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THIN SOLID FILMS OF CLOSELY-PACKED CdS NANOCRYSTALS AS MEDIA FOR HOLOGRAPHIC GRATE WRITING

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Thin 500 nm solid films of 1.6-1.8 nm CdS nanocrystals were produced and their photophysical response were studied by using conventional holographic recording setup with He-Cd UV writing laser and He-Ne reading one. Extremely small size of CdS nanocrystals promotes high yield of photochemical and photophysical processes which involve permanent capture of optically excited electron-hole pairs on the surface traps.

CdS nanocrystals were synthesized by reaction between cadmium thioglicerate and sodium sulfide, both dissolved in dimethylformamide. The fast mixing of these solutions results in creation of colloidal CdS nanocrystals, surface captured by thioglicerole monolayer. This surface monolayer prevents CdS nanocrystals from recrystallization providing ultrasmall highly monodisperse colloidal particles to occur. The overall concentration of resulting CdS colloidal solution was 10^{-3} M. Then an appropriate amount of acetone or dioxane into colloidal solution was added until it became cloudy and CdS nanocrystals were deposited onto quartz glass. The resulting matrix-free thin solid film of CdS nanocrystals did not contain soluble ions or molecules, as well as any polymers.

The absorption spectra of thin film of CdS nanocrystals show strong excitonic transition at 3.75 eV, which reveals strong effect of quantum confinement in such nanocrystals. X-ray diffraction analysis shows the nanocrystals possess wurtzite structure with the average size of about 1.6-1.8 nm. This is twice less than the Bohr radius of exciton in bulk CdS. The photoluminescence spectra exhibit a broad band in the blue-green region which can be attributed to the radiative recombination through deep surface traps. While, nonradiative channels include the creation of permanently trapped electrons or holes at the surface of nanocrystals. The surface trapped electrons and holes create strong electric filed inside CdS nanocrystals which can induce the changes in refractive and absorption indices of irradiated CdS nanocrystals. To examine this mechanism we utilized the holographic method which is highly sensitive to the changes in both refractive and absorption indices.

The cw He-Cd laser beam (λ=325 nm) was splited into two ones, which interfere at the surface of thin film of CdS nanocrystals giving interference fringes with the period of about 2 μm. The wavelength of He-Cd laser beam falls in the excitonic absorption band of CdS nanocrystals so that the various photophysical processes can be achieved in the nanocrystals. The second He-Ne laser beam (λ=632 nm) served as a probe one to watch for creation of diffraction grid inside CdS thin film. The photodiode was used to register the intensity of diffracted He-Ne beam during the writing of holographic grid. All experiments were made at room temperature.

Fig. 1 shows the dynamics of diffraction intensity in transmittance of He-Ne beam registered during the irradiation of CdS film by interfered He-Cd beams.

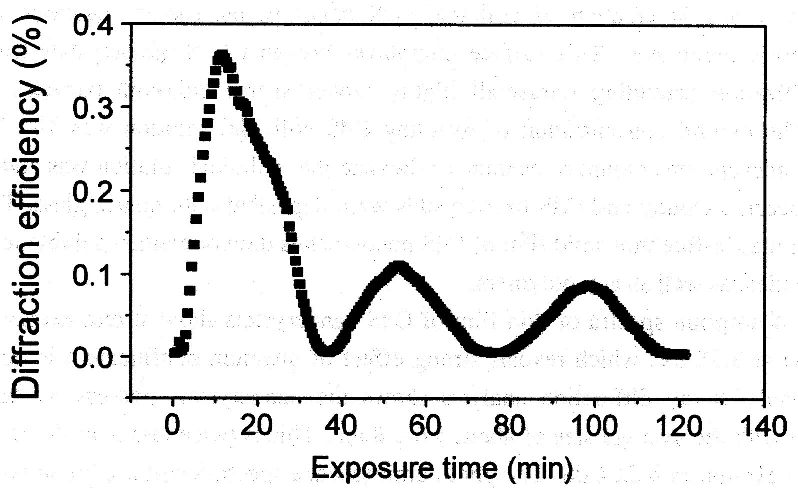

Figure 1: Diffraction intensity vs exposure time of thin solid film of CdS nanocrystals.

The diffraction intensity shows multipeak behavior during holographic writing. This multipeak dynamics can be described well by light diffraction on thin holographic grid. Each peak should correspond to the phase shift on π of light passed through irradiated and non-irradiated fringes. But this approach would require enormous changes in refractive index during writing. Since only minor changes in the morphology of thin film of CdS nanocrystals were detected we propose the mechanism of holographic grid formation based on the induced Kerr effect. The strong electric field inside irradiated CdS nanocrystal created by trapped electron-hole pairs causes changes in the refractive index. Normally, the Kerr effect can not be large enough to cause the multipeak behavior during holographic writing. Probably other mechanisms should be involved to explain the results obtained in this work, like the cyclic cancellation of internal electric field by each even electron-hole pairs generated in irradiated CdS nanocrystals.

In conclusion, it is expected the high, nearly 100 % volume concentration of CdS nanocrystals in thin films studied allows to reach large diffraction intensity on thin films of CdS nanocrystals, which makes them a promising photorefractive material.

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