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Deposition Of CDSE Thin Film For Photovoltaic Applications

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Abstract
Cadmium selenide (CdSe) thin films were deposited by chemical bath deposition technique on glass substrates. Films were deposited at 80ºC bath temperatures. We determined structure of as-deposited thin films by X-Ray spectroscopy. Optical properties of as deposited films is studied by absorption spectra. The optical absorption spectra showed a band gap is of 1.74 eV. The scanning electron microscope (SEM) study indicates that grain size increases with increase of bath temperature. The study of physical, optical and electrical properties reveal that the CdSe thin film can be suitably employed in Photovoltaic applications.

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I. Introduction

Cadmium sulfide is commonly used as n-type semiconducting layer for heterojunction thin films solar cells. Multilayered CdSe films can be employed in the manufacture of the photovoltaic devices [1]. The CdSe film has been deposited by various techniques, such as electron beam evaporation [2], r. f. sputtering [3], molecular beam epitaxy [4], spray pyrolysis [5], chemical bath deposition [6,7]. Chemical bath deposition is a method of growing thin films of certain materials on a substrate immersed in an aqueous bath containing appropriate reagents at temperatures ranging from room temperature to 100°C. In this study, we report the preparation of CdSe thin films onto microscope glass slides by CBD method. The structural, morphological and optical properties of the as-prepared films are investigated.

II. Experimental

Thin Film Preparation

The CdSe thin films were deposited using mixture of aqueous solutions of cadmium sulphate, selenium powder, sodium sulphite, trisodium citrate, triethanolamine (TEA), hydrazine hydrate, and sodium hydroxide (NaOH), where TEA was used as the complexing agent and sodium hydroxide for adjusting the pH. The substrates used for the deposition of CdSe thin films were commercial microscope glass slides (Blue Star) with the size of 75 x 25 x 1.35 mm. Before deposition, the substrates were degreased in HNO_3 solution for 24 h, cleaned by commercial detergent and finally rinsed with de-ionized water and dried in desiccator. This process was carried to ensure clean surface, essential for formation of nucleation centers required for thin film deposition. All chemicals used in the present investigations were AR grade. Aqueous solutions of 0.5 M cadmium sulphate ($CdSO_4$), 0.5 M sodium selenosulphate (Na_2SeSO_3), 0.4 M trisodium citrate, triethanolamine (TEA), 80 % hydrazine hydrate and 5 M sodium hydroxide (NaOH) were used to prepare thin films. Sodium selenosulphate was prepared by refluxing 0.5 M selenium powder mixed with 1 M sodium sulphite in de-ionized water, which was heated to 80 °C for 8 h [8]. Cadmium sulphate solution (20 mL) was taken in a 50 mL glass beaker to which 30 drops of TEA, 5 mL NaOH and 5 drops of hydrazine hydrate solutions were added slowly under continuous stirring. Initially, the solution was milky and turbid due to the formation of $Cd(OH)_2$ suspension. Addition of excess NaOH led to the dissolution of turbidity and made the solution clear and transparent. Then 5 mL trisodium citrate and 20 mL freshly obtained sodium selenosulphate solutions were added slowly with constant stirring. pH of the final mixture was adjusted to ~ 13. Pre-cleaned glass substrates were inserted into the reaction mixture standing parallel with the walls of the beaker, which was kept in constant temperature bath for 4 h at 80º C. Thereafter, the substrate coated with CdSe was removed, rinsed with distilled water, and dried in desiccator. It was observed that the film was uniform, well adhered, and reddish in color [9]. Adhesion of the film was confirmed by centrifugal method. Thickness of the film was found to be ~ 300 nm by using weight difference method. It is noted that the growth is highly dependent on temperature and concentration of complexing agent.

Characterization techniques

As-deposited thin film of CdSe was characterized for structural, optical and electrical properties. Glancing incidence angle X-ray diffraction (GIXRD) pattern of the film was recorded on a Bruker AXS,

Germany (D8 Advanced) diffractometer. The scanning range of diffractometer used is 20–80º (2θ), using Cu-$K_{\alpha 1}$ radiations with wavelength 1.5405 Å at 0.5° The surface morphology was studied by scanning electron microscopy (SEM, JOEL-JSM-5600). Transmittance and absorbance spectra were recorded in the range 300–1000 nm by means of Jasco V630 spectrophotometer. The resistivity of the films was determined by four probe method.

III. Results And Discussions

Structural and Compositional Studies

Fig. 2 shows X-ray diffraction pattern of as-deposited CdSe thin film. The XRD peaks indicate that the film is polycrystalline in nature. The 2θ peaks 25.30º, 42.2º and 49.70º corresponds to reflection from (111), (220) and (311) planes, respectively. The (111) plane is the preferred orientation and it is the close-packing direction of the zinc-blend structure of cubic CdSe phase (JCPDS card No 91-0191). Crystallite size (D) of the film was calculated using Scherrer's formula [8] from the full width at half maxima (β) of the peakes expressed in radians,

$$D = \frac{K\lambda}{\beta Cos\theta} \qquad (1)$$

where 'K' is constant dependent on crystallite shape (0.89), 'λ' is wavelength of $CuK_{\alpha 1}$ radiation, and 'θ' is angle between the incident and scattered X-rays. The average crystallite size (derived from Fig. 2) is found to be < 10 nm.

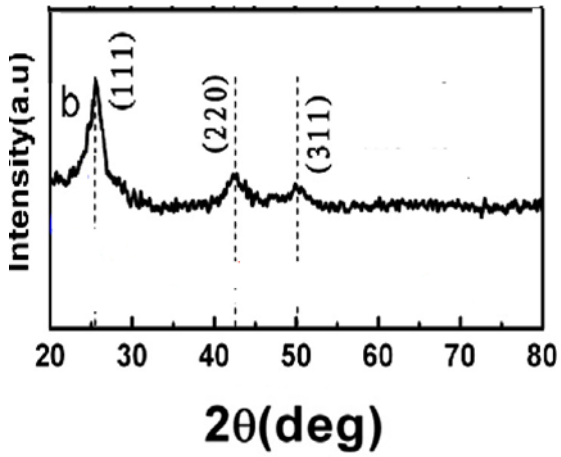

Figure. 1. GI XRD pattern spectrum obtained from the as-deposited CdSe thin film.

Surface morphological and topographical Studies

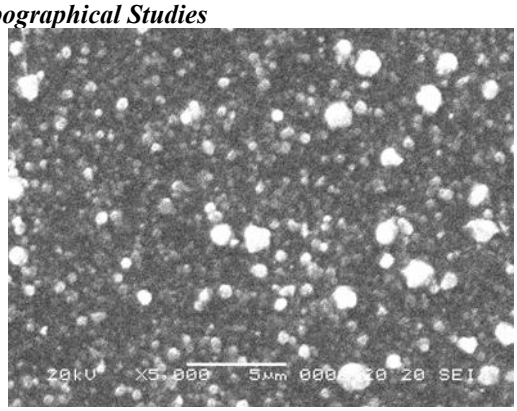

Figure. 2. SEM image of as-deposited CdSe thin film

Fig. 2 shows a. SEM image of the as-deposited ZnSe film which confirms, uniform deposition. The fine grains were well defined, spherical with different sizes and were uniformly distributed over a smooth homogeneous background corresponding to the nanocrystalline phase of CdSe. Some of the grains are seen to be united/fused forming agglomerates and the grain size obtained from SEM is about ~ 100 ± 20 nm.

Optical Studies

Fig. 3a inset shows transmittance and absorbance spectra obtained from as-deposited CdSe thin film. The optical transmittance of over 65% is noted in the visible region. The relation between the absorption coefficient α and the incident photon energy (hν) [8] can be written as,

(2) $$\alpha h\nu = A(h\nu - E_g)^n$$

where 'A' is constant, n= ½ for direct allowed transition, 'E_g' is optical band gap of the material. Fig. 3b shows the plot of $(\alpha h\nu)^2$ against (hν) for CdSe thin film derived from the absorbance spectra. Extrapolating the straight-line portion of the plot of $(\alpha h\nu)^2$ vs (hν) for zero absorption coefficient value gives the band gap, which is found to be 1.74 eV at room temperature.

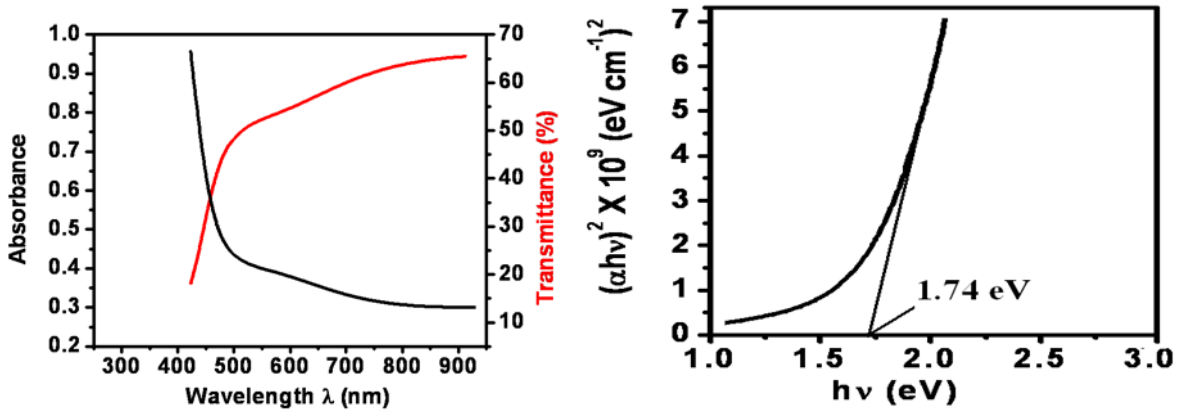

Figure. 3. (a) Plot of absorbance and transmittance versus wavelength, (b) Plot of $(\alpha h\nu)^2$ versus (hν) obtained from as-deposited CdSe thin film.

IV.Conclusion

CdSe thin film were grown using ammonia free precursor solutions with appropriate selection of the growth parameters by inexpensive CBD. The as-deposited film present excellent adherence, uniform deposition, smooth morphological and nanocrystalline properties, confirmed by SEM and XRD analysis. It is found that the as-deposited CdSe films are highly oriented with cubic zinc blende structure, and the preferred crystal orientation is (111) plane. The XRD FWHM also suggests that the crystal quality of the as-deposited CdSe films is reasonably good. The EDAX study shows almost stoichiometric deposition. Energy band gap of the asdeposited CdSe film is 1.74 eV and it is quite close to the reported value of 1.88 eV, which shows a blue emission. The study of physical, optical and electrical properties reveal that the CdSe thin film can be suitably employed in Photovoltaic applications.

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