

DESIGN OF 3D OPTICAL MEDIA WITH PERIODICALLY DISTRIBUTED EMITTING CENTERS

S. O. Klimonsky¹, T. Bakhia¹, N.S. Borodinov¹, A.V. Knotko¹, N. Yu. Vereschagina²

¹ Department of Materials Science, M.V. Lomonosov Moscow State University, 119991 Moscow, Russia

² D.I. Mendeleev University of Chemical Technology of Russia, 125047 Moscow, Russia

Abstract: Media with periodically distributed absorbing or emitting centers open new possibilities in a design of microoptical devices. However three dimensional (3D) structures of such type have not been obtained up to now. This question is considered in the present work. A multistage approach based on the colloid crystal technique has been suggested and structures consisted of CdSe quantum dots periodically distributed in ETPTA photoresist matrix have been prepared.

Structures with periodically distributed absorbing or emitting centers (PDAC and PDEC structures, correspondingly) open new possibilities in design of microoptical devices. Particularly absorbing structures permit to create photonic crystals with complex dielectric index contrast. Especially interesting case is realized when the photonic resonance connected with the refractive index contrast overlaps with the absorption feature, hence creating a “resonantly absorbing photonic crystal”. A one dimensional (1D) multilayer Bragg stack referred to as resonantly absorbing Bragg reflector was designed from an absorbing semiconductor and demonstrated efficient optical switching [1]. Then a 2D absorbing structure with periodically distributed dye was created and investigated in [2, 3]. This structure behaved not only as an imaginary refractive index photonic crystal, but also as a microscopic waveguide array with a controlled dispersion opening the way to the efficient color separation of light [3, 4]. In the present study we analyze possible ways to create 3D PDAC and PDEC structures based on the colloid crystals technique.

The worked out approach consists of the following stages:

1. Synthesis of SiO₂ microspheres with a narrow dispersion by the multistep modification of the Stöber method [5].
2. Growing of opal-type thin film photonic crystals by the vertical deposition technique [6] (Fig. 1a).
3. Filling of the structure with ETPTA photocurable resin followed by a photopolymerization and a creation of the opal-polymer composite.
4. Inversion of the structure by dissolving of SiO₂ microspheres in HF (Fig. 1b).
5. Incorporation of CdSe quantum dots into the colloid crystal films and into the inverse structures.
6. Filling of the inverse structure cavities with the photocurable resin followed by the photopolymerization and creation of the 3D PDEC structure.

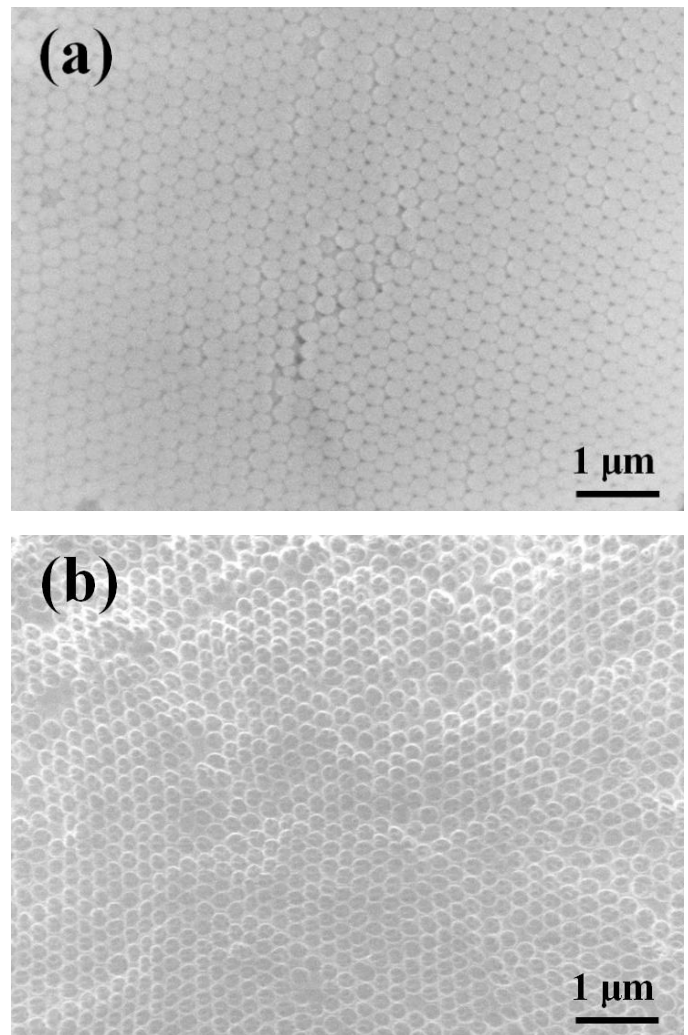


Fig. 1. Scanning electron microscopy images of SiO₂ opal-type film (a) and inverse ETPTA film (b).

Some of transmittance spectra obtained for our samples are shown in Fig. 2. The modification of curve 4 in comparison with curve 3 is accounted for CdSe quantum dots absorption (see curve 1). The photonic band gap is responsible for deep drops in curves 3, 4 near 560-570 nm. The band gap almost disappears in SiO₂-ETPTA composite (curve 5) due to close

values of SiO₂ and ETPTA refractive indices ($n = 1.45$ and 1.47 , correspondingly). The transmission spectrum of SiO₂-ETPTA composite with the periodically distributed quantum dots (curve 6) demonstrates a drop near 617 nm also, which is presumably connected with the photonic band gap induced by the imaginary refractive index contrast.

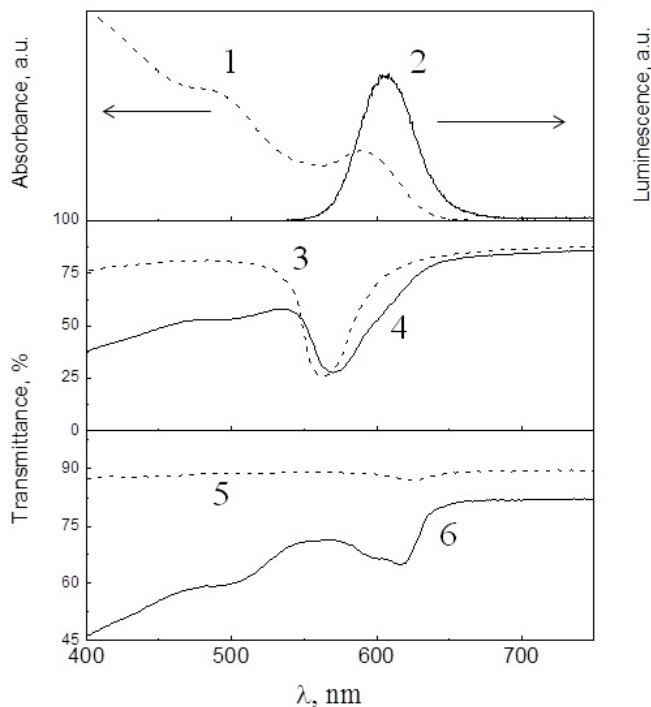


Fig. 2. 1 – absorbance spectrum of CdSe quantum dots with the diameter of 5.1 nm; 2 – photoluminescence spectrum of the same quantum dots (300 nm excitation); 3 – transmittance spectrum of the opal-type film shown in Fig. 1a; 4 – transmittance spectrum of the same film after the quantum dots incorporation; 5 - transmittance spectrum of a similar film filled by the photoresist (SiO₂-ETPTA composite without quantum dots); 6 - transmittance spectrum of a similar film with quantum dots incorporated into the opal matrix before filling with the photoresist (SiO₂-ETPTA composite containing periodically distributed quantum dots).

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