Volume-04
Issue-01
January-2019

ISSN: 2455-3085 (Online)
RESEARCH REVIEW International Journal of Multidisciplinary
www.rrjournals.com[UGC Listed Journal]

CdSe thin film: Synthesis & Characterization

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ARTICLE DETAILS

Article History
Published Online: 20 January 2019

Keywords
Semiconductor, Thin films, X-Ray diffraction, Conductivity, Optical.

ABSTRACT

CdSe thin films have been deposited by dip technique using trichloroacetic acid as a complexing agent. The structural characterization of films have been studied by X-Ray diffraction. X-ray diffraction pattern prove crystallinity of the deposited films that crystallize in the hexagonal phase of CdSe. The films show high absorption and band gap value which were found to be 2.10eV. The specific conductivity of the film was found out to be 1.234x10^{-7} ohm cm^{-1} at 300 K.

1. Introduction

Cadmium selenid (CdSe)is naturally grown as n-type and hexagonal, cubic or mixed crystal structure with direct band gap energy of 1.7eV at room temperature [1]. This makes it interesting materials for various applications such as solar cells, photodetectors, light emitting diodes, and other optoelectronic devices [2-5]. It also shows bright luminescence in the visible range of optical spectra [6]. It has high absorption coefficient near the band edge, which allows its use in the thin film devices; it is especially interesting for application in solar hybrid system [7-8]. The CdSe thin films with different morphology such as nanowires ,nanotubes, nanorods and needle have been obtained [9-13].

Inorganic thin films with controlled morphology and properties can be fabricated using chemical method. Deposition of CdSe by chemical method has been carried out by many workers. The complexing agent plays an important role in the formation of CdSe thin film. Khomane [14] used formic acid as a complexing agent to deposit CdSe thin film. Okereke et al [15] prepared CdSe thin films by using triethanolamine as complexing agent, Gopalkrishan et al [16] have used ethylene diammine tetra acetic acid as chelating agent for synthesis of CdSe thin films.

In this paper, CdSe thin films are deposited on glass substrates by using dip method. CdSe thin films have been synthesized first time using trichloroacetic acid as complexing agent. The thickness measurement technique, X-ray diffraction, scanning electron microscopy, EDAX, optical absorption and electrical measurement technique is used to characterize the films.

2. Experimental Details:

Every chemical applied in preparation have been analytical level. Ammonia, selenium powder, cadmium sulfate, sodium sulphite and trichloroacetic acid were utilized. Sodium selenosulphate (0.2 M) became applied selenideion resource for synthesize of cadmium selenide samples. The mixture became ready by heating 3.0g selenium fine particles accompanied by 9.0 g Na_2SO_3 in 100mL two fold purified water for 8 hour on 353 K. Mixtures became cool, filter to take out solid residue and put in storage in flask [17].

In the synthesis of CdSesamples, 10 mL of (0.2 M)cadmium sulphate octahydate have been in use in 100 mL glass vessel, and after that it be chelated by means of trichloroacetic acid. 15 mL(5N) ammonia became mixed this reactive solution. Afterward 10 mL(0.2 M) sodium selenosulphate is further mixed in vessel.30 mL distilled water become mixed in the bath

By using pH meter, pH of reactants was measured. It was observed to be 10.20. The glass vessel becomes placed in the ice. The solution was stirred strongly prior to dipping non conducting as well as conducting substrates, which were mounted upright somewhat slanting in reaction mixture. Temperature of reactive solution became formerly allowable to rise to 298 K extremely gradually. Once four hour was completed, templates have been distant. The deposited glass substrate was dried in nature and used for structural, optical, morphological, compositional and electrical characterization.

Overall Chemical reaction is as follows:

$$Cd^{+2} + \text{Trichloroacetic acid (TA)} \longrightarrow [Cd\,(TA)]^{+2}$$

$$Se + (SO_3)^{-2} \longrightarrow [SSeO_3]^{-2}$$

$$[SSeO_3]^{-2} + 2\,OH^{-} \longleftrightarrow Se^{-2} + (SO_4)^{-2}$$

$$[Cd\,(TA)]^{+2} + Se^{-2}\ CdSe + TA \longrightarrow$$

X-ray diffractometer having Copper Kα_1 ray of 1.54056 Å became used to study crystallographic analysis. The range of 2θ angles was from 10^0-80^0. The X-ray tube became working at 15 kV, 15 mA with a scanning rate of 0.25 second/ stage. The standard JCPDS data were used, for comparative purpose. The crystallographic parameters all thin films have been examined applying X-ray technique.

The optical parameters determinations have been done in electromagnetic spectrum order 400-800 nm with the help of double beam spectrophotometer. Tungsten Halogen light is applied as a polychromatic radiance supply. The radiation from the source is focused on the monochromator input slit via a convex lens.

The exterior topography of cadmium selenide samples is studied using instrument scanning electron microscope Stereoscan 250 MK-III., Cambridge Instruments Ltd., made instrument became utilized to view face topography of cadmium selenide.

The electrical conductance of heated CdSe samples on amorphous glass slide becomes measured via applying two probe techniques at 300–525 K. Thickness of films has been computed via difference in weight technique. the maximum thickness observed was 0.54 µm for CdSe thin films.

3. Results and Discussion:

3. 1 Thickness Estimation

All the samples have been uniformfirmly bound to substrates, homogenous and specularly reflecting with darken red shade. Extreme thickness of films has been computed via difference in weight technique via using equation.

t = m/σA---------------- 1

Where m-mass of the sample coated on the surface of material [18]. Thickness was measured every one hour. The behavior of thickness verses preparation period for cadmium selenide sample shown in diagram 1. Sample thickness increase by means of dipping period, nevertheless subsequently four hour development increases maximum and afterwards remains constant. This is primarily because of decreasing in amount of the free ions with reaction period in addition to dissolve of the sample in the reactive mixture.

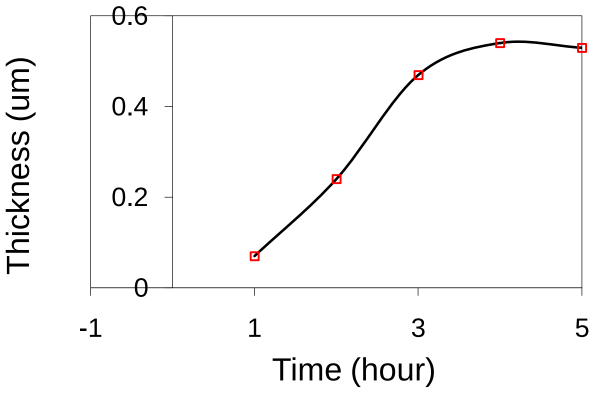

fig1: Plot of thickness in opposition to deposition time of cadmium selenide.

3.2 Structural Analysis

X-ray diffractometerhaving Copper Kα_1 ray of 1.54056 Å became used to study crystallographic analysis. The range of 2θ angles was from 10^0-80^0. The X-ray tube became working at 15 kV, 15 mA with a scanning rate of 0.25 second/ stage. The standard JCPDS data were used, for comparative purpose. The crystallographic parameters all thin films have been examined applying X-ray technique.

X-ray diffraction spectrum of cadmium selenide samples synthesized on glass templates is represented in Figure 2. The structural information, in general crystalline feature, lattice constants, dislocation density, micro strain, as well asparticle parameters of cadmium selenide samples have been examine using X-ray diffracted pattern. After doing careful investigation of information, it is observed that cadmium selenide samples were crystalline character having a hexagonal phase [JCPDS-08-0459]. The large bumpin the pattern was observed because of non-crystalline templates. It may also contain a few non crystalline form of the sample. The diffraction pattern indicates plane at inter planar distance 3.720 Å at two theta value 23.90^0 that match up (100) peak of hexagonal nature. Similar crystallographic pattern was indicated for CdSe films obtained by electrode position method [19]In the pattern mixed phases were not obtained. Consequently, dip technique is appropriate for the production of cadmium selenide in solitary structure.

Lattice constants of the hexagonal nature were estimated using inter planar distance value by applying mathematical form [20]

$(1/d^2) = (4/3)\ (h^2+k^2+ hk)/a^2) + (l^2/c^2)$ ----------------- 2

Wherein h, k and l were planes and d is distance between two planes projected via applying Bragg's relation. Achieved lattice factors "a" in addition to "c" were 4.296 and 7.064 Å, correspondingly. The obtained magnitudes are in very well match able with formerly account.[21]. A method that decide the extent of the preferential orientation parameter 'f' for a obtained peak proportional to different peaks in sample became utilized [22]. Consistent with such method the desire orientation parameter 'f' (100) of (100) peak for cadmium selenide sample had been estimated via the portion of (100) peak strength over summing up of peak heights of each planes have been calculated for sample. f(100) = 0.3317, f(101) = 0.2349, f(110) = 0.1515, f(112) = 0.1045, f(202) = 0.0893, f(203) = 0.0878. Full width at half maximum of cadmium selenide sample corresponding to mainly maximum orientation recommend that samples are have roughly the like crystallite dimension. The usualunit dimension (D) of samples was projected utilizing Scherer's theory [23]

D = (Kλ/βcos θ) --------- 3

Wherein, θ is glancing angle, β represents full width at half maximum, K represents invariable called as character parameter, in use as 0.9 via taking into account the crystallites to be sphere-shapedand λ represents wavelength of rays. Typical particle dimension became observed to 59.72nm. Microstrain arises in cadmium selenide sample became considered applying mathematical representation;

ε = βcosθ/4 ------------- 4

The obtained magnitude of microstrain became originated to 5.803 x 10^{-4}. Dislocation density was determined applying expression [24]

$\delta = n/D^2$--------5

wherein n is parameter that is identical to one for least dislocation density. The obtained magnitude became originated to 2.98 x 10^{14} m^{-2}. Facts of stress and granule dimension were acquired using full width half maximum of observed planes. Williamson Hall investigation was simplify technique in which collectively dimension induced and strain induced widening is utilized via taking into account the plane width as a utility of glancing angle [25]. The FWHM is the linear totaling of the strain and crystallite dimension applying following mathematical formula;

[βcosθ/λ = (K/D) + εsinθ/λ]------6

Fig 3 corresponds to the graph of βcosθ/λ in opposition to sinθ/λ for cadmium selenide sample shows a linear nature. Slope of chart represents quantity of residual strain that found to -1.32 x 10^{-3} for cadmium selenide sample. Inverse of cut off βcosθ/λ axis represents granule dimension as 59.21nm. Negative magnitude of residual strain intended compressive strain in sample. Deposited sample does not contain contaminations; strain became developed at substance and substrates junctions. This is because extremely tiny particles were attached to templates because of face tension consequence.

The volume of the cell had been measured using equation

$V= a^2c$ ------7

The volume became turn out to be 130.37 $(Å)^3$.The number of crystallites/ unit area may be found out utilizing mathematical form

$N = (t /D^3)$--------- 8

Where t = thickness of a sample. The calculated number of crystallites/ unit area became turn out to 2.535 x 10^{15} /m^2 for cadmium selenide sample.

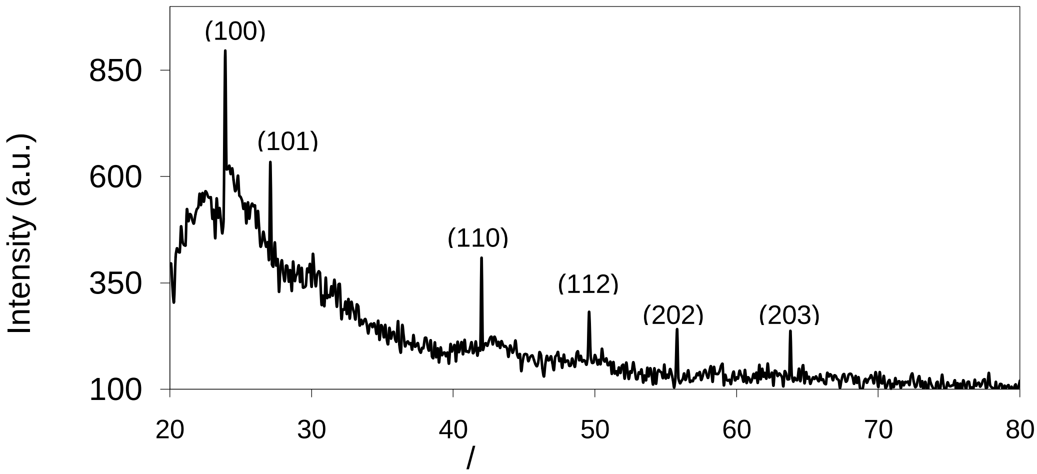

Fig.2: X-ray diffractogram of cadmium selenide sample.

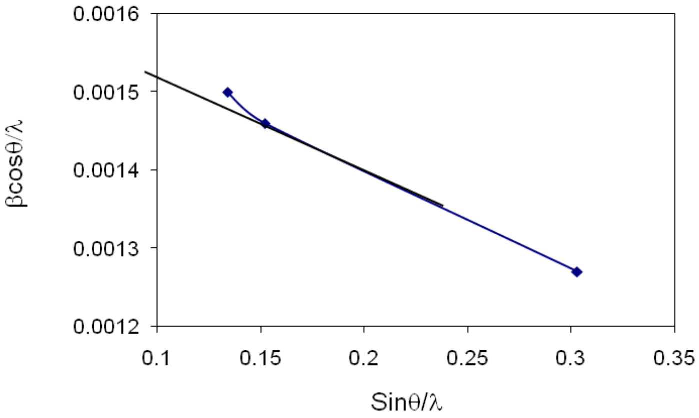

Fig. 3: W-H plot of cadmium selenide sample.

3.3. Optical Analysis of CdSe Sample

The optical parameters determinations have been done in electromagnetic spectrum order 400-800 nm with the help of double beam spectrophotometer. Uncoated glass plate applied as blank in the measurement. The optical absorption became estimated with related to wavelength. Spectra were mostly utilized to determine absorptivity, band energy and the nature of transition. Tungsten Halogen light is applied as a polychromatic radiance supply. The radiation from the source is focused on the monochromator input slit via a convex lens. The resultant ray from the monochromator is cut utilizing a mechanical chopper. Such chopped ray is subsequently occurrence on the sample near normal geometry and the transmitted ray is directed to the photo-detector. The detector determines the intensity of the transmitted ray with the assist of lock-in amplifier.

Optical parameters were considered via observing the transmission and absorbance magnitude of cadmium selenide sample. The higher value of transmission close to 700 nm matches up with the essential absorption edge. They represent photon energy requisite to stimulate an electron transversely in the band energy. Cadmium selenide is not soak up radiation at larger wavelength whilst the majority absorbing radiation in wavelength 400-500 nm. Diagram 4 illustrates absorption in opposition to wavelength for cadmium selenide sample. Absorption enhance a bruptly at lower 700 nm. The absorption coefficient is estimated via applying mathematical form;

$\alpha = (A/t)$ -----------9

The absorption coefficient diminishes along with raise in wavelength. At 400 nm, absorption coefficient became observed to 2.592 x 10^4 cm^{-1}even asat 800 nm absorption coefficient became observed to be 1.85 x 10^3 cm^{-1}. The optical gap of cadmium selenide sample be measured via scheming a plot among $(\alpha h\nu)^2$ with photon energy represented in figure 5.Cut off the linear segment of graph $(\alpha h\nu)^2$ in opposition to hν for nought absorptivity magnitude provide the optical gap. The optical gap of cadmium selenide sample became turn out to 2.10eV. This magnitudeis greater than 1.74eV account for the cadmium selenide [26] a blue shift of 0.36eV may be found out. This is mainly because of nano dimension crystallite. The optical energy magnitude is prejudiced via a variety of parameters such as thickness, particle dimension, crystallographic factors, carrier density, and existence of contamination; divergence as of stoichiometry of sample as well ascrystal lattice strain. The cadmium selenide sample designate the direct transition because the slope of plot of ln (hν-Eg) in opposition to ln (αhν) was roughly 0.5.

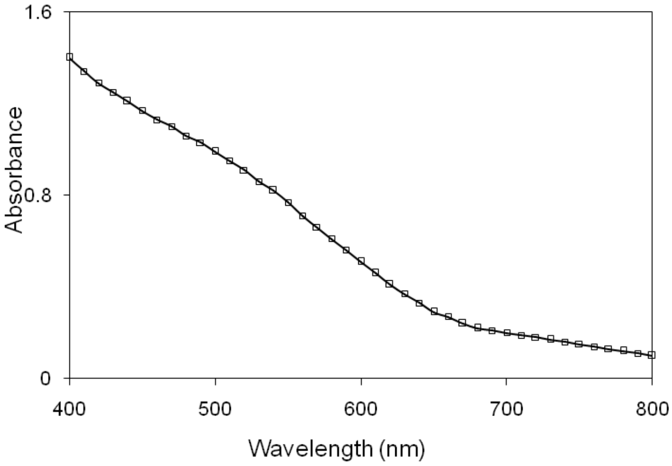

Fig 4: Absorption spectra of cadmium selenide thin film.

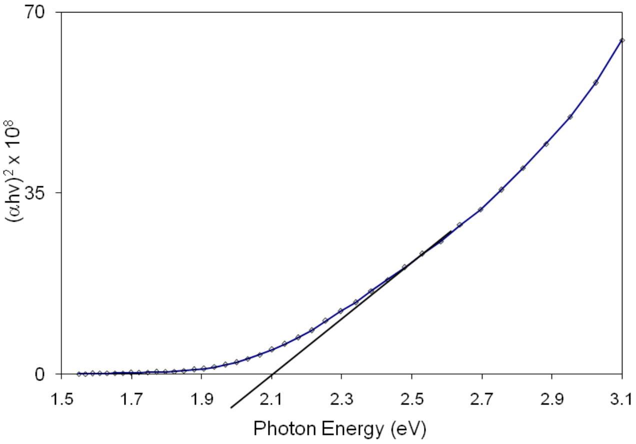

fig 5: Estimation of optical energy of cadmium selenide thin film.

3.4 Morphological Analysis of CdSe Sample

The exterior topography of cadmium selenide samples is studied using instrument scanning electron microscope since it acting an extremely imperative character on the outcome of cells. Stereoscan 250 MK-III., Cambridge Instruments Ltd., made instrument became utilized to view face topography of cadmium selenide.

So as to additional reveal the dimension and crystalline phase of samples, image became taken and represented in Fig 6. The obtained picture of sample is composed of globular crystallites of approximately 65nm. The grains were cumulative in form clusters.

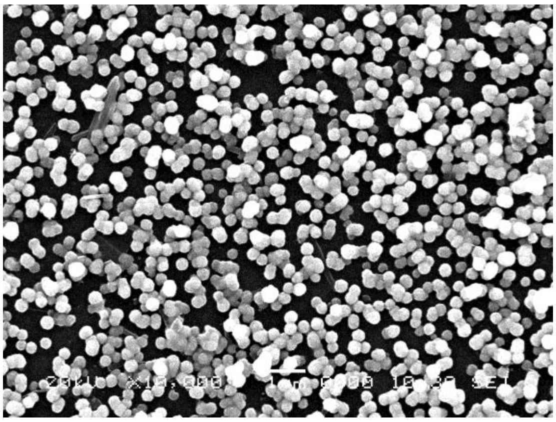

Fig.6: Microscopic image of cadmium selenide sample.

3.5 Electrical Analysis of CdSe Sample

Fig. 7 indicates conductance on opposite temperature of film. The sample shows semiconducting nature. At 300 K the specific conductance became turn out to be 1.234 x 10^{-7} (Ω cm)$^{-1}$.Little magnitude of conductance might be because of lower crystalline nature as well as minute thickness of sample. This may be because of granule border not continuities, occurrence of face states. Owing to granule border was not continues, the space between nucleus efficiently enhance as well as raise the height of granule boundary potential ensuing in diminish in quantity of carrier in addition to mobility. Consequently the electrical conductivity reduces. This curve demonstrate a comparable nature deduce its outcome usingPetritz [27] theory in that conductance is thermal stimulate and it indicated in mathematical form;

$\sigma = \sigma_o \exp(Ea/kT)$ --------- 10

wherein$\sigma_o$is invariable. Activation energy might attain using slope of plot. In this situation, the activation energies have been in limit of 0.11-0.30eV. The calculated values were reliable with formerly obtained. Temperature activation energy indicates an average magnitude of barrier height between two crystallites consists of the combining results of carrier density in addition to mobility. The common reliance of conductivity on temperature is obviously dependable, and point out the occurrence of potential among two crystalline granules, that might be rise above via thermally activated process.

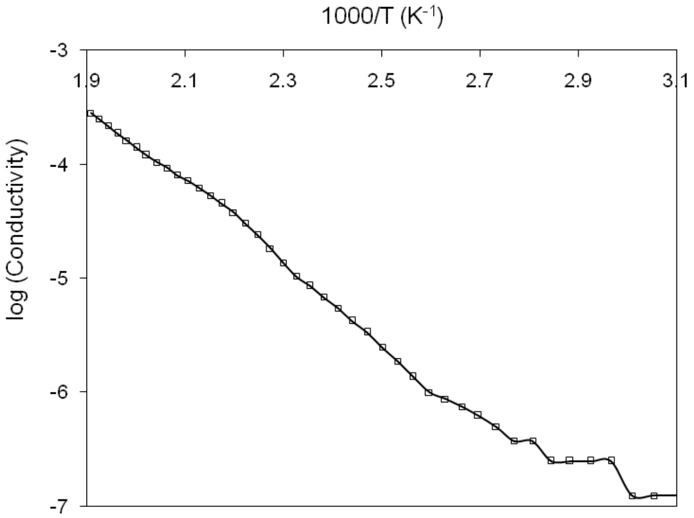

Fig.7: Electrical conductance of cadmium selenide sample.

4. Conclusion

The deposition of CdSe thin film on glass substrate was carried out using dip method. CdSe thin film was polycrystalline along with some amorphous phase present in it. From scanning electron micrograph studies, it was revealed that CdSe thin film is uniform, homogeneous and well coverage to glass substrate. The optical analysis showed that the CdSe thin film has optical energy of 2.10eV. The film is semiconducting with room temperature electrical conductivity of the order 10^{-7} (ohm cm)$^{-1}$

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