CdSe Thin Films Prepared By CBD Structural, Optical and Electronic Properties: A Review

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Abstract:

In this research, the semiconductor material CdSe thin films were prepared by the chemical bath deposition (CBD) method, and characterized by XRD (x-ray diffraction), PL (photoluminescence) techniques, SEM (scanning electron microscopic) and UV visible. Investigated PL study observed emission and excitation spectra in different wavelengths in different ranges of UV and calculated light yields. They are for near UV-based LEDs and display devices. Powder X-ray diffraction revealed a cubic phase of CdSe nanocrystalline thin film with a preferred orientation along the (111) plane. The SEM micrographs showed the film surface was composed of spherically shaped grains over the entire glass substrate.[2] Optical band gap energy Eg of CdSe thin film decreased from 1.43 eV to 1.20 eV with Ni-Co dual doping and the lowest value of Eg was 1.20 eV for the sample at the same molar ratios of Ni and Co (0.04-0.04). Ni-Co dual doping of CdSe thin film improved its properties to be used as a solar cell.[3] The SEM studies showed some layered growth of films along with few fibres and XRD results show the polycrystalline nature of the films.[4]

Key words: CBD, EDX, PL, SEM, X-Ray Diffraction

Introduction:

A thin film is prepared by condensing the matter in atomic/molecular/ionic form onto a substrate. Physical or chemical methods deposit thin films. In recent years, II-IV semiconductors in nano-crystalline form have experienced interesting electrical and optical properties.[1] Nano-structures of CdSe thin films have received more attention because of its fundamental and applied interests in diverse fields such as electronic industries [2], solar energy utilization, space science, production of high memory computer elements, various

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type of sensors and other nano-scale devices[3]. Among the various wide band-gap II-VI binary semi-conducting compounds, cadmium selenide (CdSe) is a promising and widely used material for applications like solar cells [4], light-emitting, and photonic devices. In addition to their applied interest, thin films play an important role in the development and study of materials with new and unique properties. Examples include multiferroic materials[5], and superlattices that allow the study of quantum phenomena[6]. The thin film properties can be controlled by the thickness parameter that makes their use in modern technologies[1]. Crystalline and nano-crystalline thin films have remarkable importance in high technology like solar cells, polarizers, magnetic sensors[5], magnetic thin films in recording devices, interference filters, microelectronic devices, A. R. coating, gas sensors, photoconductors, IR detectors, superconducting films, temperature controller in satellite, anticorrosive and decorative coatings[7].

Noteworthy contributions in the field:

F. G. Hone et al.[2] illustrated that deposition of CdSe deposited from a chemical bath containing cadmium acetate, tartaric acid, ammonia and sodium selenosulphate, at a bath temperature of 85 0 C and pH of 9.5, cadmium acetate dehydrate source of Cd ions, sodium selenosulphate which provided Se ions, and tartaric acid as a complexing agent. Ammonia used to adjust pH of aqueous solutions. The films were characterized using a variety of techniques. Powder X-ray diffraction revealed a cubic phase of CdSe nano-crystalline thin film with a preferred orientation along the (111) plane. The SEM micrographs showed the film surface was composed of sphericis ally shaped grains over the entire glass substrate. The elemental composition of the thin film was confirmed by energy-dispersive X-ray spectroscopy. Optical band gap energy was found 1.86 eV. X-ray diffraction study revealed the cubic phase of Cadmium Selenide thin film. The average crystal size of the CdSe thin film obtained using the Debye-Scherrer equation was found 4 nm.

A. M. Abdulwahab et al.[3] reported that CdSe, CdSe: 0%Ni-8%Co, CdSe: 2%Ni-6%Co, CdSe: 4%Ni-4%Co, CdSe: 6%Ni-2%Co and CdSe: 8%Ni-0%Co doped thin films prepared by chemical bath deposition (CBD) technique. The precursors of cadmium chloride, sodium seleno-sulphite, ammonia, tri-ethanolamine, nickel chloride, and cobalt chloride were used in this process. The deposited thin films were annealed for 1 h at 500 ◦ C. Structural analysis confirmed that all the CdSe thin films (pure and Ni-Co dual doped) have hexagonal system except CdSe: a 4%Ni-4%Co thin film which has a cubic system. Ni-Co dual doping, with the same molar ratios, changed the structure of CdSe thin film from a hexagonal structure to a cubic structure. Dual doping with Ni and Co changed lattice parameters and crystalline size of CdSe thin films. The crystallite size increased by doping CdSe thin film with either Ni or Co, while it decreased by doping CdSe thin film with both Ni and Co as dual doping. The smallest value of crystallite size 19 nm for samples of the same molar ratios of Ni-Co (0.04-0.04). Ni-Co dual doping changed the absorbance of the CdSe thin film. The absorbance increased when Ni molar ratio was higher than Co, while it decreased when Co molar ratio was higher than Ni. The Optical band gap energy Eg of CdSe decreased from 1. 43-1.20 eV with Ni-Co dual doping and lowest value of Eg was 1.20 eV for a sample at the same molar ratios of Ni and Co (0.04-0.04). Ni-Co dual doping of CdSe thin film improved it properties to be used as a solar cell.

Smriti Agrawal et al.[4] showed co-deposition Cd (S–Se):CdCl 2 films with doping of La using chemical deposition technique at RT for18 hours in a 25 ml beaker with 1M cadmium acetate, an appropriate ratio of thiourea, sodium-selenosulphate solutions, tri-ethanolamine and 30% aqueous ammonium hydroxide. For preparing doped films, calculated proportions of 0.01M solutions of cadmium chloride and lanthanum oxide are also added to the original mixture. SEM studies showed some layered growth of films along with few fibers. There is vacant space between the clusters of non-homogenous spherical grains. XRD results show the polycrystalline nature of the films. The optical absorption spectra are recorded in the wavelength range 350–700 nm. Optical absorption spectra confirmed the presence of La in lattice and show direct band-gap nature of the materials. The PL excitation is done with 365 nm line of mercury, In PL spectra, the observed two peaks are attributed to transitions between excitonic levels and energy levels of La.

M. Piryaei, et al.[5] concluded that CBD could be employed for the preparation of stoichiometric CdSe thin films on the glass substrates at different values of pH. To obtain desired thin films, 50 ml of 0.5 M cadmium acetate are taken in 200 ml capacity beaker and 25% ammonia solution slowly added to it with constant stirring. The solution becomes milky and turbid because of the formation of $Cd(OH)_2$ suspension. Further, the addition of excess ammonia dissolves turbidity and makes solution clear and more transparent. Thereafter UV-visible studies realized that prepared CdSe semiconductors has the lowest bang gap energy at the pH of 12.09. XRD pattern of deposited films indicated the presence of crystalline cubic phase(111) as the preferred plane orientation and the best quality of crystality is at the pH of 11.90. The SEM study proved that deposited CdSe films are irregular in the shape and size. RBS analysis found that Cd to Se ratio approximately remains constant at the pH of 11.90 and pH of the solution affected on stoichiometry of deposited CdSe thin films.

Kerrie M. Morris et al.[6] reported the CdSe thin films prepared by CBD containing solutions of cadmium acetate and sodium seleno-sulphite. The cadmium acetate solution was prepared by adding cadmium acetate powder to 20ml deionized water and mixing until dissolved. In this study, only the wurtzite type structure was identified but this was successfully coupled with a CdTe layer to give moderate efficiencies, with an efficiency of 12.3%, from a 280 nm thick CdSe film with a surface coverage of 59%. This resulted in an optimal diffusion of CdSe into CdTe to form the ternary compound CdTe 1-x Se x. The lower band gap of 1.39 eV increased the EQE response at higher wavelengths up to 950 nm without leaving a remaining CdSe layer. Thinner films of CdSe (< 175 nm) were not thick enough to lower band gap of CdTe effectively increasing the response at wavelengths >900 nm. Thicker layers, greater than 340 nm, reduced the band gap of CdTe by forming the ternary compound but left a CdSe layer that absorbed too much light to work as an effective window layer.

Measurement Techniques:

(1) Thickness measurement:-

In present work the Gravimetric method adopted to determine thickness of prepared thin films.

(2) Optical transmission/absorption Spectral Studies:-

Such studies impart informations about the value and the nature of the band gap associated with the materials under study. The results of such studies will be compared to those of photoconductivity excitation spectral studies. Normally blue shifts are expected under particle size reduction. Hence such studies will be useful in studying particle size effects.

(3) Electrical studies:-

Attempts are made to include studies on photovoltaic effect in bulk as well as nano-crystalline forms in such thin films. Short circuit voltage (Voc) open circuit voltage (Voc) and the behaviour of current with voltage are undertaken. Important parameters like fill factor and efficiency are also obtained. Resistivity measurement, and electrical properties are observed in prepared materials.

Analytical Techniques:

(1) Scanning Electron Microscopic (SEM) studies:-

Such studies are useful regarding morphological features of the films. The nature of materials prepared and grain size etc., are known from such studies. A correlation is shown between SEM and XRD studies.

(2) X-Ray Diffraction (XRD) Studies:-

For further characterization of these materials, X-ray diffraction (XRD) will be done. Parameters like crystal structure and the lattice constants etc. Will be determined and correlated with nano-particle studies.

(3) Transmission Electron Microscopy (TEM) Studies:-

It is high-resolution technique used to reveal structural details, size distribution and morphology of nano-particles. Precise particle size of bright field images as well as dark field images are provided by the TEM, and it provides details regarding nano-particles as it utilizes energetic electrons to provide information regarding morphologic, compositional, and crystallographic information.

(4) Energy Dispersive X-ray (EDX) analysis:-

Energy Dispersive X-ray Spectroscopy (EDX) is used to determine the composition of a sample such as thin films. The method relies on the generation of characteristics X-rays, that reveal the identity of the elements present in the sample. Typically this technique is used in conjunction with scanning electron microscopy.

(5) The Photoconductivity Rise and Decay studies:-

Proper electrodes are formed on the films prepared by the CBD technique and photo conducting rise and decay studies of the variety of films prepared are undertaken under the excitations of visible radiations. Life time and mobility of the carries and the trap depth are derived on this study. Effect of particle size on photoconductivity also investigated.

(6) Photoconductivity Excitation Spectra:-

Such studies will be performed by irradiating the material with different wavelengths and recording the corresponding photocurrent with suitable instruments. The maximum excitation may correspond to band gap and hence important parameters like band gap will be obtained from such studies. It is expected that such studies may also reflect information about the presence of impurities in the form of hump or smaller peaks in the excitation spectra.

Conclusion:

The current study enhances our understanding of the fundamental mechanisms involved in the preparation of thin films, highlighting chemical bath deposition as a straightforward yet highly effective method. This technique allows for the creation of thin films that are not only smooth and homogeneous but also exhibit a remarkable reflective quality and strong adhesion properties. In the experiments conducted, both undoped and doped cadmium selenide (CdSe) thin films were successfully fabricated. The films, deposited onto glass substrates at varying temperatures, demonstrated robust photoluminescence (PL) spectra. These spectra are linked to transitions between excitonic energy levels, a phenomenon that has been published in previous research. The findings from this study indicate that these CdSe thin films can be applied in a variety of optoelectronic devices and solar cells, opening new avenues for innovation in these technologies

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