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Studies on structural and optical characterizations of CdAlS thin films

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Abstract:

Chemical Bath Deposition (CBD) technique was employed for synthesis of CdS, and Al doped CdS thin films. Al doped CdS films are annealed at different temperatures in air. CdS, as deposited Al doped CdS and annealed Al doped CdS films were characterized by XRD, Scanning electron microscopy (SEM) and UV-Visible spectrophotometer. The variation of lattice parameters and grain size with annealing temperature were investigated from XRD data. SEM study concluded that Al doping did not have significant effect on the surface morphology of CdS thin film.

Key words: Chemical Bath Deposition, CdS thin films, Doping, XRD

1. Introduction :

CBD is a low-cost, relatively simple and practical method for covering complex substrates and offers excellent control when depositing thinner films. Al-doped CdS thin films show low electrical resistivity of about 48 Ω cm. The doping of group III elements has been found to decrease the resistivity of CdS thin films. The effect of Al incorporation on the structural and electrical properties of CdS has been investigated to determine the feasibility of CdS films for the potential technological application. The structural properties are investigated in many of the manuscript for as-deposited Al doped CdS films. The present article deals with synthesis of purely CdS and Al doped CdS films and effect of annealing temperature on structural properties of Al doped CdS thin films.[1-5]

2. Experimental details:

The CdS and Al doped CdS films used for the study were deposited using chemical bath deposition technique on glass substrate. All the chemicals and reagents used are of analytical grade. The stock solutions CdCl₂ (0.2 M), 7M NH₄OH, 2.5M NH₄Cl, 1M (NH₂)₂ were previously prepared.

2.1. Preparation of purely CdS film: 20ml of CdCl₂, 20ml of 7M NH₄OH, 5ml of 2.5M NH₄Cl and 40ml of 1M (NH₂)₂CS taken in reaction bath from stock solutions and all filled with up to 200 ml with doubled distilled water. The pH of the solution was adjusted to 11 pH by slowly adding the aqueous NH₃. [6-8]

2.2. Preparation of Al doped CdS thin film: 20ml of CdCl₂, 20ml of 7M NH₄OH, 5ml of 2.5M NH₄Cl and 40ml of 1M (NH₂)₂CS taken in reaction bath from stock solutions and all filled with up to 200 ml with doubled distilled water. Aluminium doping was carried out by adding the appropriate amount of 0.02 M Al₂(SO₄)₃. The pH of the solution was adjusted to 11 pH by slowly adding the aqueous NH₃. Glass substrate was previously immersed in chromo sulphuric acid for 24 hr, and cleaned with acetone, rinsed with double distilled water. The reaction beaker was kept in oil bath.

Temperature of the oil bath was previously kept at optimized temperature of 80°C. Cleaned glass substrates were mounted on substrate holder and immersed in deposited solution. The substrate holder was rotated at slow speed of 45 rpm by means of DC geared motor for optimised time of 30 min. In the reaction mixture CdCl₂ was used as Cd²⁺ source, (NH₂)₂CS used as S²⁺ source and NH₄OH was used as complexing agent. The thin uniform yellow CdS and Al doped CdS thin films were obtained at the end of the reaction. The prepared Al doped CdS thin films are annealed at different temperatures of 373, 473, and 573 K. The CdS, as-deposited Al doped CdS and annealed Al doped CdS thin films are characterised using XRD and SEM.

3. Results and Discussion

The XRD spectra of CdS and Al doped CdS thin films are recorded using Regacu Miniflex II diffractometer and displayed in Fig. 1

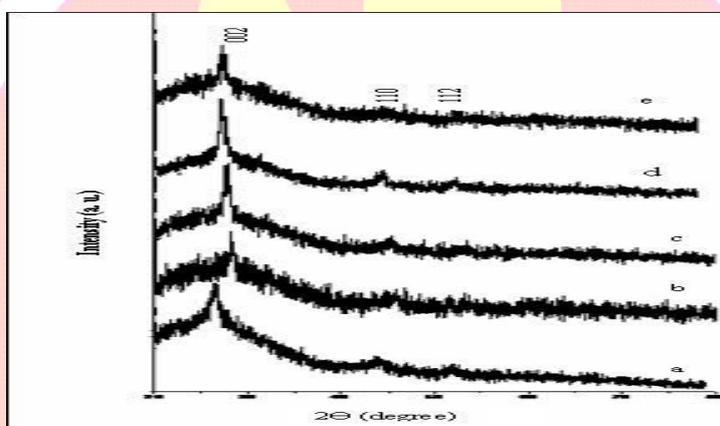


Figure 1. XRD pattern exhibits three preferential peaks

XRD pattern exhibits three preferential peaks assigned to (002), (110), and (112), orientations of hexagonal phase of CdS material. The position of (002) peak is shifted slightly with Al doping observed from figures 1a and 1b. The (110) and (112) peaks are observed disappeared with Al doping. The effect of annealing clearly observed in fig. 1d assigned to appearance of the (110) and (112) peaks. The appearance of the peaks (110) and (112) confirmed that Al doped CdS thin film annealed at 473 K retained the hexagonal phase CdS. The annealing temperature increased to 573 K height of (002) peak decreased and (110) and (112) peaks were disappeared that confirmed the annealing temperature increased above 573 K crystalline phase of Al doped films transfer to polycrystalline phase. Although the hexagonal phase of CdS transform from crystalline to polycrystalline however the stichiometry of CdS would not change by Al doping. The observed diffraction patterns are in good agreement with the standard crystallographic data of JCPDS card No. 80-0006 of CdS material. The values of lattice constant *a* and *c* for hexagonal planes of the CdS and Al doped CdS thin films were calculated from XRD data.[9-12]

The calculated values of lattice constant '*a*' and '*c*' are 4.1.18 (4.121) and 6.759 nm (6.682 nm) respectively. The quantities in the parentheses shows the values of '*a*' and '*c*' obtained from standard JCPDS card 80-0006. The calculated values of '*a*' and '*c*' are very close to observed values of CdS thin films. The values of lattice constant *a* and *c* are observed decrease on doping of

Al. The effect of annealing temperature was clearly observed on lattice constants; the variation was displayed in table 1 and presented in Fig.2.

Film type	Annealing Temp. K	Lattice const. 'a' nm	Lattice const. 'c' nm	Grain Size nm	Thickness μm	Band Gap E_g eV
CdS/ CdAlS as-deposited	305	4.1018/4.0431	6.759/6.486	3.5/26	1.56/1.22	2.421/2.29
Annealed at 375 K/475 K	375/475	4.277/4.041	6.5/6.486	20/8	1.12/0.89	2.31/2.70
Annealed at 575 K	575	4.444	6.584	10	1.11	2.82

Table 1 shows the variation of grain size with Al doping and annealing temperature, and presented in Fig 2.

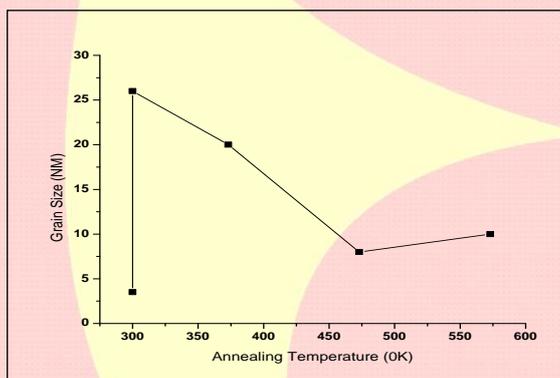


Fig. 2. Variation of Grain Size against annealed temperature

The grain size of the CdS was observed increased on Al doping. Further the grain size is decreased for annealed films as compared to as-deposited Al doped CdS films. The average grain size of pure CdS thin film is 3.5 nm and 26 nm for Al doped CdS films.

SEM (scanning Electron Microscopy) images are displayed in Figure 3 for pure CdS, Al doped CdS and Al doped CdS films annealed at 475K.

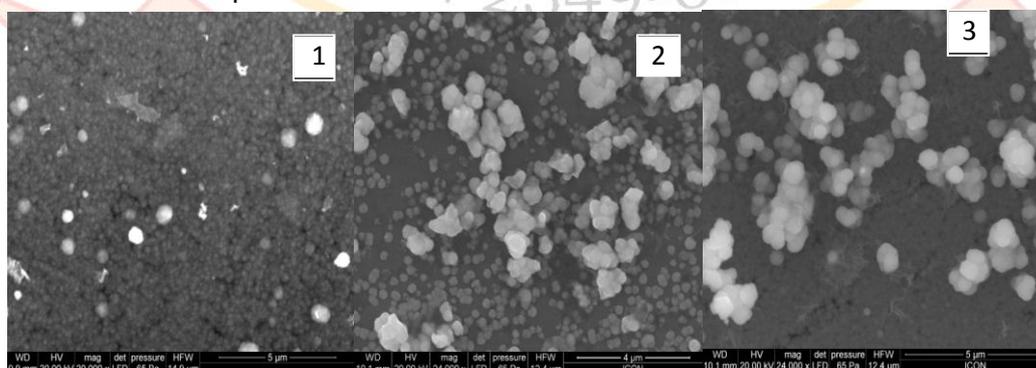


Fig. 3. SEM images for

- 1) Pure CdS thin film at 305 K, 2) Al doped CdS thin film and 3) annealed at 475

SEM image for pure CdS film compactness was high, the surface's uniformity was good, the particle size was quite fine, and the particle size distribution was also narrow. These characteristics are in good agreement with the film's high transparency. Some of the larger sized grains assigned to colloidal particles of S ions. Al doping did not have significant effect on the surface morphology of CdS thin film. There are some spheroid shape growth appears as the creation of nucleation centre on the film surface. These are most probably aggregated due to colloidal particles formed in solution and then absorbed on the film. The SEM image of Al doped CdS film annealed at 473°K shows increase in uniformity of the CdS film and smaller size Al granules are homogeneously substituted in the CdS phase of film. Over the highly compact Al doped CdS phase slightly higher density of scattered crystallites of Al grains with shrinking size as compared to as-deposited Al doped CdS film were observed.

4. Conclusion:

CdS and Al doped CdS thin Films were successfully synthesized using aqueous solutions of CdCl₂, (Al)₂SO₄ and (NH₂)₂CS using Chemical Bath Deposition technique. The XRD study revealed the hexagonal phase of the purely CdS and Al doped CdS thin films. From XRD data it is concluded that Al doped CdS phase homogeneously substituted with CdS phase at 475 K annealing temperature. The XRD study shows that the hexagonal structure of CdS is not much affected with respect to Al doping. The grain size is observed increased with Al doping and decreased with annealing. The change of lattice parameters was observed with Al doping and heat treatment.

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