusion, our photonic material has both properties of ordered photonic crystals: band gap and high reflectivity; and disordered structures: weak localization. We created a unique, complex, self-supporting, multilayer grating in dichromate sensitized pullulan. The grating has pullulan nanospheres and nanopillars, arranged in a random manner, are confined between DCP Bragg layers. We show that combination of order and disorder significantly widens the band gap.

This DCP structure could have many applications: for novel optical filters, optical document security, optical data storage media, biomimetics.

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