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14. ABSTRACT

We report the simultaneous control of the polarization state and emission bandwidth of colloidal nanocrystal quantum dots by embedding them in chiral reflector-based microcavities. Significant improvements in directionality and color purity have been observed in the polarized light output arising from the enhanced coupling between the NQD-excitons and the confined electromagnetic field.

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We report the simultaneous control of the polarization state and emission bandwidth of colloidal nanocrystal quantum dots by embedding them in chiral reflector-based microcavities. Significant improvements in directionality and color purity have been observed in the polarized light output arising from the enhanced coupling between the NQD-excitons and the confined electromagnetic field.

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Circularly Polarized Emission from Colloidal Nanocrystal Quantum Dots Confined in Sculptured Thin Film Based Microcavities

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Abstract: We report the simultaneous control of the polarization state and emission bandwidth of colloidal nanocrystal quantum dots by embedding them in chiral reflector-based microcavities. Significant improvements in directionality and color purity have been observed in the polarized light output arising from the enhanced coupling between the NQD-excitons and the confined electromagnetic field.

In comparison to many efficiently luminescent materials, a distinct feature of semiconductor nanocrystal quantum dots (NQDs) is that their emission properties are highly susceptible to modification due to characteristics in many application environments. The emission wavelength can simply be tuned by varying the size and/or the material composition of nanoparticles during fabrication, even though their chemical properties remain substantially invariant. Therefore, the same NQD-device configuration can be adopted for different nanocrystals to emit over a broad wavelength regime, covering the visible (0.4-0.8 μm) and near-infrared (0.8-2.5 μm) spectral regimes.[1,2,3] Of equal importance is the control of the polarization state and bandwidth of the NQD emission for potential applications in bio/chemical sensing, multispectral imaging, quantum computing and cryptography, polarized optical interconnects, spintronics, etc.[4,5] We report in this conference the observation of narrow-bandwidth circularly polarized (CP) emission from a thin layer of semiconductor nanocrystals embedded in a polarization-selective resonant microcavity. The microcavity consists of two sculptured-thin-film (STF)-based chiral mirrors separated by a spacer layer. The polarization-dependent reflection of the structurally left/right-handed STF chiral reflectors inhibits the presence of right/left CP, which induces the resonance of left/right CP[6,7]. When the nanocrystals are sandwiched between the chiral mirrors, the confinement applied by the microcavity will alter the density and polarization state of the optical modes within it, and spatially and spectrally redistribute the emission output. The enhanced coupling between the NQD-excitons and the confined electromagnetic field will result in CP emission from the embedded NQDs with significant improvement in light output directionality and color purity.

Figure 1 shows a schematic drawing of the structure of the microcavity device containing NQD emitters. A layer of CdSe/CdS nanocrystals, inserted between two spacer layers of SiO2, was enclosed by top and bottom chiral STF mirrors, which were structurally left-handed comprising 6 structural-periods. The left-hand and right-hand circularly polarized (LCP and RCP) emissions of the photopumped core/shell NQDs coupled in the microcavity were resolved in the measurement and plotted in Figure 2. The free-space luminescence of the core/shell-NQD layer is also included in the figure for the sake of comparison. It has been observed that the LCP and RCP light emitted by the cavity-coupled NQDs exhibit significant differences in intensity and bandwidth: the FWHM bandwidths of the LCP and RCP emissions are 9.36nm and 21.55 nm, respectively, while the peak intensity of the LCP emission is four times higher than that of the RCP emission. By optimizing the chiral-reflector performance, a complete suppression of the RCP emission is predicted by our calculation results, which leads to the pure LCP output from the cavity-embedded NQDs.

The spatial distribution of radiation power (emission pattern) of the NQDs in microcavity was measured and plotted in Figure 3. The measured Lambertian-radiation pattern of the free-space luminescence of NQDs is also plotted for reference. It is evident that the introduction of microcavity structure brings about a drastic change of NQD emission patterns, which is, again, due to the non-uniform spatial distribution of the density of photon states in the microcavity. The emission from the NQDs within the cavity can therefore be strongly directed vertically from the mirror surface if proper cavity design is adopted. Due to the simple and cost effective fabrication of the microcavity devices combined with their favorable optical emission properties with excellent stability also above room temperature, such devices might be attractive alternatives to currently available commercial laser diodes operating in this spectral range. To this end, the electrically pumped microcavity light emitting diodes (LEDs) is envisaged. We have recently demonstrated the stable operation of non-cavity NQD-LEDs at high brightness (~4000cd/m^2) over hundreds of hours (Fig. 4), showing the potential of achieving high-performance microcavity NQD-LEDs in the near future.

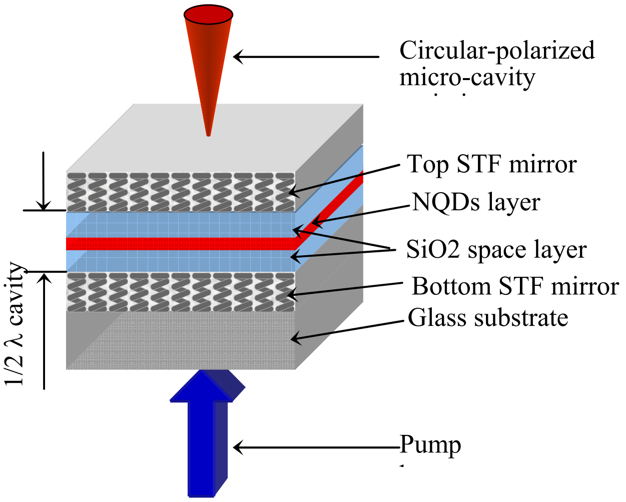

Fig.1 Schematic drawing of the structure of the microcavity device

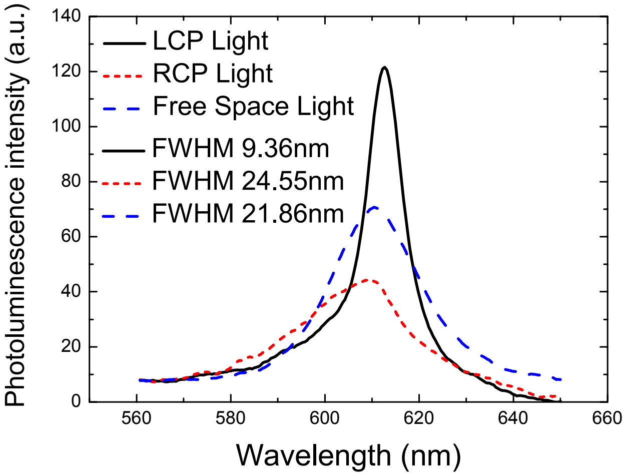

Fig.2 PL spectra of LCP, RCP and free space lights

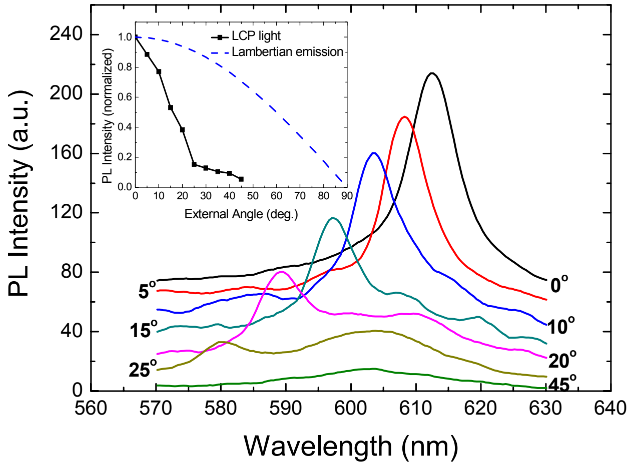

Fig.3 PL spectra of LCP light as a function of the detection angle. The inset shows the spatial distribution of radiation power of LCP light

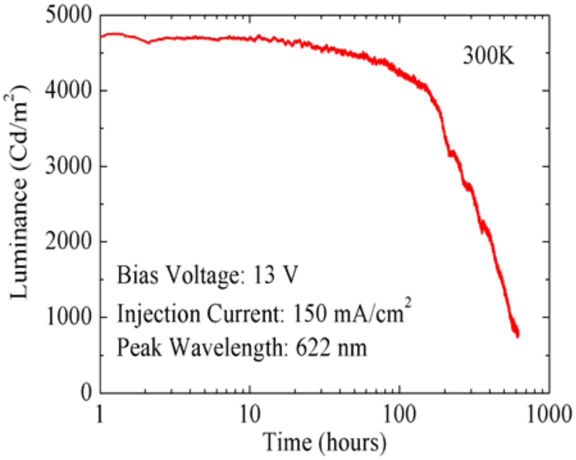

Fig. 4 Lifetime characterization of the NQD-EL performance

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