Quantum dots by UV- and X-Ray lithography

M.F.Bertino[1,*], R.R.Gadipalli[1], L.A.Martin[1], B. Heckman[1], A. Yamilov[1],

N.Leventis[2,*] S.Guha[3], J. Katsoudas[4], V. Zyryanov[4], R. Divan[5], D. C. Mancini[5]

[1]Department of Physics, University of Missouri-Rolla, MO 65409, USA Email: Massimo@umr.edu
** Corresponding author. Tel.: +1-573 341 6221; fax: +1-573 341 4715.*

[2]Department of Chemistry , University of Missouri-Rolla, MO 65409, USA E-mail: leventis@umr.edu
** Corresponding author. Tel.: +1-573 341 4391.*

[3]Department of Physics, University of Missouri-Columbia, Columbia, MO 65211, USA

[4] Center for Synchrotron Radiation Research and Instrumentation, Illinois Institute of Technology, Chicago, IL 60616.

[5]Center for Nanoscale Materials, Argonne National Laboratory, 9700 S. Cass Ave., Bldg. 440 Rm. A130 Argonne, IL 60439-4812

In the last few years, a wide array of quantum dot-based devices and composites has been proposed for applications ranging from non-linear optics to light emitting diodes, sensors, and lasers. Large-scale applications of these devices and materials, however, are limited by cost and manufacturing issues. It was recognized early that applications could be made more readily available if quantum dots could be synthesized with bottom-up lithographic techniques. However, progress in this direction has been sluggish. Only very recently patterning of substrates with quantum dots was reported, and it was obtained by photocorrosion of films of pre-formed quantum dots, which is a top-down approach.

We recently demonstrated that quantum dots can be synthesized in selected regions of porous matrices by photodissociation of appropriate precursors. Here we expand those methods and we show that quantum dots can be produced with UV- and X-ray lithography. Perhaps more importantly, we show that patterns can be produced with a resolution on the order of the limit of fabrication of the masks (10-20 μm) that penetrate for up to 12 mm inside the gels. Examples of structures produced with our technique are reported in figure 1.

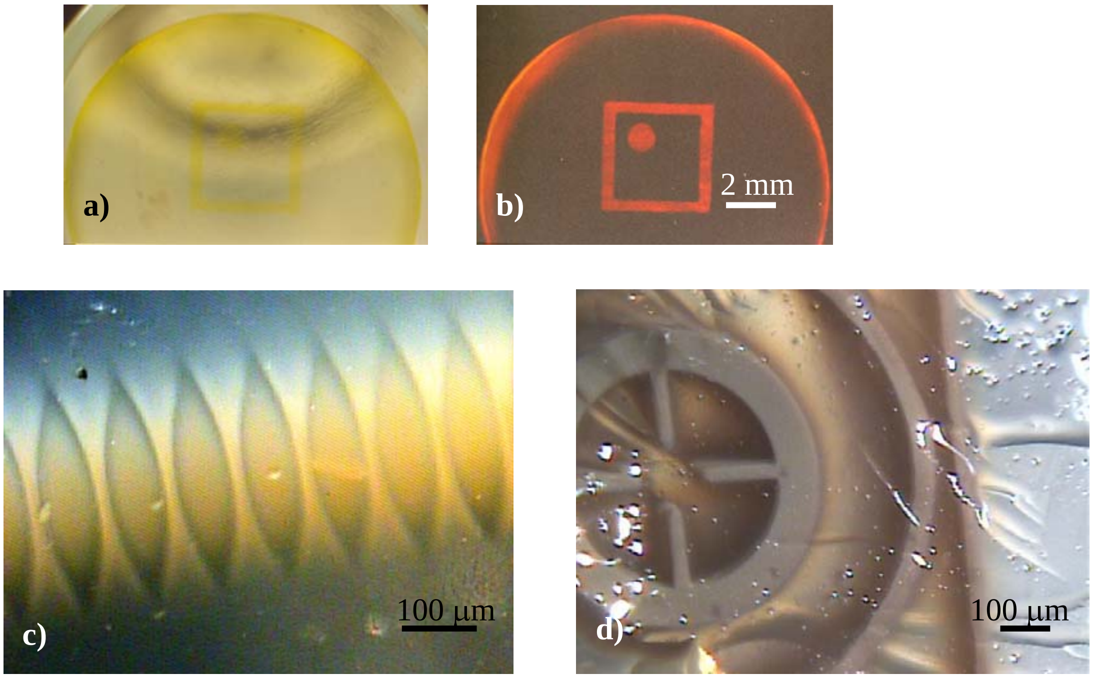

Figure 1. (a-b) CdSe patterns obtained with UV lithography. (b) Shows the photoluminescence of sample (a), obtained by illuminating the patterned sample with the 457.9 nm line of an Ar^+ laser. A laser goggle was interposed between the sample and the camera to filter the laser glare from the photoluminescence of the CdSe quantum dots. (c-d) PbS patterns obtained with X-Ray lithography.

We will also show that: (i) the mean size of the quantum dots can be easily controlled by adding capping agents to the precursor solution, (ii) the quantum yield of the composites can be increased to up to about 30% by photoactivation, (iii) the density of the patterns can be increased by electroless deposition, (iv) the process depends only weakly on the incident energy of the X-Rays.

Our technique is water-based, uses readily available reagents, and high aspect ratio patterns are obtained a few simple processing steps. These features make our technique an excellent candidate for the mass production of three-dimensional quantum dot devices and for the production of patterns of materials with a high refractive index to be used for photonic applications.