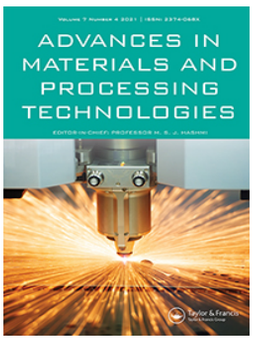

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Optical, morphological, electrical properties and white light photoresponse of CdSe nanoparticles

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ABSTRACT

II–VI nanocrystalline semiconductors offer a wide range of applications in electronics, optoelectronics, and photonics. The study of the morphological, electrical, and optical properties of Cadmium selenide (CdSe) nanoparticles prepared with tri ethanolamine (TEA) as a complex agent is reported in the paper. Cadmium acetate as a Cd source and (Na2SeO3) as a Se precursor. Transmission electron microscope (TEM), field emission scanning electron microscope (FESEM), energy dispersive x-ray (EDX), and ultraviolet-visible spectroscopy (UV-VIS) were used to characterise the synthesised nanoparticles for their optical, compositional, morphological, and electrical properties. The film of CdSe was deposited on the glass substrate. The electrical characterisation of CdSe thin films at various temperatures dark electrical conductivity and photoconductivity reveal that the films were semiconducting in nature, indicating the suitability of these films for photo sensor applications.

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KEYWORDS
'Capping agent'; photodetector; CdSe; photoconductivity

1. Introduction

The creation, design, and application of nanomaterials or nanostructures, as well as the fundamental understanding of the relationships between physical attributes and material dimensions, are all part of nanotechnology. Materials or structures on the nanoscale scale may exhibit novel physical events or possess novel physical properties [1]. When particles are on the nanoscale scale, the ratio of surface atoms to interior atoms increases compared to particles on higher scales, such as the micrometre scale [2]. Nanomaterials' large surface area allows them to change or increase a variety of qualities, including mechanical, optical, and electrical properties. The exceptional and tunable chemical, physical, and optoelectronic properties of nanoscale semiconductors, such as CdS, CdSe, CdTe, and others, are influenced by shape, size, and composition, have increased interest in using these materials in various applications [3]. CdSe has devoted a large area to semiconductor nanomaterials and expanded its research because of its promising applications in a variety of technological

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fields. Semiconductors, such as CdSe, absorb light in the visible to the infrared region and are widely used as light harvesters in various devices such as photodetectors and sensors [4,5]. The preparation of semiconductors with high quality, stability, and reliability remains difficult, posing significant challenges to their practical application. High-quality II–VI semiconductors with controlled defects and impurities are required for electronic and optoelectronic applications [6]. Due to the optical and electrical properties of CdSe nanoparticles are linked to their morphology, considerable effort has been put into controlling their structure, shape, and size. CdSe nanocrystallites of various shapes, such as particles, rods, tetradrods, and tetrapods, have been synthesised using controlled nucleation and growth rates [4]. The binding of ligands to the surface of semiconductor nanocrystals has piqued the interest of researchers because ligands are necessary for optimising, tuning, and tailoring the physical and chemical properties of these functional nanomaterials [7]. Size control of nanoparticles is still an important step in the successful application of nanotechnology. Understanding the role of the capping agent is critical for the development of controlled nanoparticle synthesis, as well as the prevention of nanoparticle aggregation/agglomeration caused by a surfactant adsorption layer on the particle surface. A thorough understanding of the role of surfactants can lead to the possibility of controlling particle size by varying surfactant concentration [8,9]. CdSe nanostructures are frequently produced from toxic precursors via high-temperature chemistry routes, which can be avoided by using different organic ligands. According to the literature, several complexes or surface-capping materials were used in the preparation of CdSe nanoparticles. The most common have hydroxyl (-COH), carboxyl (-COOH), thiol (-SH), or amine (-NH2) functions that are ready to conjugate to Cd without further modification. These ligands prevent aggregation by adsorbing onto the surface of the nanocrystal and control the size of the nanocrystal by forming reverse micelle structures [10–12]. Due of its suitable Eg, it is photosensitive in visible wavelength regions. It is widely used in photosensors, solar cells, and other applications [13,14].

The important question that we are attempting to answer in this paper is whether the incorporation of TEA as a capping agent onto the surface of CdSe nanoparticles results in any noticeable enhancement of its properties and whether the results materials can be used as a photodetector.

Table 1. Elements composition weight % from EDS result of CdSe capped with TEA.

Element	CdSe-TEA w%
C	-
O	10.59
S	2.57
Se	24.42
Cd	45.04

Table 2. Conductivity and activation energy of CdSe-TEA.

Sample	Conductivity	Activation energy
CdSe-TEA	**$8*10^{-7}$**	**0.38744**

2. Experimentation

2.1. CdSe nanoparticles preparation

According to our paper [15], CdSe capped with TEA was prepared. Precipitation of the NPs was followed by centrifugation of the solution and re-dispersion in formic acid to produce nanopowder. CdSe-TEA nanoparticles dispersed in formic acid are depicted in Figure 1.

2.2. Results and discussions

The size and shape of the CdSe NPs were studied using TEM imaging. The TEM images of the CdSe NPs are shown in Figure 2. Figure 2 shows that the prepared CdSe nanoparticles capping by TEA agent have spherical shaped nanoparticles with slight agglomeration composed in 50–60 nm.

A scanning electron microscope was used to examine the surface morphology of TEA-capped CdSe thin films (SEM). SEM is a practical and versatile tool for studying and analysing the surface morphology of thin films. The typical FESEM micrograph of CdSe-TEA NPs is shown in Figure 3. The shape and morphology of NPs are depicted in SEM micrographs. It demonstrates the formation of spherical CdSe NPs. The well-defied smooth nanoparticles are clearly visible. The average grain size of the films was around 55 nm.

EDS measurements on the nanoparticles were performed to investigate the chemical composition of CdSe NPs. The EDS spectrum for the demonstrative CdSe NPs capped with TEA is shown in Figure 4. The presence of selenium and cadmium in the compounds is confirmed by the EDS patterns. the element weight percent composition of CdSe-TEA was Se = 24.42 and Cd = 45.04. see table 1 which show the elements ratio of CdSe NPs.

Figure 1. CdSe nanoparticles dispersed in formic acid.

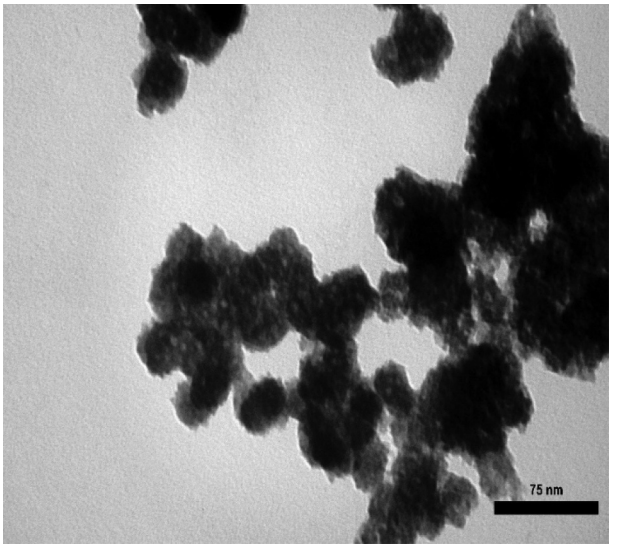

Figure 2. TEM micrograph of CdSe-EDTA (a) CdSe-TEA (b).

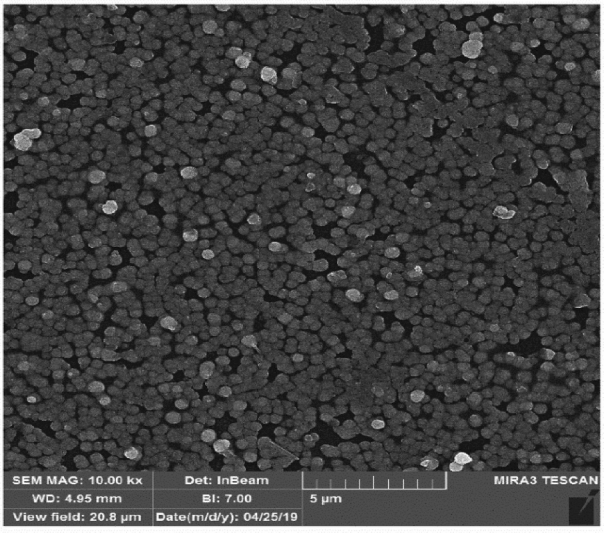

Figure 3. FESEM images of CdSe NPs.

Figure 5 depicts the absorption spectra of CdSe-TEA. The absorption edge has a wavelength range of 620 nm to 450 nm, with a 710 nm blue shift in the bulk CdSe absorption area [16].

figure 6 show the band gap of CdSe thin films deposited on glass. The Eg value for CdSe nanoparticles prepared with TEA is (2 ± 0.01) eV. Due to quantum confinement in the CdSe nanostructures, the detected values of Eg are greater than the value of the bulk energy gap of CdSe (1.74 eV) [17].

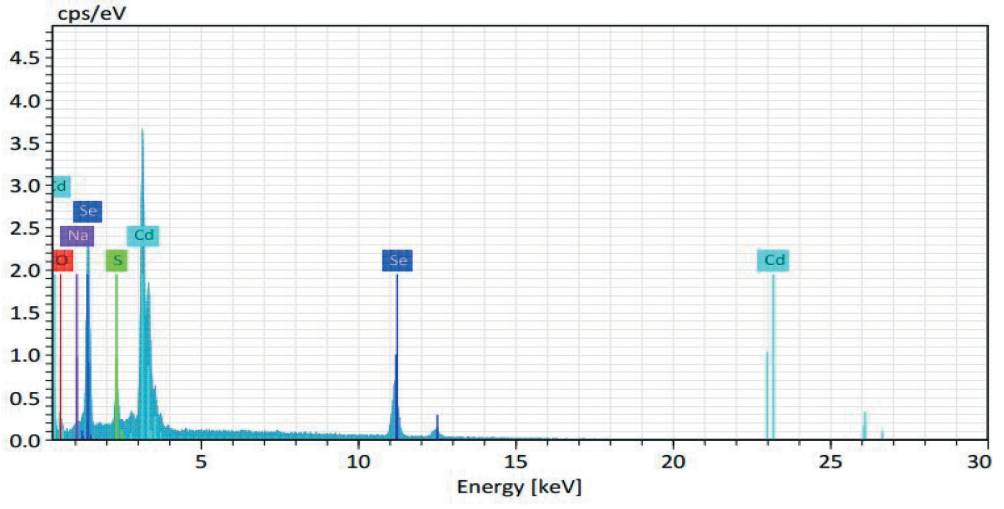

Figure 4. Se and Cd atomic concentrations of CdSe-TEA.

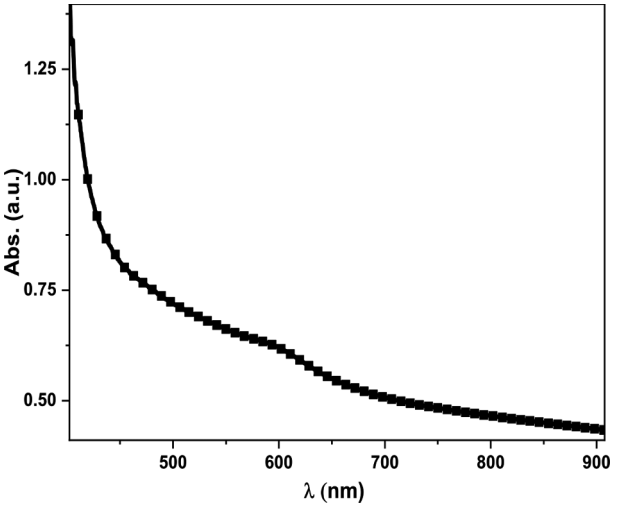

Figure 5. Absorption spectrum of CdSe thin films deposited on glass.

The PL spectra of CdSe-TEA nanoparticles excited at various excitation wavelengths ranging from 350 to 450 nm are shown. The graph clearly shows the photoemission peaks at approximately 620 nm, which are attributed to free exciton recombination. When compared to bulk CdSe, this emission peak is blue shifted. This characteristic indicated the quantum-confined effect. CdSe-TEA nanoparticles with a band gap of 1.9 eV were obtained from the PL peak. Figure 7 shows that the emission band at 620 nm does not change as the excitation wavelength increases. There was no discernible emission because the excitation wavelength was greater than 450 nm. For full excitation wavelength scanning, the band edge's full width at half maximum (FWHM) is maintained. The emission

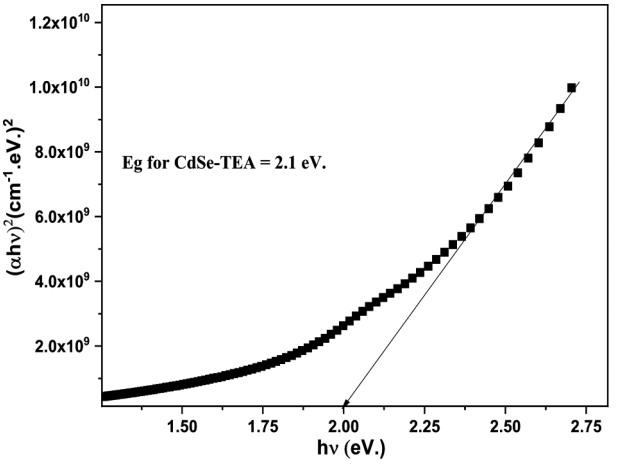

Figure 6. Band gap of CdSe thin films deposited on glass.

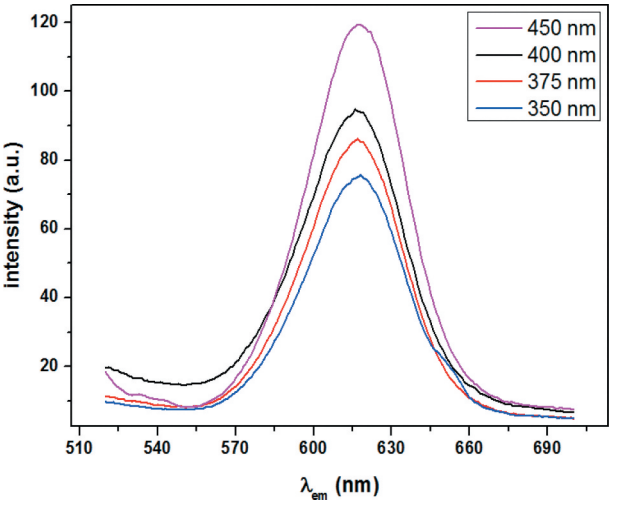

Figure 7. Photoluminescence spectra of CdSe-TEA nanoparticles at different excitation wavelength.

spectrum was used to calculate the full-width-at-half-maximum (fwhm), which is related to particle-size distribution. The fwhm values tell us about the sample's monodispersity. A CdSe-TEA 41 nm fwhm value corresponds to a narrow size distribution.

Figure 8 depicts the intensity of the PL as a function of the excitation wavelength. The intensity of the PL increases as the excitation wavelength increases [3,18,19]. Figure 9 depicts the intensity of the PL as a function of the excitation wavelength.

To investigate the electrical behaviour and conduction mechanisms of CdSe NPs, (I–V) current-voltage characteristics in the dark were measured using a two-probe scheme in the voltage range (1–40) V for CdSe nanoparticles. The I–V behaviour of CdSe is depicted in Figure. The obtained current vs. voltage curves are symmetric and linear up to the operating range of applied voltage.

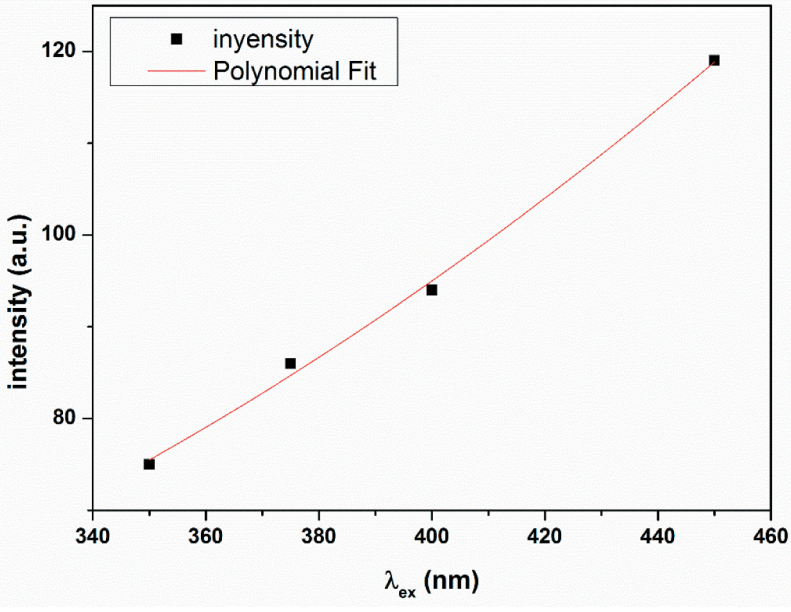

Figure 8. Variation of PL intensity with wavelength.

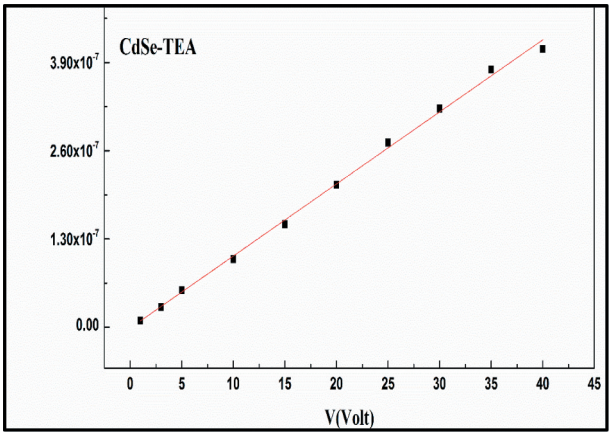

Figure 9. Plot showing variation of current voltage.

The DC electrical conductivity of semiconducting materials is an important property to consider when looking for applications in photosensitive/photovoltaic devices [20]. CdSe nanoparticles' electrical conductivity in the dark was accomplished at temperatures ranging from 293 to 373 K. Figure 10 depicts the temperature dependences of electrical conductivities for as-prepared NPs.

Temperature causes an increase in electrical conductivity. This behaviour indicates that the semiconductor material behaves. Because the graph is nearly linear, CdSe thin film has only one type of conduction mechanism. table 2 show the conductivity and activation energy of CdSe-TEA.

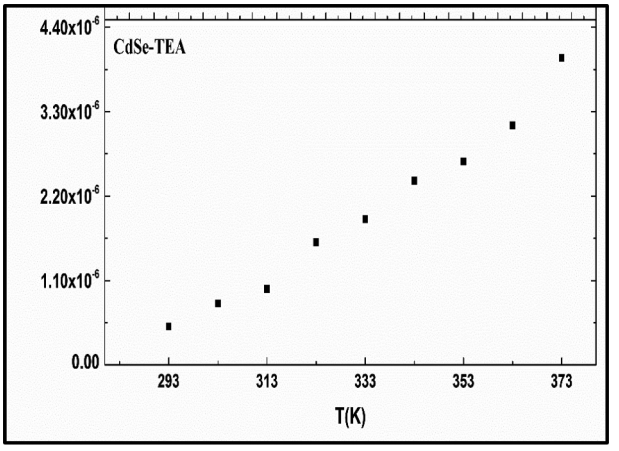

Figure 10. Variation of conductivity with temprature.

Figure 11 depicts Arrhenius plots of conductivity of CdSe NPs. The temperature-dependent exponential increase in DC conductivity. The activation energy (Ea) is calculated using the slope of the ln versus 1000/T plot. The graph shows straight lines, indicating that conduction in synthesised samples occurs via an activated process.

The table contains the values of σ and E. The activation energies obtained from conductivity measurements are quite low, as shown in the table.

A 40 mW/cm2 AL/CdSe-TEA/Ag photodetector with a power density of 40 mW/cm2 was built and tested in the dark and under a halogen lamp. These were investigated using a Keithley 2400 at room temperature with forward and reverse bias voltages ranging from −5 to +5 V, with electrical measurements performed in a sandwich configuration. The diodes exhibit nonlinear and rectifying I–V characteristics, indicating that the junction is properly configured.

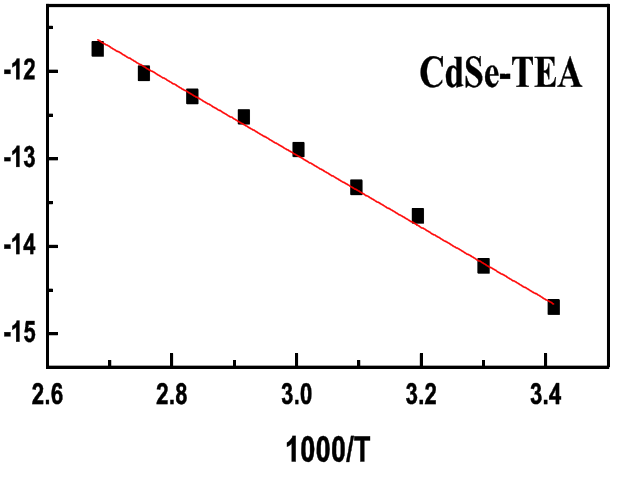

Figure 11. Variation of Ln σ verses 1000/T (K^{-1}).

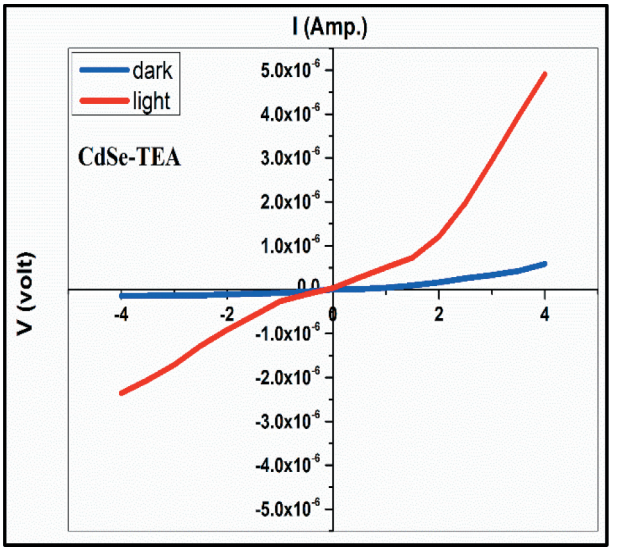

Figure 12. I–V characteristics of an AL/CdSe-TEA/Ag photodetector in darkness and illumination.

Figure 12 shows the I–V characteristics of an AL/CdSe-TEA/Ag photodetector in darkness and illumination. The reverse current was found to be very weak, while the forward current increased dramatically as the bias voltage increased. The results show that when exposed to incident light, the MSM structure's forward and reverse photocurrents increase. Furthermore, the photocurrent grows exponentially as the forward bias voltage increases, indicating that its behaviour is nonlinear. The photoconductivity, photosensitivity, and photocurrent gain for CdSe–TEA were 1.72*10-5,1892 and 19.92, respectively, according to the characteristic curves.

3. Conclusions

These studies attempted to understand the effect of complex agent type on the morphological and electrical transport properties of CdSe thin films. The type of capping agent used can influence the morphologies and energy gaps of the prepared nanoparticles. The photoluminescence mapping of individual nanoparticles reveals the presence of high PL intensity, which is due to the synthesised nanocrystals' high crystallinity and good surface states. Based on the arguments presented above, the developed CdSe nanoparticles show promise for use in photonics device fabrication, solar cells, and photodetectors.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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