Synthesis of CdSe nanostructure using thermal evaporation method toward Light-emitting-diode

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ABSTRACT
Efficient Light-emitting-diode (LED) constructed of CdSe/Si CdSe nano particles were synthesized through thermal evaporation method using tube furnace and Ar as carrier gas. The synthesized nanoparticles were subjected to structural, optical, morphological, and electrical investigation. The nanoparticles structural properties studied by X-Ray diffraction, confirm the formation of hexagonal structure of CdSe (NPs). The preferred growth direction toward (100) orientation. Crystallite size was calculated by Scherrer’s equation. The surface morphology formation studied by Scanning Electron Microscopy (SEM) and average grain size also has been calculated. FESEM images revel sheets and tetra pods constructed of nano particles with average size 15-40 nm. Ultraviolet-visible (UV-Vis) absorption spectrum showed the absorption peak of CdSe at 350 nm. PL measurements show the emission peaks at 641 and 678 nm. The results of (I-V) measurements show the large ratio between the darkness and light state, which shows the correct behavior of LEDs. The ideality factor was estimated at the optimum conditions and it has been found (1.18).

Keywords: Thermal evaporation, CdSe nanoparticles, Light-emitting-diode (LED)

1. INTRODUCTION
Semiconductor nanoparticles or quantum dots, have received much attention due to the quantum confinement effect, where the surface electrons of the semiconductor crystallites
possess size-dependent wave functions [1]. At this dimension, the surface area to volume ratio of the particles is amplified and the surface atoms become dominant contribution to the physical and chemical properties. These properties possessed by semiconductor nanoparticles are characterized by variability of energy structure or bandgap which can be modified by enhanced surface attributes with particle size reduction [2, 3]. In particular, the narrow band gap CdSe nanoparticles have become interest in the past two decades because they have useful features for photovoltaic applications, laser, biochemical sensors, biomedical imaging, solar cells [4-15].

Research on semiconductor nanocrystals is an important field in modern nanoscience and nanotechnology [16-21]. Among the various materials, CdSe nanostructures are undoubtedly the most studied, due to their tunable emission in the visible range, the advances in their preparation, and their potential use in industrial and biomedical applications [22-28]. The CdSe nanostructures have interesting physical and chemical properties as well as potential importance as nonlinear optical materials [29-31]. They are semiconductors with quantum size effect and can be used for electroluminescent devices and sputtering target to produce photoconductive films and infrared filters [32-34]. The CdSe, because of its high photosensitive nature, is widely preferred in the fabrication of different optoelectronic devices, photoconductors, thin film transistors, gamma ray detectors, etc. [35-37]. It has both cubic and hexagonal structures and relatively wide direct band gap of 1.74 eV at room temperature [38, 39].

Light-emitting-diode (LED) device characterized by power conversion efficiency, external quantum efficiency and luminous efficacy. Luminous efficacy of these devices is high around 150 lm/W and it depends on the type of semiconductor and device architecture [40]. The power conversion efficiency is the ratio of radiant power output to input electric power. The overall conversion efficiency depends on mechanisms that control carrier injection, carrier recombination, and LED package. These mechanisms can be combined into an efficiency parameter called external quantum efficiency [40].

2. EXPERIMENTAL SECTION

The preparation of CdSe nanostructure is carried out in a single stage controllable horizontal tube furnace with a quartz tube (50 cm) long and (3 cm) in diameter. The quartz tube was cut and the two ends of the tube been altered to be suitable and fitted for entry and exit the gas. A pure Cadmium Selenide powder is used as a raw material (0.5 g) of CdSe is placed in clean ceramic boat (1×1×10 cm). The boat was placed at the center of the tube furnace, and the Si substrates are positioned down the stream of the gas flow. The quartz tube is purified from residual gases using pure Argon with flow rate (500 ccm) for 5 minutes, then the temperature was raised inside the furnace to 850 °C with Argon gas (Ar) (200 ccm).

Finally, black powder is deposited on the substrates and the walls of the quartz tube, the furnace left to cool down naturally to collect the product.

3. PROPERTIES OF THE CdSe NPs

Synthesized of CdSe NPs were analyzed by different characterization techniques at room temperature. The structural characteristics of the synthesized NPs were analyzed by X-Ray
system (Shimadzu - XRD6000, Shimadzu Company, Japan). The X-Ray source was Cu-Kα radiation with 0.15406 nm wavelength. Optical properties was assessed using a UV-visible spectrophotometer (CARY, 100 CONC plus UV-Vis-NIR, Split- beam Optics, Dual detectors) spectrophotometer equipped with a xenon lamp at a wavelength range at 300-900 nm.

The FESEM study by Tescan Mira3 France. Photoluminescence (PL) was measured using the Perkin Elmer Spectrophotometer Luminescence LS 55 equipped with FL Win lab software. For current–voltage measurement, a Keithly-2430 digital source meter was used.

4. RESULTS AND DISCUSSION

4.1. Structural analysis (XRD)

Fig. 1. XRD pattern for CdSe films prepared by thermal evaporation method.

The XRD patterns of CdSe films. The results of all conditions shows that the CdSe have pure wurtze hexagonal structure as comparing with (JCPDS) cards. The film is polycrystalline in nature with hexagonal and the major peak is in the direction (100), (002), (101) and (110) with high intensity indicate the dominate growth direction and minor small peaks in the direction (103), (112) and (203). For flow rate (200 sccm). It’s observed that the higher intensity in the direction of (100) is for the flow rate (200 sccm) that indicates that the 200 sccm flow rate tends to enhanced the crystallinity. CdSe growth At 850 ºC. The peaks placed at 2θº = 23.8º, 25.3º, 27.0º, 41.9º, 45.7º, 49.6º and 63.8º. The average size of the crystallites has been determined by the mostpreeminent (100) orientation using the Debye-Scherrer’s formula (41):

\[ D = \frac{K\lambda}{\beta\cos\theta} \]
where, K denotes the Scherrer’s constant \((K = 0.94)\), D is the average crystallite size, \(\beta\) is the full width at half maximum (FWHM) of a Gaussian fit, \(\lambda\) is the wavelength of the \(\text{CuK}_\alpha\) radiation \((\lambda = 0.1546 \text{ nm})\) and \(\theta\) is the half diffraction angle. The crystallite size was estimated and found to be \(~41 \text{ nm}\).

### 4.2. The Morphological study

![SEM images for CdSe films prepared by thermal evaporation method at 850 ºC](image)

**Fig. 2.** SEM images for CdSe films prepared by thermal evaporation method at 850 ºC.
The FESEM images of CdSe NPs were recorded at different magnifications as shown in Fig. (2). FESEM images reveal sheets and tetrapod’s consist of nanoparticles with a size ranging from 15 to 40 nm.

4. 3. EDX analysis

Shows Energy-dispersive spectroscopy (EDX) analysis of CdSe NPs, which reveals that the CdSe NPs are mainly composed of cadmium and selenium elements Fig. (3).

4. 4. UV-Vis absorption studies

The CdSe NPs was also monitored through the UV-Vis spectroscopy. Fig. (4) show the absorbance bands of CdSe NPs at a wavelength around (350) nm. The molecules undergo electronic transitions in the UV. It is clearly seen that the absorption is decreasing sharply below~ 400 nm. Fig. (5) show the optical transmittance spectra of the CdSe film. The increased thickness leads to decrease in transmittance. film show increasing in transmittance at the wavelengths longer than 390 nm, which is agreed with the optical properties of CdSe semiconductor in the (UV-Visible) range, Below 380 nm there is a strongly decrease in the T% of the films, which is due to the strong absorbance of the films in this region. The absorption coefficient (α) was calculated using Lambert law. Plots of (α) versus the photon energy (hv) in the absorption region near the fundamental absorption edge indicate direct allowed transition in the film material. Extrapolating the straight line portion of the plot (αhv)² versus (hv) for absorption coefficient value gives the optical band gap (Eg), and its dependence on film thickness is illustrated. The band gap of the film 3.4 eV as shown in Fig. (6).
**Fig. 4.** Optical absorbance of CdSe.

**Fig. 5.** Transmission as a function of wavelength for films.
Fig. 6. \((\alpha h\nu)^2\) as a function of photon energy.

4.5. PL properties for CdSe

Figure (7) PL emission spectra of CdSe NPs with an excitation source operating of 425 and 450 nm, it is clear the emission peaks at 641 and 678 shows a red-shift compared, which may result from the quantum size effect, which are corresponding to 1.93 and 1.82 eV respectively. Hence, this band corresponds to the photo absorption near the band energy (NBE) edge of the conduction band. Broad peaks were observed due to the band edge emission or size distribution of the nanoparticles and narrow peaks were observed due to surface defects which consist of cadmium vacancies and interstitial selenium which act as acceptors and selenium vacancies and interstitial cadmium which act as donors [42-43].

4.6. I-V characterization

The results of the (I-V) measurements at forward and reverse bias in dark for (n-CdSe/p-Si) devices prepared at optimum condition are shown in Figure (8). When the diode is forward biased, anode positive with respect to the cathode, a forward or positive current passes through the diode and operates in the top right quadrant of its I-V characteristics curves as shown. Starting at the zero intersection, the curve increases gradually into the forward quadrant but the forward current and voltage are extremely small. When the forward voltage exceeds the diodes P-N junctions internal barrier voltage, which for silicon is about 0.7 volts, avalanche occurs and the forward current increases rapidly for a very small increase in voltage producing a non-linear curve. The “knee” point on the forward curve.
Fig. 7. PL for CdSe films with an excitation source operating of (A) 425, (B) 450.
In the case of darkness, the voltages of (-4-4). It was observed that the current is very little and this is the norm in the case of darkness. In the case of lighting, voltages of (-4-4), and then put the lowest possible voltages 0.5 with the change in wavelength from 400 - 640 nm.

The difference between darkness and light is the increase current in the case of lighting. The ideality factor of a diode is a measure of how closely the diode follows the ideal diode equation. The ideality factor all devices were estimated at the optimum conditions and it has been found (1.18) as show in Table (1).

Table 1. IV Characterization of CdSe LED.

| Thermal Evaporation |  |  |
|---------------------|-------------------|
| J, A/cm²            | n*                | Φ, eV  |
| 5.5×10⁻⁷            | 1.18              | 0.594  |

5. CONCLUSIONS

CdSe nanostructures were successfully synthesized using the thermal evaporation method, where CdSe molecules were synthesized at a temperature of 850 ºC. The crystal size has been estimated from the most prominent (100) was found to be ~41 nm. The shape and size of the CuNPs were examined from the morphological studies (SEM). The formation reveal
sheets and tetrapod’s consist of nanoparticles. The UV absorption peak at 350 nm and the band gap at 3.4 eV clearly indicates the synthesis of CdSeNPs. All nano-sized CdSe NPs have good optical properties and PL properties of thin CdSe Films are highly dependent on factors such as film thickness, mixing and disintegration, size and structure of NPs, surface roughness and material impurities. The results of (I-V) measurements show the large ratio between the darkness and light state, which shows the correct behavior of LEDs. The results confirm the usefulness and efficiency of the heat treatment method, which can produce high purity of CdSe nanoparticles and simple. The shape and structure of the product strongly depends on the conditions of the preparation. The CdSe application in LED shows good electrical properties.

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References


