

Colloidal synthesis of ZnTe nanocrystals by laser ablation and fabrication of hybrid light emitting device

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Zinc telluride (ZnTe) nanocrystals (NCs) have generated the interest of researchers as an electrode material in hybrid light emitting devices (HLEDs) due to its potentially high capacity. However, due to the restricted fundamental charging capacity of the electrode materials, the available energy of existing nanomaterial light emitting devices remains enough for a wide range of applications. In this research, ZnTe nanocrystals were synthesized using Nd: YAG laser at energy 600 mJ by 150 pulse number to form a battery device out of ITO/ZnTe/TPD/Ni. The spectra of the ZnTe NCs were assessed using ultraviolet-visible (UV-VIS) and photoluminescence (PL). The results proved that the synthesized NCs were nanocrystalline structures. The energy gap (E_g) within ZnTe NCs regarded as (PL) spectrum has been identified to be about 3.6 eV. ZnTe NCs produced via laser ablation enhance the functionality of the HLEDs by increasing the carrier's charge mobility and, as a further benefit, by facilitating recombination processes inside ZnTe NCs with TPD organic polymer. In addition to lighting at 3V, current-voltage (I-V) specifications establish suitable environment as well as formation.

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1. Introduction

The generation of electrical power from photovoltaic light conversion is gradually increasing. This may be ascribed to the development of novel renewable energy materials and low-cost production systems, which has resulted in a decrease in the cost of a watt-hour generated by photovoltaic means. Using polycrystalline semiconductor thin films is an intriguing approach to lower the cost of photovoltaic cells [1].

The covers of batteries are made up of several semiconductor and conductive organic polymer layers, including the absorber or active material. Zinc tellurium (ZnTe), silicon (Si), gallium arsenide (GaAs), TPD, and PEDOT: PSS [1,2] are now used in the industrial fabrication of high-efficiency light emitting devices [2,3]

For many years, researchers have been interested in the Zinc telluride (ZnTe) semiconductor, which belongs to the II-VI family owing to their suitable band gaps and high absorption coefficients. ZnTe has mostly been investigated in the last ten years as a polycrystalline thin film and as a nanocrystal, and a zinc telluride (ZnTe) has been identified as an interesting thin-film HLEDs material. It has been created as a thin film using laser ablation, electrodeposition, and spray pyrolysis, and it has mostly been employed as the absorber material of thin-film light emitting devices [3, 4].

Recent ZnTe deposition techniques are based on dispersing ZnTe nanocrystals in water or organic solvents [4-6] and transforming them into ZnTe thin films utilizing simple and inexpensive deposition processes such as dip-coating or spin-coating and an annealing procedure. Many approaches have lately been studied in order to overcome the limitations of ZnTe NCs-based cathode [5,6].

Furthermore, when already realized on a combination (ZnTe NCs and TPD organic polymer), all of these components should be as large as possible in order to set up a technique. A standard approach to generate transparent devices, as proved in nanocrystals and organic semiconductors, is working to components with low contrast sensitivity and high absorbance [6,7].

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However, nanostructured ZnTe with a high surface area promotes electrolyte side reactions, resulting in irreversible capacity loss during the first cycle. Furthermore, this method is insufficient to increase ZnTe high electric conductivity altogether. To further overcome the constraints of the ZnTe cathode, nanostructured materials might be blended with a highly conductive and elastic matrix to form a nanocomposite structure [8,9].

One of the most important problems in this work is controlling the thickness of the layers while depositing them on the glass ITO substrate. As the thickness of the layer's increases, it causes a disconnection in the electrical current passing through the device. Therefore, the deposition of the layers must be controlled, and the best solution for this is to deposit the layers separately from the others in a way chemical spraying and drying in oven.

Laser ablation synthesis (LAS) in solution is a physical approach that may be used instead of chemicals. Typically, the methods most often employed for the creation of nanoparticles involve the use of toxic substances as indicators as well as reducing or stability agents [9]. In addition, LAS has a low environmental effect since it does not require any preparations or reducing chemicals and may produce high purity colloids while producing no toxic waste [10]. Laser-ablation synthesis techniques have emerged as an effective and adjustable technique for nanomaterials synthesis [8-10], demonstrating the ability to be used for the synthesis of nanostructures using several starting materials in a variety of liquid environment.

In the current assignment, a simple sustainable synthesis method for reconstructing colloidal ZnTe nanocrystals by laser ablation deposition with TPD layer on the ITO surface to fabricate ZnTe-hybrid light emitting devices (ZnTe-HLEDs) is used, as well as an investigation of the physical and physicochemical effectiveness of the resulting ZnTe-HLEDs is used. The electrolyte that adds ZnTe NCs to the surface of the TPD substrate improves surface area while also providing the best available technology specific-capacity, good cycle-stability, and exceptional efficacy. Because of these properties, ZnTe NCs are a great candidate as an emissive material in ZnTe-HLEDs. Also, for improved reversible performance of the develops the hybrid light emitting device environment friendly.

2. Experimental work

All of the main compounds were purchased from Fluka company, which were employed without further purification. Initially, 0.8 g of zinc chloride ($ZnCl_2$) and 0.3 g of sodium telluride (Na_2Te) were dissolved in 40 ml of deionized water (Na_2H_2Te). The Nd: YAG laser operating at (1064 nm) with energy up to 600 mJ/pulse was used to synthesis ZnTe NCs (see Fig.1). The laser beams of a focal length of 20 cm focused on the mixed solution from a lens distance of 5 cm. A container was spinning to generate homogeneous nanocrystals and stirred for 2 hours before passing the nanocrystals solution with an increased pulse number of 150 pulses, allowing the color of the ZnTe NCs solution to change to light green. The ZnTe NCs were then cleaned five times with deionized water before being completely vacuum packed.

The setup of the established hybrid light emitting device used two layers. ZnTe NCs and TPD (N, N'-bis (3-methylphenyl)-N, N'-bis (phenyl) benzidine) organic polymer provided by Sigma-Aldrich Chemie GmbH progressively poured upon it. Organic polymeric coating dissolving 40 mg/ml in ethanol by injection on ITO glass substrate using covered spinning at 2000 r.p.m. in around 10 second for separate covered polymers. To avoid crashes, the first layer was 0.2 wt% ZnTe NCs in the cover, the second layer was always layer TPD conductive polymer. Immediately after coating in a 40 °C oven for 10 minutes, the coating on each cover dries away. The thicknesses of the films have been measured by interference method (Tolansky method of thin film thickness measurement) while the thickness of TPD layer appear to be 30nm, while a ZnTe NCs cover appears to be 10 nm thick. Next that, a nickel (Ni) cathode is coated in system layer. Hybrid light emitting devices processing ZnTe nanocrystals covering TPD may create ZnTe and TPD ions transport rates in HLEDs in response to a light emitting devices work.

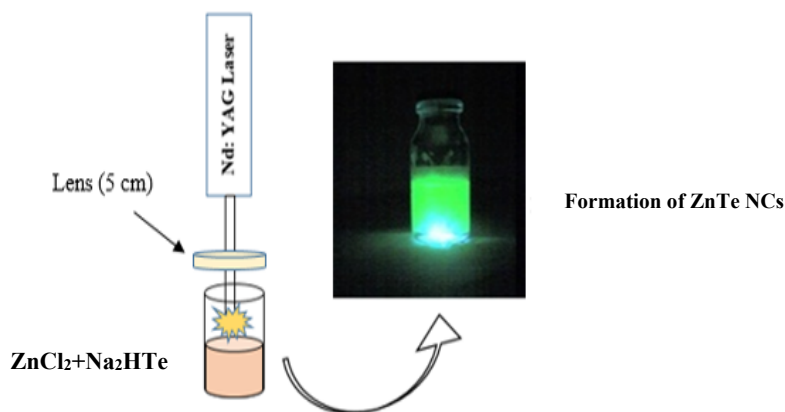


Fig.1. Laser ablation technique of ZnTe NCs colloidal formation.

3. Results and discussion

Figures 2 and 3 illustrate the absorption and photoluminescence (PL) spectra of ZnTe NCs at room temperature. A UV-VIS band spectrum analyses the absorption of high-level ZnTe NCs. These findings have been obtained in an adequate setting when compared to the absorption spectra of previous studies [11-13]. Figure 3 exhibits the photoluminescence of ZnTe NCs, which suggests that a specific energy band conduction occurs at 530 nm. Excessive fluorescence occurs as a result of the emission of the near-band edge of ZnTe NCs, with additional highlights at 460 and 620 nm caused by free excitons recombination [12]. These broad emissions are linked to deep-level leaks, which can be caused by defects in structure. According to that circumstance, the presence of the relevant defect identified as a beyond observer, an emission associated with nanocrystalline defects ZnTe NCs might be due to Cd or Te vacant seats [14-18]. The energy-gap in ZnTe NCs must have been established formulated at essentially 3.6 eV.

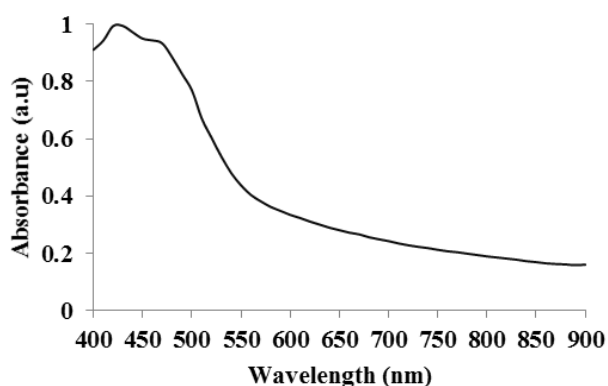


Fig. 2. Absorption spectra of ZnTe NCs.

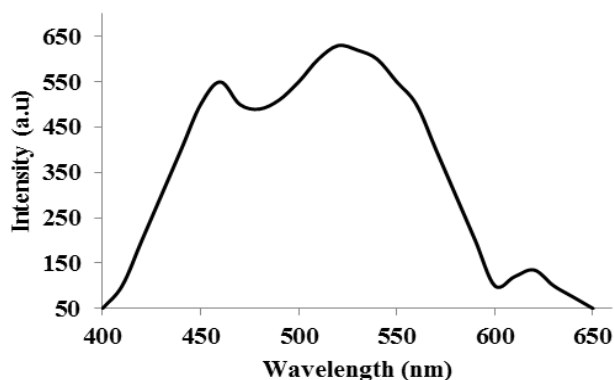


Fig. 3. PL spectra of ZnTe NCs.

As shown in Fig.4, the surface topography of the grown ZnTe NCs has been imaged using SEM at 50 KX magnification. The NCs covering's SEM properties serve as an acceptable notice for the formation of ZnTe NCs. Image J software (version 1.8.0) was used to analyze the SEM image and histogram of particle size distribution of the ZnTe NCs. The average grain size was found to be around 10 nm Figure 4 depicts spherical morphology with low aggregation of NCs generated at 100 nm scale.

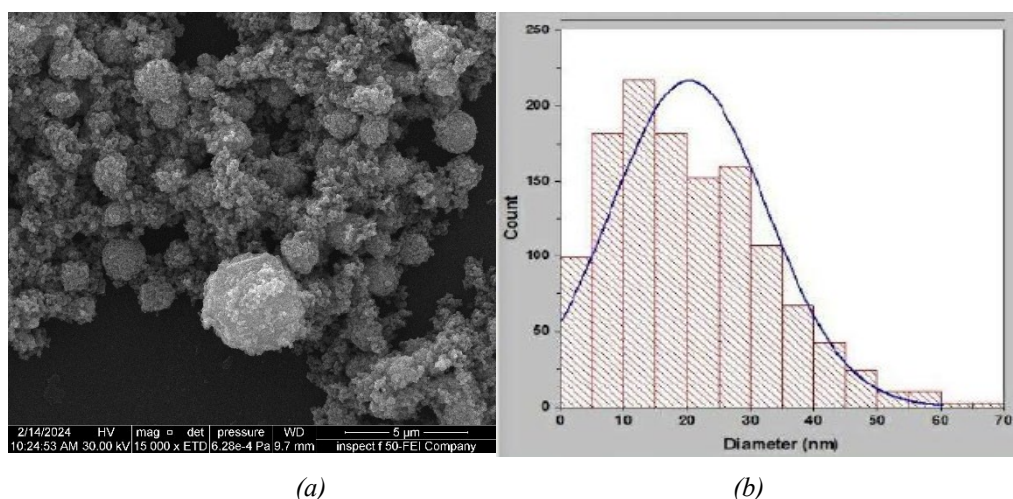


Fig. 4. (a) Scanning electron microscope (SEM) of ZnTe NCs (b) Image and histogram of size distribution of ZnTe NCs.

The electrically charged ZnTe NCs that perform in Hall Effect assignments of magnitude are described. Developed and introduced a semiconductor electrical characterization technique called Hall Effect Metrology (DHEM). HEM provides depth profiles of critical electrical properties through semiconductor layers at nanometer-level depth resolution. HEM is based on the differential Hall effect (DHE) method, which makes successive sheet resistance and mobility measurements on a layer using Hall effect and Van der Pauw techniques as the thickness of the layer is reduced through successive processing steps, typically involving chemical or electrochemical etching or oxidation. The data obtained as a function of thickness removed can then be used to determine the depth profiles of carrier concentration, resistivity and mobility. Thin films with thicknesses of 10, 20, and 30 nm exhibit semiconductor activity and n-type conductivity. Table 1 summarizes the Hall Effect.

Table 1. Overview of Zinc telluride nanocrystals Hall Effect measurements with varying thickness.

Sample	Thickness (nm)	Conductivity ($\Omega\cdot\text{cm}$) ⁻¹	Mobility (cm^2/Vs)	Hall Coefficient (cm^2/C)
ZnTe	10	2.56	48.5	-1.23×10^8
	20	1.48	16	-1.27×10^8
	30	1.34	13.5	-1.31×10^8

When compared to other ZnTe NCs thicknesses, it was suggested that ZnTe NCs had strong conductivity at 10 nm thickness. In addition, the mobility of ZnTe NCs at 10 nm thickness is greater than that of ZnTe NCs at 20 and 30 nm thicknesses, implying that the ZnTe are impacted by a decrease in the resistance of the ZnTe NCs, which suggests that, amid substantial increases in the NCs, the growth of recombination extremely emerged a ZnTe battery device and induced charges, which governed. In the light of the improved electron confinement in ZnTe NCs, mobility in a carrier increases as dimensions' decrease.

This feature separates batteries from commercial batteries, which operate at higher voltages and have lower efficiency [19,20]. Figure 5 explains the I-V combinations of the ZnTe-HLEDs achieved with the ITO/ZnTe/TPD/Ni performance. The figure shows the capacity to rearrange with a general conversion voltage of 3 V voltage bias and a current of just under 0.01-0.44 mA.

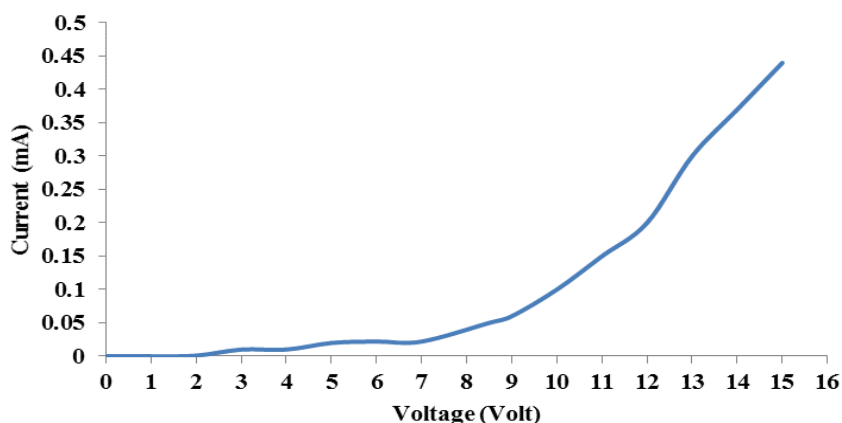


Fig. 5. I-V characters of the ITO/ZnTe/TPD/Ni HLEDs.

A hybrid light emitting device product performed current-voltage reveals an overall increase concerning current induced beside a decrease during the depletion-edge layer's size. The propagation band barrier will decrease in the forward bias owing to dramatic increase dispersion of ions (ZnTe and TPD) inside the valence and conduction band [20]. Because allowed towards charge besides discharging processes shifted significantly across one cycle to another remained when the stream is steady for the duration of the cycle [21,22]. The number of charging and discharging cycles that a ZnTe-HLEDs may go through before it stops operating is referred to as its life-cycle. The discharge depth has a significant impact on the life of ZnTe-HLEDs.

The depths of discharge describe how much of a battery's storage is consumed. As a result of the rechargeable batteries provide ions (TPD) to (ZnTe NCs) owing to system discharges, recombination would increase the forward bias's current flow [23]. At this point, these processes emerge as a result of multiple techniques that influence the production of batteries. One particular technique stands out, as it does not seem to be directly controlled by another synthesis. Insufficient results have an influence on success, as is shown in a band gap the semi-conductors that is operating even more devices for generating current [22-24]. These devices in the gap charge domain can be

classified as surface imperfections, barrier annealing, output recombination, and boundary configurations [24]. Figure 6 illustrates a view of an ITO/ZnTe/TPD/Ni displays the light emitted by this component.

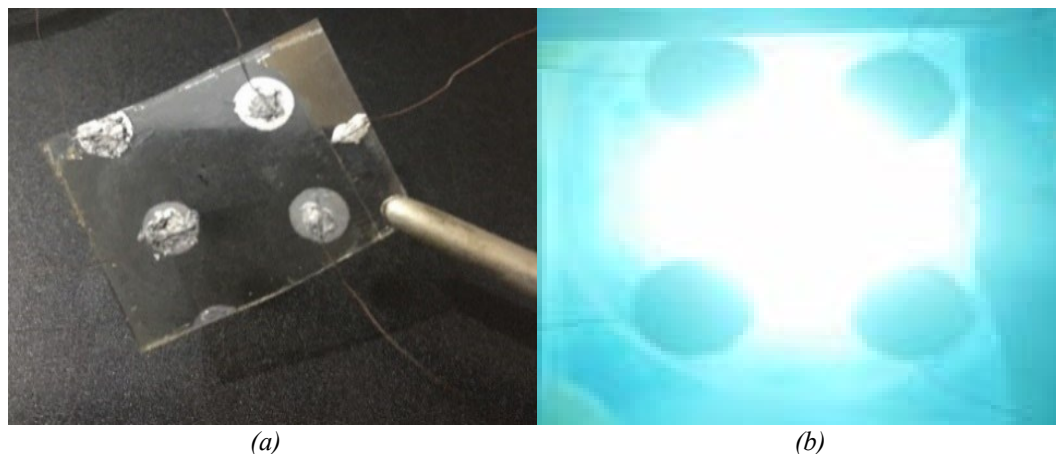


Fig. 6. (a) A picture of the ITO/ZnTe/TPD/Ni HLEDs (b) Light illumination produced by ITO/ZnTe/TPD/Ni HLEDs.

4. Conclusion

In conclusion, the controllable size of ZnTe NCs by laser ablation technique is supported by composition analysis, which has been very beneficial because the size reduced as the number of laser pulses increased and they had deep imperfections. These imperfections can be constructed in a number of ways, as well as nano-electronic devices. ZnTe NCs raised more the ability of the HLEDs by boosting the charge mobility of the carrier as well as the interactions between ZnTe NCs and TPD organic conductive polymer ions. Likewise, using TPD conductive polymers in battery with ZnTe NCs semiconductor layers resulted in a complex formation of conductive polymers and semiconductor nanomaterials, resulting in high-performance HLEDs efficiency. The current forward can thus explain the suitable contact between the layers of TPD and ZnTe NCs.

The current-voltage characteristics are completely matched with the needed voltage, which produces critical features for the functioning of the light emitting system. A progressive interaction development in the HLEDs involving ZnTe NCs and TPD organic polymer ions may give forward current flow bias in order to use confined volts and create positive outcomes for light output. The development of a ZnTe-HLEDs utilizing semiconductor materials (ZnTe NCs) and (TPD) resulted in the light emitting device working with a few voltage and a high flow.

Nonetheless, research-arranged innovative conductor supplies continue to push the limits in terms of cost, conversion efficiency, extended lifetime, and stability. As new nanomaterials and approaches emerge, light emitting devices will undoubtedly have a greater impact on our daily lives in the next years. Furthermore, new nanomaterial preparation processes should be applied to reduce the cost of nano-storage capacity studies.

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