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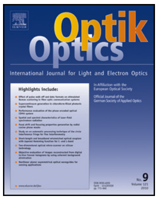

Original research article

Optical, electrical and photoelectrical properties of nanocrystalline cadmium selenide films for photosensor applications

E.M. El-Menyawy*, A.A. Azab

Solid State Electronics Laboratory, Solid State Physics Department, Physics Research Division, National Research Centre, 33 El-Bohouth St., Dokki, Giza 12622, Egypt

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ABSTRACT

In this work, CdSe powder was synthesized by using an aqueous route in the presence of polyethylene glycol as a surfactant. The as-prepared powder was used to prepare different film thickness (101–179 nm) using thermal evaporation technique. The structural, optical, electrical and photoelectrical properties of the films have been reported. The structural properties of the films were studied by X-ray diffraction and high-resolution transmission electron microscope techniques. The films were found to have nanostructure nature in which the particle size increases with increasing film thickness. The optical properties of the films were investigated using transmittance and reflectance spectra in wavelength range 200–2500 nm. The optical band gap of the films was determined as a function of film thickness and showed high band gap compared to bulk material due to quantum size effect. The refractive index was also calculated and analyzed in which the dispersion parameters were determined. The electrical resistivity was found to decrease with increasing film thickness due to size effect. Under illumination, the resistance of the films was found to decrease in which the films are promising candidates for photosensor applications.

1. Introduction

Semiconducting nanocrystals have been the focus of research due to their unique physical and chemical properties and their several applications in modern technology. Up to date, they are used in different fields such as medical applications, light emitting diodes, laser and hybrid solar cells [1–4]. CdSe is an important member of II–VI group with a good sensitivity to the light and reasonable electron mobility [5]. It has direct band gap energy around 1.7 *eV* matching a wide range of solar spectrum [6]. Owning to their promising properties, CdSe nanocrystals have earned pronounced attention for industrial applications such as nanoelectronic devices [7], infrared filters [8], gamma rays detectors [9] and optoelectronic devices [10].

The advent of new ways to precisely obtain metal chalcogenides provides a variety of properties. In this regard, there are several techniques used for preparing CdSe with different morphologies and particle sizes. These techniques include hot coordination solvents, solvothermal, hydrothermal methods. It was found that the properties of resultant nanostructure semiconducting materials are dependent on the chemistry involved in their synthesis [11].

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* Corresponding author.
E-mail address: emad_elmenyawy@yahoo.com (E.M. El-Menyawy).

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A numerous effort has been extensively conducted on research of CdSe material starting from synthetic routes to many modifications on physical and chemical properties. In 1990, Brennan et al [12] prepared CdSe nanocrystals by solvothermal reaction using $Cd(CH_3)_2$ as a cadmium source and trioctylphosphine oxide as solvent reaction. Since this date, CdSe nanocrystals have been prepared by different methods with different morphologies [13–16]. Among different techniques, hydrothermal method has been widely used to synthesize different materials due to its simplicity, good crystallinity of the products and low temperature of synthesis. In our previous studies, we synthesized and characterized nanocrystals based on PbSe [17] and ZnSe [18] by hydrothermal method. The results showed that the morphology of the PbSe nanocrystals can be controlled by adjusting of polyethylene glycol content [17]. The results showed also that ZnSe quantum dots can be prepared by the same way [18]. The preparation of chalcogenides by this method includes the presence of polyethylene glycol as a surfactant. This may be results in production of chalcogenides with low conductivity in which the polyethylene glycol has poor conductivity.

In this study, CdSe is synthesized by hydrothermal method and used as source material to prepare CdSe films by thermal evaporation technique. It is aimed to combine the advantages of both methods. The structural, optical and electrical properties of the films are investigated. Finally, the sensitivity of CdSe to light exposure is also examined.

2. Experimental

CdSe powder was synthesized by conventional hydrothermal method. In a typical process, 1 mmol of cadmium nitrate and 1 mmol of sodium selenite were dissolved in 100 ml distilled water and the mixture was magnetically stirred for 10 min. Then, 0.1 g of polyethylene glycol (M_w = 20,000 g/mol) was added to the solution with continuous stirring. After that some drops of ammonia solution were added to adjust the pH of the solution to 12. Hydrazine hydrate was also added to the prepared solution. The final solution was transferred into a stainless steel Teflon-lined autoclave. The autoclave was sealed and maintained at 150 °C for 12 h. The final product was filtered and washed several times with ethanol, acetone and water, and then was dried at 60 °C for two hours.

CdSe films were deposited on glass and quartz substrates by conventional thermal evaporation technique using coating unit model (Edwards E 306 A). Glass-coated substrates were used for structural and electrical measurements, whereas the quartz-coated substrates were used for optical measurements. The pressure inside the chamber was pumped down to about 2×10^{-5} Torr before starting the evaporation process. The film thickness was measured after vacuum breaking by using interferometric method [19]. The factors which have effect on the film thickness such as deposition rate (2 Å/s), the distance between the filament (15 cm) and substrate and the position of the sample on the substrate were kept constant for each thickness.

Crystal structure of CdSe powder and films was carried out by Bruker D8 diffractometer and CuK_α radiation of wavelength 1.5418 Å. The diffraction angle (2θ) ranged from (4–80°) with a speed of the detector 2° per min. The tube current and voltage were 30 mA and 40 kV, respectively. The films were measured in terms of grazing incident in-plane mode. The transmission electron microscope, (Joel JEM 2100), was used to determine the morphology and particle size of the films.

The optical properties of the films were studied by using spectrophotometric measurements. Spectrophotometer (JASCO model V-570-UV–vis-NIR) was used to measure the transmittance and reflectance of the films in the wavelength range 200–2500 nm.

The absolute values of total measured transmittance, T_m, and reflectance, R_m, after introducing corrections resulting from the absorbance and reflectance of the substrate are calculated by [20]:

$$T = T_m \left(1 - R_q\right) \tag{1}$$

and

$$R = R_m R_{Al} \left[(1 - R_q)^2 + 1\right] - T^2 R_q \tag{2}$$

where R_q and R_{Al} are the reflectance of reference quartz substrate and that of the reference aluminium mirror, respectively.

The electrical resistance and current-voltage characteristics of planar CdSe films samples were recorded by Keithley 2635 A source-meter using two point probe technique. The measurements were achieved on planar samples using indium films as electrodes. An area of 1 cm^2 for the films deposited on glass substrate was selected in which two gold contacts separated by a distance of 1 cm were used. Illumination was achieved by white light provided using halogen lamp (100 W).

3. Results and discussion

3.1. Structural properties

3.1.1. X-ray diffraction

The X-ray diffraction (XRD) pattern of CdSe powder prepared by hydrothermal method is shown in Fig. 1. The pattern shows several diffraction peaks with inter-planar spacing values of 3.714, 3.491, 3.285, 2.556, 2.141, 1.976, 1.831, 1.635, 1.453, 1.402, 1.375, 1.304 and 1.238 Å; these values are indexed to wurtzite structure of CdSe according to the standard data (JCPDS 77-2307). These results have also been obtained by Sobhani and Salavati-Niasari [21] in which CdSe was also prepared by hydrothermal method using $3CdSO_4.8H_2O$ and $SeCl_4$ as cadmium and selenium sources, respectively. The most intense