Waveguides based on colloidal QDs embedded in PMMA and SU8

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Nanocomposites based on the integration of colloidal quantum dots (CQD) into a polymer matrix are a very potential material to develop novel integrated photonic devices, because such a multicomponent material combines the properties of CQD with the technological feasibility of polymers. CQD are semiconductor nanostructures synthesized by colloidal chemistry and they present the advantages of joining the three dimensional confinement of carriers characteristic of quantum dots (QDs) with the tuning of the emission and absorption wavelength just by controlling the size and shape during their chemistry process [1]. In addition, as a consequence of their small size (1 nm to 10 nm) these nanostructures show strong quantum confinement, being its emission practically temperature independent [2]. Moreover, chemical methods allow controlling the emission wavelength by changing not only the NQDs size but also their base material without modifying the preparation method. In this way the NQDs emission can cover a broad range of the optical spectrum using CdS [3], CdTe [4] and CdSe [5] in the visible range, and PbS [6], PbSe and InAs [7] in the near infrared. For these reasons, NQDs are interesting candidates to be incorporated as active medium in new optoelectronic devices. However, in order to make these nanostructures compatible with the photonic technology they have to be embedded in a solid state matrix. In this way, the use of polymers as a host material seems to be a good choice, because they are cheap, flexible and they can be easily processed into films by coating techniques and patternable by UV or e-beam lithography [8].

In this work NQD-PMMA nanocomposite films are proposed as novel material to implement active waveguides. For this purpose The NQD-PMMA films (with thickness between 1 and 2 µm) were deposited on a SiO_2/Si substrate (see inset of figure 2). Since the refractive index of PMMA (1.489 at 600 nm) is higher than the one of SiO2 (1.458 at 600 nm) the nanocomposite can act as core layer of the waveguide. As result, if the appropriate concentrations of QDs in the polymer are chosen their PL can be coupled to the waveguide modes when the structures are optically pumped [9]. In addition, wavelength tunability of the NQDs allows the control of the active wavelength (from 400 nm to 2 µm) just by changing the material of the dots and their size [10] without modifying the fabrication conditions. In this way waveguiding of the PL of CdS (450 nm), CdSe (600 nm), CdTe (550 nm) and PbS (1100 nm) is demonstrated. Moreover, when more than one QD family is embedded in the polymer the structure can present multicolor waveguiding [8-9]. For example, figure 1 shows the guided PL spectra in a waveguide embedding CdS (blue, 452 nm), CdTe (green, 539 nm) and CdSe (red, 601 nm) QDs. It is worth noting that it was critical to adjust the relative amounts of QDs into the matrix in order to avoid (or compensate) reabsorption between QDs families. The pictures at the top of Fig. 1 correspond to the three color waveguiding of the three CQDs families.

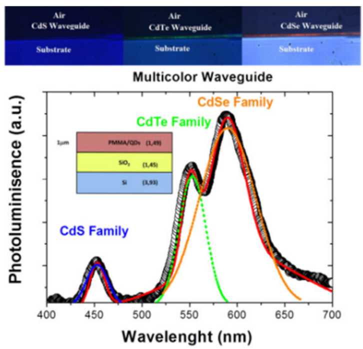

Figure 1: Bottom. PL wave-guided spectra of QD/PMMA planar waveguide with three QDs families (CdS, CdTe and CdSe). Top. Photographs of the waveguided light. The inset shows the waveguide structure.

Although PMMA is cheap and allows a trouble-free thin film processing, it is limited in the implementation of two dimensional waveguides due to the fact that it not allows patterning by UV lithographic methods. In this way SU8 seems to be a better choice because it is easily-patterned by using UV photolithography and also has a high refractive index (~1.5) interesting for waveguide applications. However, the main drawback of SU8 is its chemical incompatibility with as-syntesized QDs. In [11] the appropriate ligand exchange to disperse QDs in this polymer is proposed, making it possible to develop patterns with QD inside. Figure 2 shows a preliminary result of these new patterned structures. The spectra corresponds to the guided-PL of CdSe QDs in an 8 µm SU-8 ridge pumped with a 533 nm DSPP diode laser characterized by end fire coupling. The inset shows a photograph of the guided PL in waveguides with different widths. In all cases the structure is able to confine PL into two dimensions.

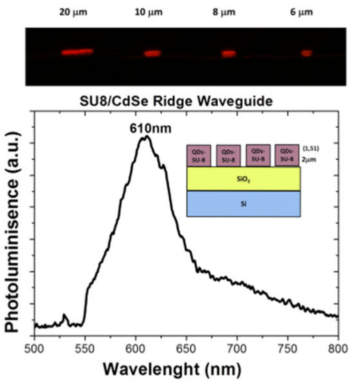

Figure 2: Top. Waveguiding PL spectrum of a CdSe-SU8 ridge waveguide. Bottom. Photographs of the waveguided light in structures with differents widths. The inset shows the waveguide structure.

Nanocomposites proposed in this work can be used as cores of active planar and stripe waveguides or in other application in organic photonic. Since they present the advantages of an easy processing and the possibility of tuning the active wavelength by the change of the base material, they are promising candidates for new integrated optic devices.

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[11] To be published.