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Enhanced white light emitting device based on ZnTe nanocrystals and conductive organic polymer by surface excitons

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The white organic lighting has been intended device appearing an emission cover light-emitting conductive polymer (Poly (p-phenylene vinylene) (PPV) and poly (p-phenylene sulfide) (PPS)) as a host material for zinc telluride (ZnTe) nanocrystals (NCs) or quantum dots (QDs) and tris-(8-hydroxyquinoline)-aluminum (Alq_3) together of titanium oxide (TiO_2) thin layer as white light emitters. The white light-emitting electroluminescence (EL) procedure be defined by of three covers deposited successively upon the ITO glass-substrate surface ITO/PVV: PSS/ZnTe NCs/Alq_3 with TiO_2/Ni. Current-voltage (I-V) attributes show a strong output current relative to the few voltages (4 V) that are used to produce acceptable white light output performance. The Commission International de l'Eclairage coordinates of the device's emitting light was recognized (X= 0.31, Y= 0.34) which were only slightly changed over a range of applied voltage (4 Volts) and correlated color temperature (CCT) was realized nearly 6250 K. The production of ZnTe NCs light-emitting device with organic polymer hole injection (PVV: PSS) and organic molecules (Alq_3 with TiO_2) was successful in white-light production.

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1. Introduction

Owing to its unique properties including size tunable, optical gaps and narrow emission, excellent transport strengths for loads, nanocrystals (NCs) have recently attracted attention as specific class of opto-electronics for many areas (such as LEDs, solar cells, lasers or photodetectors). The property of optical bandgaps in semiconductors (II-VI) nanocrystals is the same as that of conventional metal chalcogenide semiconductors [1].

Semiconductors NCs (e.g., CdSe, CdS, CdTe and ZnTe) due to their unique benefits such as high performance, good lighting, low voltage, high power consumption and long life time, LEDs provide a huge potential for display, lighting and sensing applications [1, 2].

At the surface of the zinc telluride (ZnTe) NCs, some of the discoordinated Te Atoms can provide trap states within the area of the band gap and can be considered unsafe bonds by electrons and holes. The range of radiative recombination's in trap sates leads to the white emission [3, 4].

In addition to the structural properties, ZnTe NCs of magic dimensions have a high volume-to-surface ratio which leads to a high trap-state density on the face. Trap-states in NCs are generally attractive due to their inefficiency in the application of white-light sources [4].

Polymers that conducted the production of nanocomposites are used as host matrix. The poly (poly (p-phenylene vinylene), poly(PPV) and the p-phenylene sulphide (PPS), for their high electric conductivity, their environmental stability and relatively simple synthesis, are among the most well-known conducting polymers. Polymer growth in the presence of inorganic materials significantly impacts the polymer's microstructure [5].

The fabrication of a white light-emitting devices established on organic materials is an impressive idea founded in the last few year, there can be discrimination against two kinds of NCs-LED architecture. The first interface of the device sandwiches a thin layer of NCs between a hole and an electron injection layer, which produces excitons directly inside the NC layer. The active layer consists of a mixture of NCs dispersed through a polymer or small molecule matrix in the second interface [6, 7].

The ZnTe NCs organic ligands with the main function of the surface passivation of the ZnTe NCs are conductive materials which make the load injection difficult to achieve. Thus,

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injecting distributors into ZnTe NCs is not an easy task, that ultimately reduces device efficiency overall. In the last decade considerable changes were made despite this challenge. Another uncertainty arises from the long term problems associated with charging and photo-charging effects [8, 9].

Herein, explored the use of ZnTe nanocrystalline NCs in a hybrid with conductive polymer. The application of this was further studied heterostructures a white luminous structure with the use of aluminum tris (8-hydroxyquinoline) (Alq_3) with titanium oxide (TiO_2) when a white light emitter. The emission of conductive polymers, ZnTe NCs, and Alq_3 with TiO_2 results in a closely white OLED with Commission International del'Eclairage coordinates (CIE) of $(x, y) = (0.32, 0.34)$ for a range of applied voltages between 4 and 5 Volts.

2. Experimental work

The materials that are used in works have been given without further purification by Fluka Company while American Dye Supply (Canada) has been supplied with (Poly (p-phenylene vinylene) (PPV) and poly (p-phenylene sulfide) (PPS)) and Triss (aluminum-8-hydroxyquinoline) (Alq_3).

The TeO_2 and $ZnCl_2$ were used as a source of Te with molecular-weight 195.6 mg/mol and Zn with molecular-weight 136.27 gm/mol respectively. In 25 ml distilled water, $ZnCl_2$ was melted while TeO_2 was melted in 20 ml distilled water and HCl. The TeO_2 has been blended with acid HCl until the solution is clear. Mix the precipitation solution at a steady temperature of 70 C° using a magnetic mixer. The chemical reactions are done as follows after these compounds are mixed:

$$\mathrm{TeO_2} + 4\mathrm{HCl} \leftrightarrow \mathrm{TeCl_4} + 2\mathrm{H_2O}$$

$$\mathrm{ZnCl_2} + \mathrm{TeCl_2} \xrightarrow{\mathrm{H_2O}} \mathrm{ZnTe} + \mathrm{Cl_2} \uparrow + \mathrm{H_2O} \uparrow$$

The ZnTe NCs that have been developed with the addition of isopropanol alcohol for 20 minutes proceeded by centrifugation. In several stages, the fabricating process of the LED can be illustrated. Firstly, independently dissolve 50 mg / ml in 1 ml ethanol from each PPV and PSS conductive polymers. Secondly, 50 mg / ml Alq_3 doped with TiO_2 powder dissolved in 2 ml ethanol. The layers were deposited in order, as in Fig.1, on the ITO glass substrate surface.

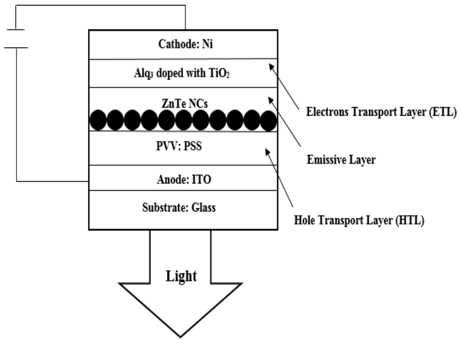


Fig. 1. Organic light-emitting device (OLED) ZnTe NCs based in a cross-sectional configuration.

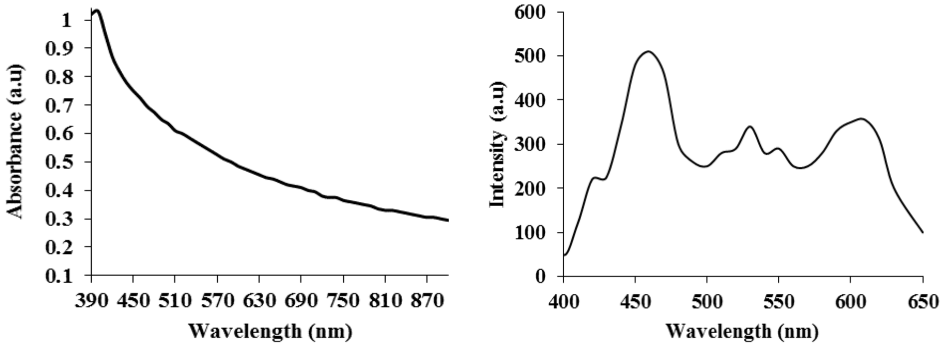
The hybrid white light-emitting devices produced are shown in Fig. 1. The configuration employed consists of layers deposited successively with spin cover at 2700 rpm for around 10 seconds for each layer in a phase segregation process on the ITO glass substrate. PVV and PSS in 1:1 were the first rows. The second layer was ZnTe NCs of 0.06% wt. After each coating is coated, the film dries 25 minutes in an oven at 45 C^o. Last but not least, the Alq_3 doped with TiO_2

deposition over the ZnTe NCs layer. The thicknesses of layers were determined by Tolansky thin film thickness measuring method, while PVV: PSS thickness and Alq_3 doped with TiO_2 layers were determined by 35, 30 nm, while ZnTe NCs thickness was 20 nm and the ITO layer's thickness and resistance by 150 nm and 8 Ω. The device will be consequently depositing nickel (Ni) cathode.

Standard configuration of OLEDs was produced. Several layers on indium tin oxide (ITO) glasses were deposited. ITO-glass substrates were washed using cleaning products and ultrasonic bath treatment with two separate solvents (isopropanol and afterwards in acetone). A spin coating of 2500 rpm was deposited of PVV and PSS conductive polymers (HTL) using an aqueous of 1.3–1.5% w/w (film thickness 60 nm). The films have been annealed in an oven at 50 C° for 20 min. In the top of the film, an ethanol solution was spin-coated with the ZnTe NCs (EM) layer (dimension 25 nm) at 2000 rpm also annealed at 40 C°for 15 min. For white light emitting devices, the thermal evaporations in the vacuum (10^{-7} mbar) of tris-(8-hydroxyquine) aluminum (Alq_3) doped TiO_2 (ETL) atop the composite layer of ZnTe NC's were done. A successful thermal evaporation of Ni metal (52 mm thick) which is the negative electrode of the structure finished the devices. The Ni electrode is used to improve electron injection by controlling the energy mix between Alq_3 with TiO_2 and ZnTe NCs.

3. Results and discussion

Fig. 2 shows the ZnTe NCs spectra of absorption and photoluminescence (PL). Fig. 2a shows an optical absorption (OA) spectrum of ZnTe NCs. It is apparent that the ZnTe NCs is absorbance in the UV and visible ranges while ZnTe NCs absorb or emit light. Thus, this indicates was essential to optically observe and control the growth of ZnTe NCs through OA spectrum [10, 11]. It is possible to identify two distinct OA spectrum bands for ZnTe NCs grown. The band are centered near 400 nm (3.1 eV), the cooling rate used to prevent Zn^{2+} and Te^{2-} ions diffusion and ZnTe NC growth was clearly indicated in the labelled trace. A red-shift occurred when the band raised near 400 nm. This is a reliable sign of quantum confinement in growing dots [11, 12].



(a) *(b)*

Fig. 2. Absorption and PL spectra of ZnTe NCs.

The photoluminescence (PL) spectrum (fig.2b) showed that the characteristic emission bands of Zn^{2+} and Te^{2-} ions are intense and evident at room temperatures [13]. The spectrum showed that the dependence of luminescence high intensity at 460 nm on the surface excitons (electron-phonon) interaction that arises from multiphoton relaxation processes and other peaks at 510, 530, 550 and 610 nm due to surface state formation [12, 13]. The redshifts in the PL spectrum from green to orange when the ion is included in ZnTe NCs that can be very interested in light device applications. These observations show that higher recombination procedures are required of surface excitons into ZnTe NCs. The energy gap of ZnTe NCs was estimated by PL in relation to the ratio of about 2.69 eV ($E=1240 / \lambda(nm)$).

The SEM images of sample ZnTe NCs were examined by SU-1500 scanning electron microscope (Japan). The scanning electron microscope of 50 Kx magnifications, as shown in fig.3, investigated the surface morphology of the prepared ZnTe NCs. An effective signifier to ZnTe NCs creation is given by the SEM images of the QDs. From the SEM images, it is clear that the surface of ZnTe film is very smooth with occasional small particles. The substrate temperature was 250 C°, rate of evaporation was 4 Å/sec, and the film's definitive thickness was 2000 Å. The ZnTe NCs were arranged during deposition, which resulted in a very smooth surface, due to the very large surface. Certain of the NCs are also found in micrographs with a slightly larger size. High temperatures of the substrate during deposition are concluded that high quality smooth surface films are beneficial. The average SEM grain is approximately 2 nm. The developed NCs are nearly spherical although NCs are clustered within the limit of 100 nm is shown in Fig. 3.

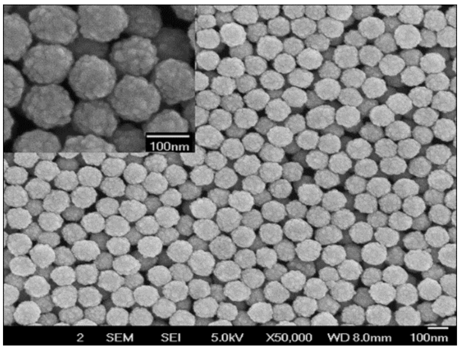


Fig. 3. Scanning electron microscope (SEM) of ZnTe NCs.

Fig. 4 reveals the hybrid junction systems I-V characteristics obtained from the ITO/PVV: PSS/ZnTe NCs/$Alq_3$with TiO_2/Ni. The Fig. 4 shows the overall constructive behavior at 4 V bias voltage, with turn-on voltage, while light emissions were perceived at current levels of almost 0.012-0.84 mA.

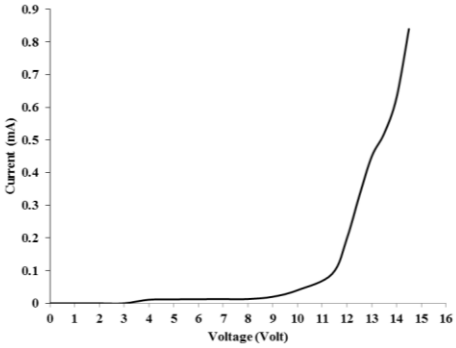


Fig. 4. I-V forward characteristics of ITO/PVV: PSS/ZnTe/$Alq_3$with TiO_2/Ni OLEDs.

The hybrid device's I-V characteristics indicate an improvement in current exponential caused by the reduction in the application layer width at the crossing point. So that electrons and holes in the conduction and valence bands are exponentially distributed the conduction band barrier can be reduced and hence the current of diffusion continues to flow exponentially raises with a growth through the lighting-device crossing significance [14, 15]. The flow current in the reverse direction is not predicated on the possible barrier level and increases the electron arise between Alq_3 doped TiO_2 and n-(ZnTe NCs) and holes between p-(PPV: PSS) and n-(ZnTe NCs) [12]. The following recombination will lead to a bias flow of just a few volts of 4 V for ITO/PVV: PSS/ZnTe/$Alq_3$with TiO_2/Ni.

These voltages (in I-V characteristics) denote the upper limit for light produced experimentally from the TPD: PPV/ CdSe QDs / Alq_3 EL unit light emissions at room temperature photomultiplier detector. Fig. 5 shows EL measuring the voltage are under 4 V forward bias voltages.

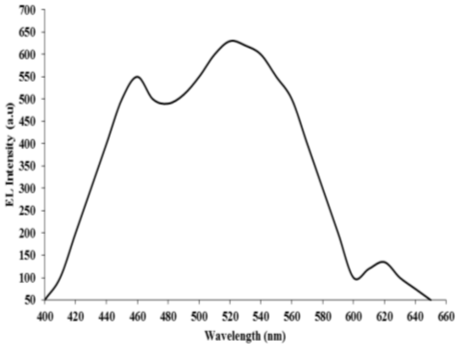


Fig. 5. Electroluminescence (EL) spectrum of PVV: PSS/ZnTe/Alq_3 with TiO_2 device.

The wavelength and color reactivity spectrum show high intensity of PVV: PSS/ZnTe/Alq_3 with TiO_2 light-emitting device shown in Fig. 5. The peaks intensities at a wavelength of 460, 520 and 620 nm were influenced by the operation condition of EL devices at 93 V AC and 350 Hz. The light-emitting device showed green-blue and red emissions are blended, and thus it was confirmed that the white light-emitting luminous color. The electrical installations of the charges in the hybrid crossing system is that, the PVV: PSS serves as the product to carry the hole and it refers to the strength production rise of light-emitting device [16]. A kind of this electrons are injected in layer Alq_3 with TiO_2 particles, there is already an electron used transport substance and product emissions. The number of electrons and their mobility is increased, which means that high electric mobility towards the ZnTe NCs layer increased [16, 17]. Hence, band to-band re-combination was considered holes and electron as of the surface excitons in the ZnTe NCs. The re-combination of the holes and electrons with defects in light emission wavelength is referred the Shockley Read Hall re-combination. For the coverings containing of ZnTe NCs and Alq_3 with TiO_2 layer, the highest emission rate rises are observed in contrast to the films without Alq_3 with TiO_2 coating. The addition of alq_3 organic molecules induces the transfer of the energy of Förster from the LUMO (Alq_3 with TiO_2) to the HOMO (ITO); this contributes to improved performance of hybrid devices [18].

From the illustration 5 The attendance of spectrum peaks at blue, green and red can be observed, when mixed, provides white light. These electrons then recombine radioactively with holes in the polymer's HOMO, leading to the energy emission of photons equal to the energy difference between the PVV and PSS [19]. An illustration of the white light released by the light-emitting device in Fig. 6 indicates EL spectrometer output light at the white light locale. Recognizable and very high are the impact of the output light.

Fig. 6. A white light development imaging of PVV: PSS/ZnTe/Alq_3 with TiO_2 light-emitting device.

The distribution of emissions of Fig. 5 chromaticity diagram has been studied in CIE 1931 diagram, Fig.7 shows color co-ordinates of EL.

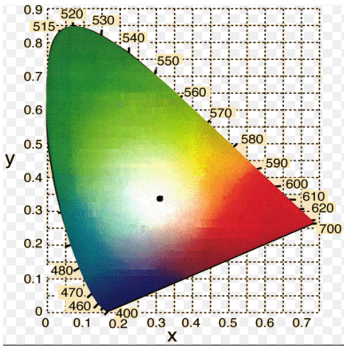


Fig. 7. The chromaticity-coordinates schemes of the PVV: PSS/ZnTe/Alq$_3$ with TiO$_2$ light-emitting device.

Fig. 7 shows chromaticity coordinates schemes of the PVV: PSS/ZnTe/Alq$_3$ with TiO$_2$ light-emitting device which responded to blue- green- red colors. The chromaticity coordinates standard which proved an x, y of EL device. The x, y CIE standard at $x = 0.31$ and $y = 0.34$ and a color temperature of around 6250 K° with a higher correlation. This means that the illumination is moving to the core of the white-light at higher temperatures, which in act results in a high efficiency from the system [20, 21].

4. Conclusion

A modified ZnTe NCs-based organic-lighting-device contributed to improved performance by PVV, PSS organic polymers, and Alq$_3$ with TiO$_2$ organic molecules layers. Alq$_3$ with TiO$_2$ layer of organic molecules utilizes many voltages of high strength and transparency for white light generation. Enhance the quality of the resultant effect on light sites and is one of the benefits of organic materials when going to the development of the area with white light. The I-V appearances output stream and successive recombination processes will allow the future bias current stream to expand using the few voltages which yield good results to produce white light by surface excitons. Fabrication of the ZnTe NCs OLED, in a strength and effectiveness of the white-light produced, between two-layer organic polymer-injection-hole (PVV with PSS) and electron injection (Alq$_3$ with TiO$_2$) was successful and could be the strong light.

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