# RESEARCH ARTICLE

## SYNTHESIS AND OPTICAL CHARACTERIZATION OF SOLAR CELL THIN FILM

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**ABSTRACT**

The polycrystalline chalcogenide semi-conductors play a vital role in solar cell due to their flattering optical properties. Among the chalcogenide semi-conductors, CdZnS is one of such kind of materials, which is an imperative for applications in various modern solid state devices such as solar cells, light emitting diode, detector etc. Due to their applications in assortment of electro-optic devices, group II-VI semiconductors have been studied extensively. In recent years, major attention is given to the study of electrical and optical properties of CdZnS thin films. In this work, Cd1-xZnxS thin films were prepared by chemical bath deposition technique. Phase purity and surface morphology properties were analyzed using Field Emission Scanning Electron Microscope (FESEM) and X-ray diffraction (XRD) studies. Chemical composition was studied using energy dispersive spectrophotometer (EDAX). Optical band gap property was investigated using UV-Spectroscopy. This work reports the effect of Zn on structural, optical properties of these films.

## INTRODUCTION

Sulphides of zinc and cadmium have been utilized successfully in various opto-electronic devices. The growth of ternary semiconductor thin films have been studied very extensively in the recent years, since these films play an important role in the fabrication of solar cells due to their flattering optical properties (Tyan, 1988). Sulphides of cadmium and zinc have been utilized in various optoelectronic devices. It is of great technological interest that cadmium zinc sulphides (CdZnS) thin films which have a wide bandgap in heterojunction solar cells and in photoconductive devices. Photoconductivity studies of II-VI compounds finds their use in broad applications like photovoltaic solar energy and thin film transistor electronics (Shashibhushan, 2008). Wide ranges of polycrystalline semiconducting materials have been studied for its photoconductivity in the visible light. Photo decay and photo response properties are employed for exploration of photoconductive materials and photovoltaic structures (Pisarkiewicz, 2004).

**Experimental Details:** The physical properties of electrodeposited Cd1-xZnxS films are dependent on the deposition parameters such as the bath temperature, the relative concentrations of the various reactants in the solution, the pH value and type of substrate. Electrodeposition technique was used to deposit the thin films of Cd1-xZnxS on glass substrate.

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The starting materials, cadmium sulphate and thiourea used are of analytical grade. For the deposition of Cd1-xZnxS thin film, a well cleaned glass substrate was immersed vertically in the solution. The temperature of bath was maintained at 70°C for 3 hours. Triethanolamine (TEA) was used as a complexing agent. Ammonia solution was used to maintain the pH of the bath at 10. Finally, the coated substrates were washed with distilled water and annealed at a temperature of 225°C. The quality of thin films generally depends on the parameters such as deposition time and temperature of deposition. The deposition parameters followed are furnished in the Table 1.

**Table 1. Deposition parameters to obtain Cd1-xZnxS thin films**

| Deposition Parameter | Optimum value / item |
|---|---|
| Deposition time | 70 min. |
| pH | 10 |
| Concentration of precursor Cadmium sulphate, Zinc sulpahte, Thiourea | 0.1 M |
| Solvent | Deionized water |
| Zn composition | 0.2, 0.4, 0.6, 0.8 |
| Deposition temperature | 70 °C |

## Structural properties

**X-ray diffraction:** The phase purity of the film was analyzed with X-ray diffraction (Miniflex, Rigaku, Japan) using CuK$\alpha$ radiation with a wavelength of 1.542Å. The structural characterization is very important in explaining structural, micro structural and electrical properties of Cd1-xZnxS thin films. The X-ray diffraction patterns were recorded from 20° to 80° as shown in Fig (1) (a) - (d).The XRD analysis show that

all the films were nanocrystalline in nature with cubic phase of Cd1-xZnxS. The XRD patterns reveal the formation of alloy Cd1-xZnxS ternary system with Zn compositions x = 0.2, 0.4, 0.6 and 0.8, respectively. The compositions were further confirmed using EDS analysis. The presence of sharp peaks indicates crystalline nature of the thin films, from Fig (1) (a-d).The observed peaks correspond to the planes (100), (002), (101), (102), (110) and (110) which is found by matching with standard JCPDS data of CdZnS (Sarika Singh and Shrivastava, 2014).
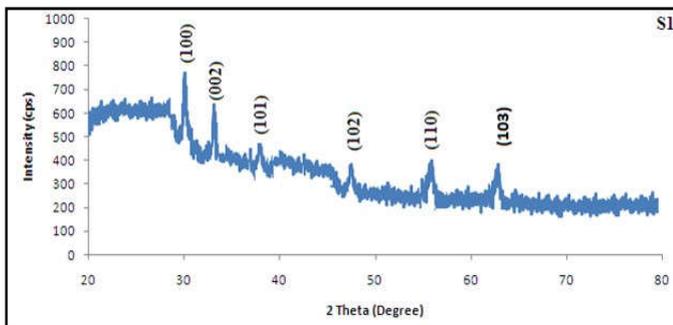


**Figure 1. X-ray diffraction pattern of Cd1-xZnxS thin films with (a) 0.2 % Zn, (b) 0.4% Zn, (c) 0.6% Zn and (d) 0.8 % Zn**

The average crystallite size of Cd1-xZnxS thin film samples were calculated by using the Scherrer formula

$$D = \frac{0.9\,\lambda}{\beta \cos\theta} \qquad (1)$$

Where, *D* - average crystallite size
*λ* - X-ray wavelength (1.542 Å)
*β* - FWHM of the peak
*θ* - Diffraction peak position.
The average crystallite size is presented in Table -3.

**Field Emission Scanning Electron Microscope Analysis:** The surface morphology of the prepared films was analyzed using a field emission scanning electron microscope coupled with energy dispersive X-ray analysis (EDAX) (FE-SEM, JEOL. JED 6300).
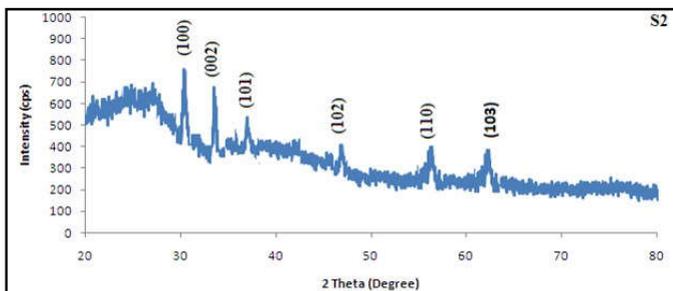


**Figure 2. (a) (b) (c) and (d) show FE-SEM images of Cd1-xZnxS thin film for sample S1, S2, S3 and S4**

FE-SEM image of Cd1-xZnxS thin films are represented in Fig (2). FESEM image resolve the nanoparticles associated with the film at high magnification of "15000 x". Fig (2) (a) (b) (c) and (d) shows the hierarchical formation (Ubale *et al.,* 2012) of the particle for Cd1Zn1-xS thin film. Fig. (2) (d) shows agglomerations of the grains. Grain size was tabulated in table-3. It is observed that the grain size decreases with increase in Zn composition. The films show a fiber like morphology as Zn composition increases, which may be useful for gas sensing applications.

**Quantitative Elemental Analysis (EDS):** The quantative elemental composition of Cd1-xZnxS thin film was analyzed using an energy dispersive spectrometer. Fig.3 shows that the prepared Cd1-xZnxS thin film was nonstoichiometric in nature.
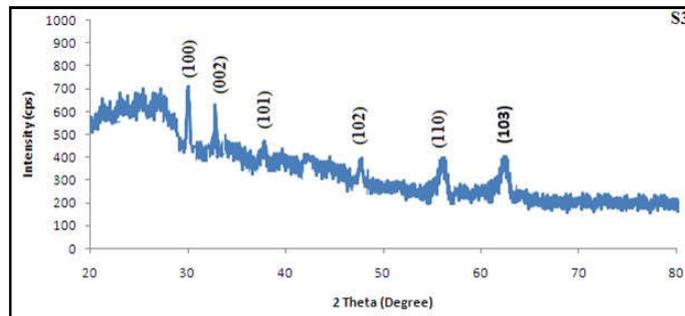


**Figure 3. EDAX of Cd1-xZnxS thin film sample (S3)**

Table 3 indicates that Cd1-xZnxS thin films are formed as nonstoichiometric.

**Optical Properties Using UV-Spectroscopy:** Optical absorption studies of hierarchical Cd1-xZnxS thin films were carried out in the wavelength (*λ*) range 300-600 nm at room temperature, using UV-visible-2450 spectrophotometer. The change in absorbance with wavelength (*λ*) is as shown in Fig (4). The band gap energies of the samples were calculated from the absorption edges of the spectra (Sanap and Pawar, 2011).
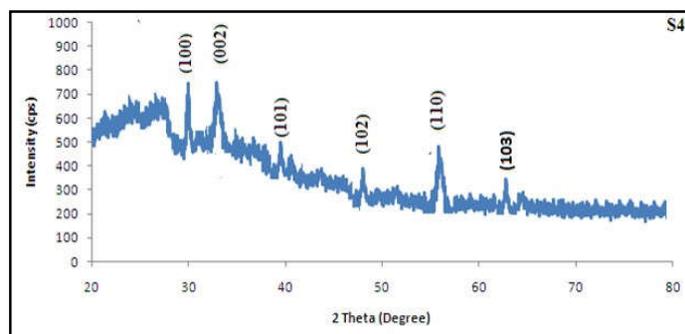


**Figure 4. Variation of absorbance with the wavelength in nm for samples S1, S2, S3 and S4**

The slope drawn from the start of an absorption edge (the onset of absorbance) and horizontal tangent drawn on absorption minimum had intercepted each other at some point shown in the Fig.4. The effects of Zn composition on the band gap (Eg) values of the Cd1-xZnxS films have been studied. In order to obtain the band gap, the absorption coefficient (α) was calculated from the absorption data Optical band gap energies of the samples were observed to be slightly varying from 3.55 to 3.71 eV, (Sharma *et al.,* 2006). It is well known that a momentous increase in the band gap energy is possible when the size of crystallites reaches the size of the quantum dots. It can be seen that the band gap varies with Zn composition in a nonlinear way (Kawar *et al.,* 2012).

**Variation of crystallite size, grain size and dislocation density with Zn composition**

The details of the composition and calculated crystal sizes varying with Zn% are given in Table (3). It is clear from Table (3), that the grain size decreases from 39 nm to 31nm with

**Table 2. Quantitative elemental analysis of as prepared Cd1-xZnxS thin films**

| Element | Observed | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | S1 | | S2 | | S3 | | S4 | |
| | wt % | at % | wt % | at % | wt % | at % | wt % | at % |
| Cd | 40.80 | 33.65 | 46.65 | 31.87 | 48.90 | 30.68 | 47.65 | 29.88 |
| S | 18.96 | 32.80 | 14.29 | 32.44 | 15.21 | 32.89 | 13.29 | 33.61 |
| Zn | 40.24 | 33.55 | 38.66 | 35.69 | 35.89 | 36.43 | 39.06 | 36.51 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

**Table 3. Details of %Zn content in Cd1-xZnxS thin film, crystallite size, grain size and optical band gap energy**

| Sample No. | Zn Content | Average crystallite from XRD (nm) | Average grain size from FE-SEM (nm) | Optical band gap from UV-VIS (eV) |
|---|---|---|---|---|
| S1 | 0.2 | 26 | 39 | 3.55 |
| S2 | 0.4 | 22 | 36 | 3.61 |
| S3 | 0.6 | 20 | 33 | 3.69 |
| S4 | 0.8 | 17 | 31 | 3.71 |
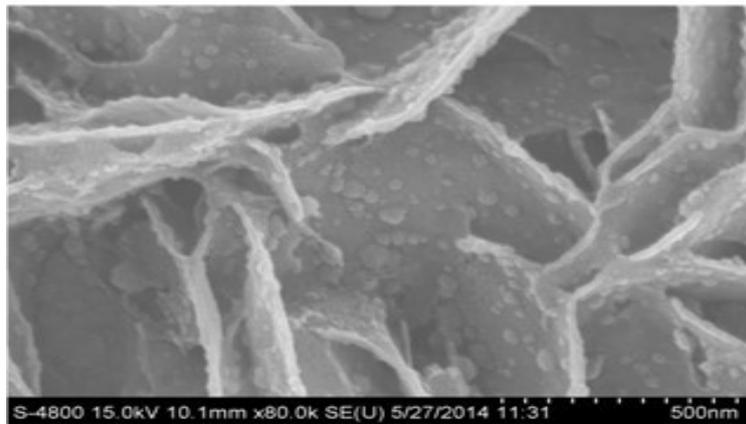


**Figure 5 a. Variation of crystallite size with Zn composition**
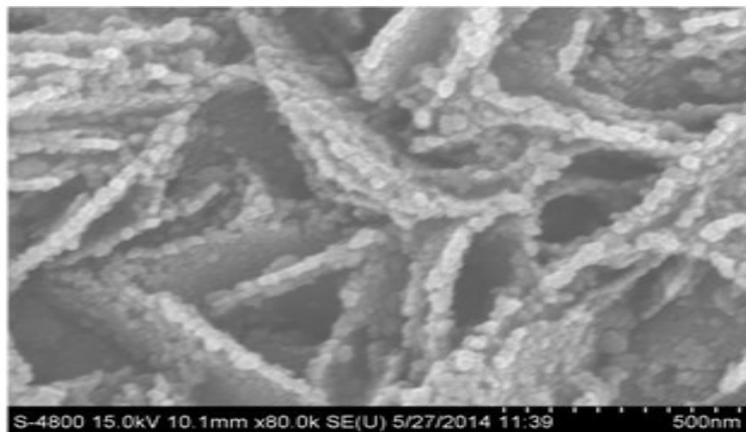


**Figure 5b. Variation of grain size with Zn composition**
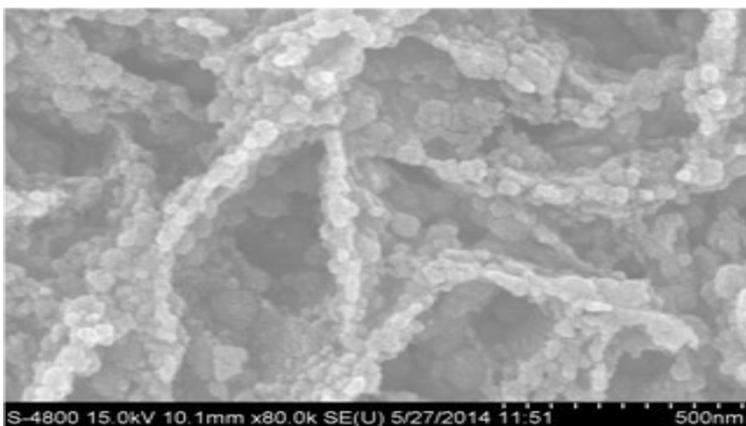


**Figure 5c. Variation of dislocation density with Zn composition**

increase in Zn composition in the thin films and optical band gap energy increases with increase in Zn composition (Celalattinbaybul and Tandesh Chandra, 2008; Sanap and Pawar, 2011; Selma and Jawad, 2012; Mahdi, 2009). This may be due to the enhancement in the crystallinity with increase in Zn which leads to minimum imperfection. A slight increase in the optical band gap energy of the films with increasing Zn% can be attributed to the increase in the crystallite and grain size.

## Conclusion

The following conclusions were derived from the reported work on effect of Zn % on the properties of Cd1-xZnxS thin films obtained by Electrodeposition technique.

1. The crystallite sizes for Cd1-xZnxS films were found to range from 31nm to 39nm.
2. The chosen deposition parameters produced Cd1-xZnxS thin films with varying Zn% with good homogeneity.
3. The peak analysis from the XRD pattern shows formation of Cd1-xZnxS thin films and confirmed by EDS data.
4. The study suggests that the increase in Zn% in the film leads to the increase in crystallite size, grain size and optical band gap energy.
5. Morphological studies on the films confirm the as-prepared Cd1-xZnxS thin films were composed of hierarchical rod like structure. The films also reveal fiber like structure as Zn% increases, which may be useful for gas sensing applications.
6. The elemental analysis confirmed that as prepared Cd1-xZnxS thin films were nonstoichiometric in nature.

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