Electrical properties and photodetector parameters of CdSe nanoparticles

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In the work, it is reported that morphological, electrical, and optical studies were conducted on nanoparticles of cadmium selenide (CdSe) that were synthesized using ethylenediaminetetraacetic acid (EDTA) as the complexing agent.The produced particles were characterized by using a transmission electron microscope (TEM), a field emission scanning electron microscope (FESEM), energy dispersive x-ray (EDX), and ultraviolet-visible spectroscopy (UV-VIS). The bandgap was discovered in the direct band, where it was estimated from the absorption. This gap is equal to 2.1 (eV). At various temperatures, the electrical properties of CdSe thin films were studied. A combination of dark electrical conductivity and photoconductivity indicates that these films can be used as photo sensors.

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1. Introduction

Functional materials like semiconductors have recently been found to exhibit specific electric and optoelectronic properties at the nanoscale, which has a significant impact on fields such as photonics, nanoelectronics, and optoelectronics. The new thermoelectric and photovoltaic capabilities of nanostructured materials have drawn the most interest of all [1-3].

Chalcogenide II-VI semiconductors like CdS, PbS, CdSe and other have captured the interest of researchers and scientists due to the broad application of these semiconductors in the building of photovoltaic and solar cells as well as optoelectronics equipment [4-6].

Cadmium selenide (CdSe), which is a part of the II-VI class, is an excellent material for the conversion of sunlight into electric power in optoelectronic devices, devices like thin-film transistors, light emitting diodes, solar cells, photodetectors, memory devices and other similar devices. Due to its suitable bandgap and high optical absorption coefficient [7-11].

In order to produce CdSe nanoparticles, numerous techniques, such as sol-gel, spray pyrolysis, colloidal and thermal evaporation, laser ablation, solvothermal or hydrothermal approach, chemical bath deposition and chemical method have been extensively utilized [12-16].

Among the above methods, the chemical method is considered one of the most important methods as it has some significant advantages like controllable particle size, easiness, cost-effectiveness, and good crystallinity of the final product [17-19].

In the current work, the preparation of nanoparticles and their casting as thin films by drop casting method and the study of their optical, morphological and electrical properties will be discussed, as well as studying of their suitability for electro-optical applications in terms of studying the coefficients of photodetector.

2. Experimentation

2.1. CdSe nanoparticles preparation

The process of preparing and diagnosing nanoparticles and their thin films was done based on our previous papers [20,21], as well as the preparation of optical detectors and methods for measuring their coefficients were mentioned in detail in our published study [22].

3. Results and discussion

TEM imaging was used to examine the CdSe-EDTA nanoparticles dimensions and shapes. Fig. 1 shows the TEM pictures of the CdSe-EDTA NPs. As revealed in Fig. 1, the CdSe NPs capped with EDTA with spherical shape particles which appeared as Agglomerated particles of 70–80 nm size.

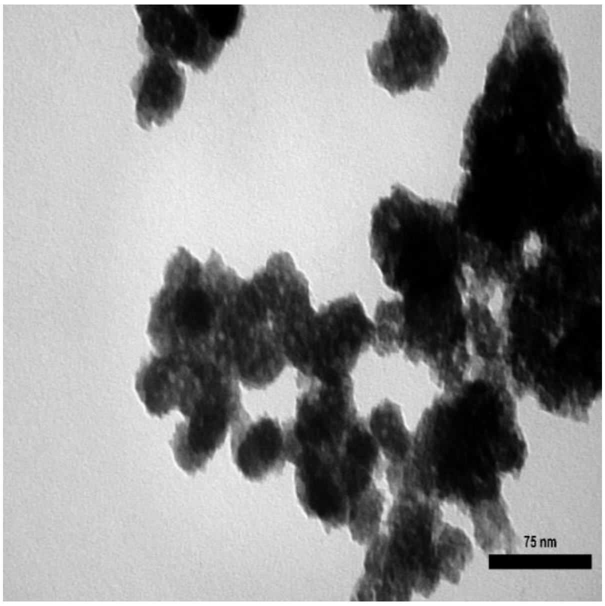

Fig. 1. TEM image of CdSe-EDTA NPs

Fig. 2 shows a typical FESEM image for CdSe-EDTA NPs. The FESEM micrographs reveal that the shape and morphology of NPs. It reveal the formation of spherical shaped CdSe NPs. clearly disclose smooth NPs that are simply distinguishable from others . The mean grain sizes of films were about 65-70 nm.

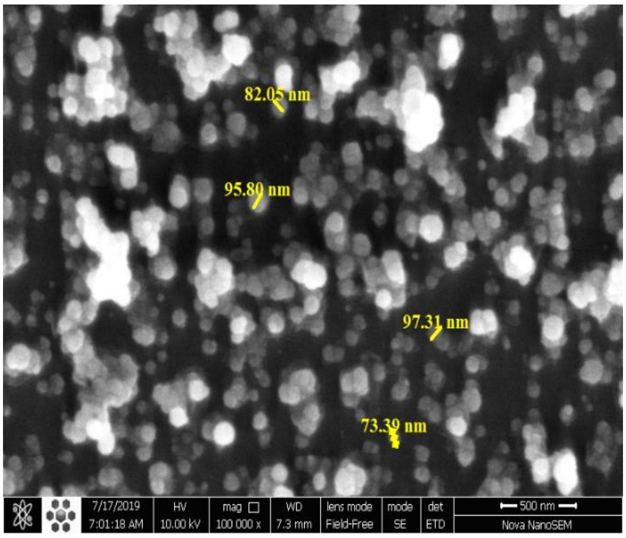

Fig. 2. SEM image of CdSe-EDTA NPs (color online)

A study of the chemical composition of CdSe-EDTA nanoparticles was carried out using EDS analyses on the nanoparticles. Fig. 3 depicts the EDS spectra of the EDTA-capped demonstration CdSe NPs in EDS.

The host material of CdSe-EDTA nanoparticles exhibits three elemental peaks two for cadmium and one for selenium which were publicized in Fig. 3. The chart displays cadmium and selenium presenting. The element weight percent composition of CdSe-TEA was Se=20.06 and Cd=41.18.

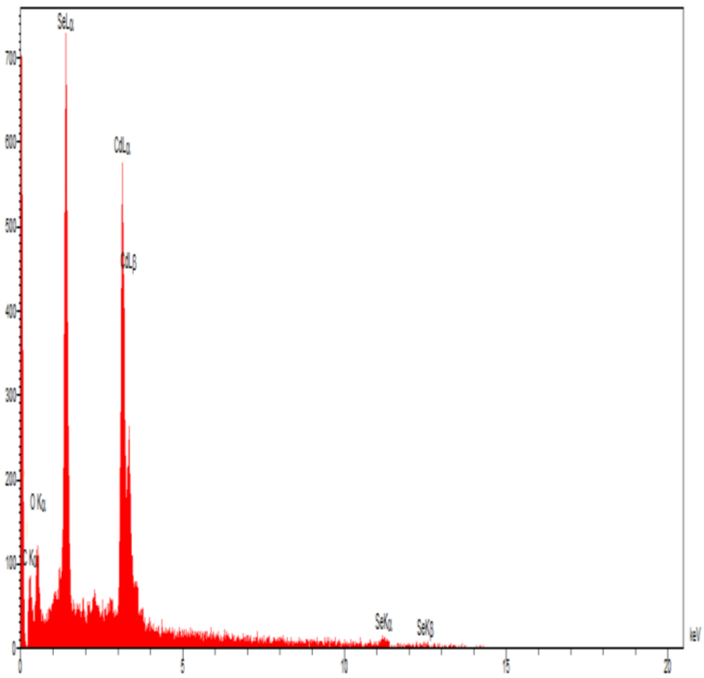

Fig. 3. EDS curve of CdSe-EDTA NPs (color online)

Fig. 4 shows the UV-visible absorption spectra of CdSe-EDTA dignified at the room temperature in the range of 300-900 nm. This figure shows that the absorbance peak appeared at 520 which is significantly blue shifted from the value for the bulk CdSe which is at about 712 nm and is due to the quantum confinement of the particles.

The band gap of CdSe thin films is shown in Fig. 6 were obtained as a function of hv. CdSe-EDTA NPs have an Eg of (2.1) eV. The reported Eg value is larger than the bulk bandgap energy of CdSe because of quantum confinement in CdSe nanostructures.

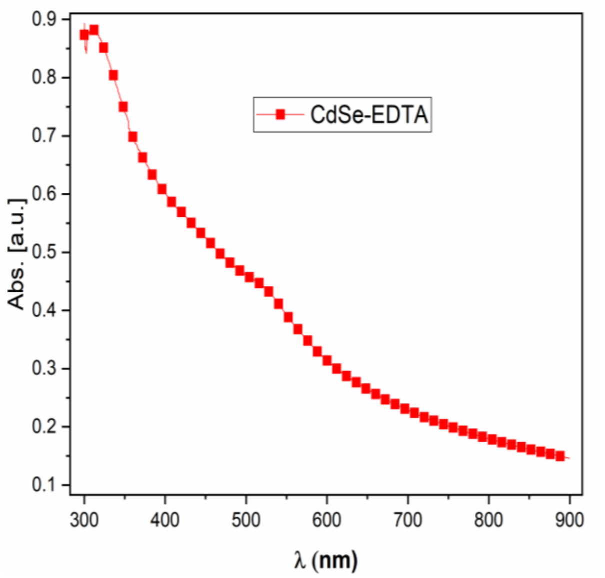

Fig. 4. Absorption spectrum of CdSe-EDTA NPs (color online)

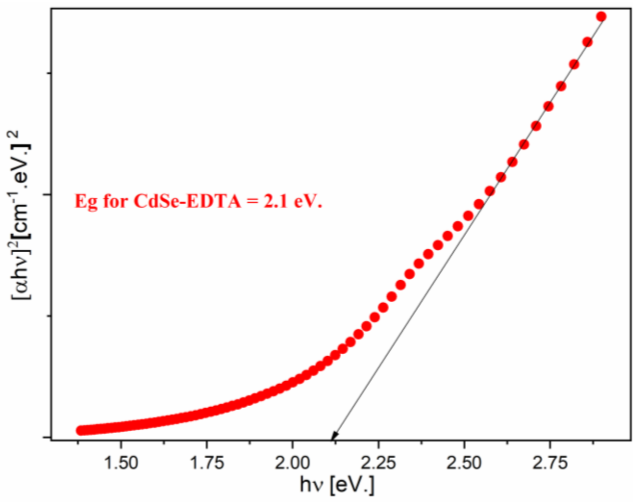

Fig. 5. Energy gap spectrum of CdSe-EDTA NPs (color online)

CdSe-EDTA nanoparticles stimulated at 450 nm excitation wavelength is presented in Fig. 6. There are distinct photoemission peaks in the graph that are caused by free exciton recombination at 620nm. This emission peak has a blue shift when compared to the bulk CdSe. The quantum-confined effect was revealed by this property. The band gap was equal to 1.85 eV which obtained from the PL peak.

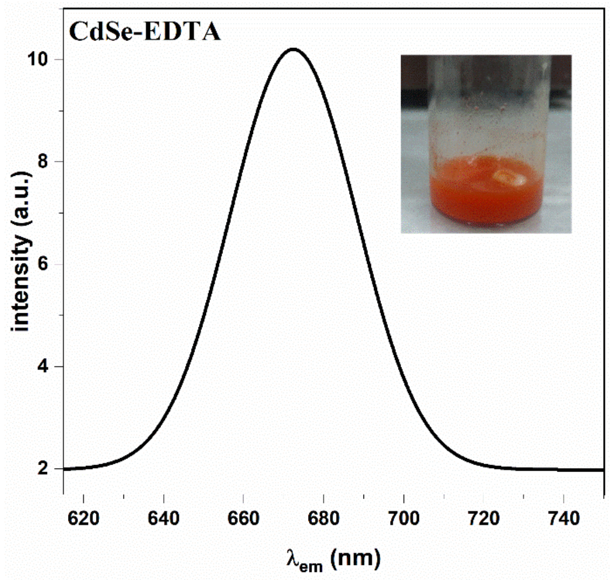

Fig. 6. Emission spectrum of CdSe-EDTA NPs (color online)

In order to explore the electrical behavior and conduction mechanism of CdSe-EDTA NPs, current-voltage characteristics were measured in the dark using a two-probe scheme. These measurements were carried out in the range of (1–40) V. Fig. 7 illustrates how the I–V behavior of CdSe can be described. The current-voltage curve that were obtained are symmetric and linear up to the point where the applied voltage is within its operational range.

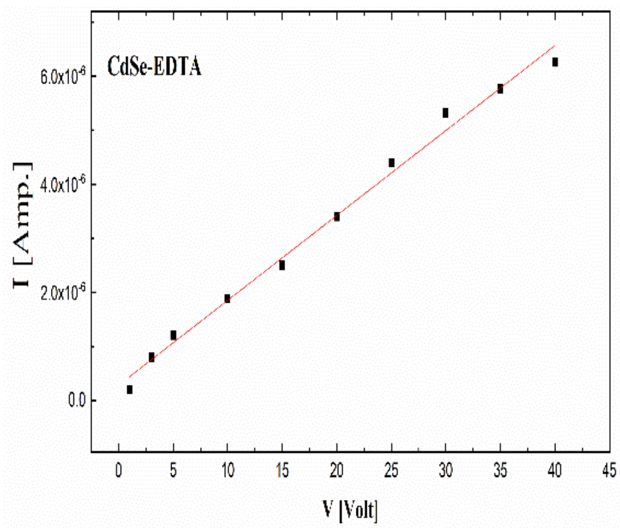

Fig. 7. Current-voltage behavior of ITO/CdSe-EDTA/ITO (color online)

At temperatures ranging from 293 to 373 K, the electrical conductivity of the CdS-EDTA film was successfully achieved in the dark. The temperature dependences of the electrical conductivities of the CdSe film are depicted in Fig. 8. From the figure can be see the incease in temparature led to increase in electrical conductivity.

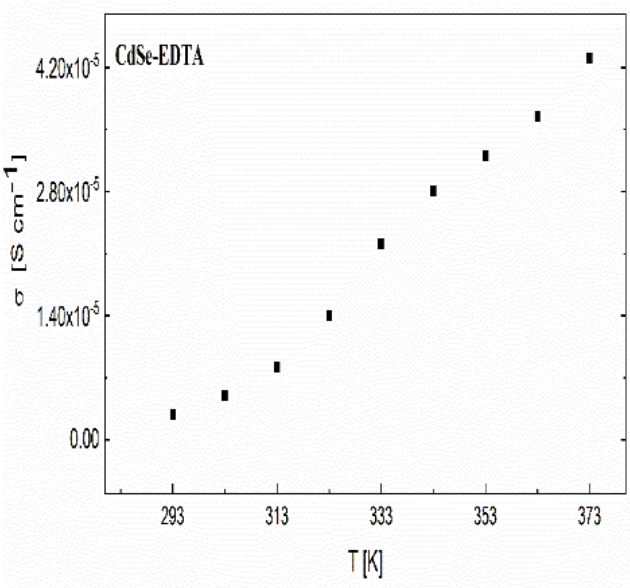

Fig. 8. Variation of conductivity with temperature

Arrhenius plots of conductivity of CdSe NPs. are shown in Fig. 9. The activation energy value (Ea) have been calculated by the ln σ slope vs. 1000*T-1 scheme assistance. The figure displays straightforward lines, that specify the process of conduction in the manufactured materials was through a process of activated with activation energy. The activation energy was equal to 0.32588.

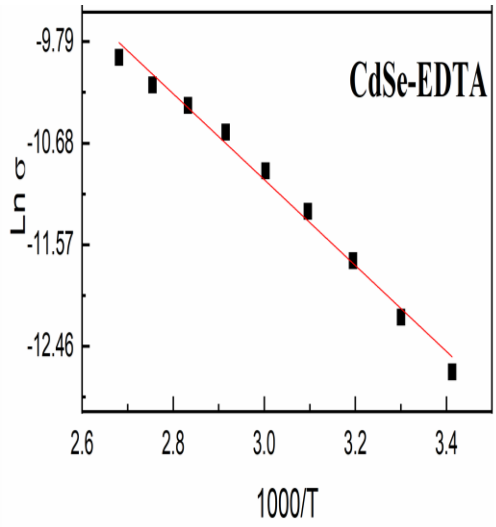

Fig. 9. Variation of Ln σ verses 1000/T (K-1) (color online)

An AL/CdSe-EDTA/Ag photodetector was constructed and put through its paces both in the absence of light and in the presence of a halogen lamp with a power density of 40 mW/cm2. This was tested using a Keithley 2400 at room temperature with forward and reverse bias voltages ranging from -5 V to +5 V. The fact that the device have characteristics that are both nonlinear and rectifying along the I–V is evidence that the junction is set up correctly.

The I–V characteristics of an AL/CdSe-EDTA/Ag photodetector have been displayed in Fig. 10 both when the device is in the dark and when it is illuminated. It was discovered that the reverse current was only very slightly present, but that the forward current increased noticeably as the bias voltage rose. The findings indicate that when the device illuminated by incident light, both the forward and reverse photocurrents experience an increase. In addition to this, the photocurrent increases at an exponential rate with the forward bias voltage goes up, which is a clear indication that its behavior is nonlinear. The photoconductivity and the photosensitivity of the device were 4.6*10-6,186 respectively and the photocurrent gain was 0.6.

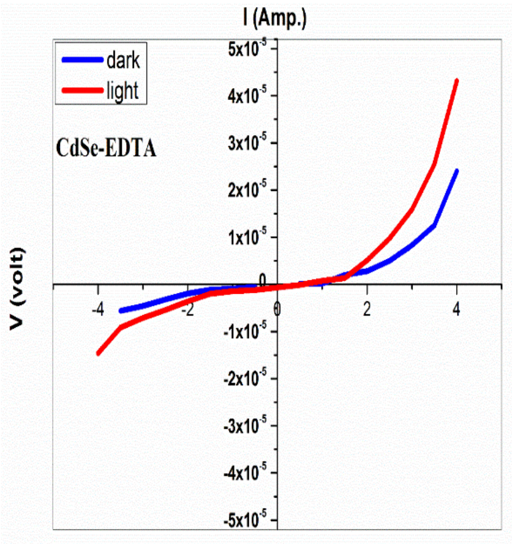

Fig. 10. I–V characteristics of an AL/CdSe-EDTA/Ag photodetector in darkness and illumination (color online)

4. Conclusions

The current work is an attempt to understand the effect of the capping agent on the work of photodetectors and the coefficients of these photodetectors those built based on semiconducting nanomaterials. When comparing the results of the current work with our previously published results, it can be noted that the difference in the type of the capping agent directly and strongly affects the electrical and optical behavior of the original material.

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