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Study of structural and electrical properties of Barium and Zinc doped CdS thin film by spray pyrolysis method

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ABSTRACT

Barium and Zinc doped CdS thin films were deposited by simple and easy spray pyrolysis method at 400°C. The crystallographic structure and the crystallite size were studied by the X-ray diffraction (XRD) pattern. Optical band gap were studied by optical absorption spectroscopy and electrical measurements by means of electrical resistivity studied by using two probe methods. On doping of Zinc and Barium, the crystallite sizes were found to increase. The optical energy band gap observed to be from 2.48 to 2.41 eV for as deposited and Zinc, Barium doped CdS thin film. The film exhibits photoconductivity phenomena suggesting its useful for sensors and photovoltaic device and from the electrical conductivity was found to be of n-type conductivity.

Keywords: Barium, Zinc doped CdS films, Spray pyrolysis, resistivity, optical property.

INTRODUCTION

In modern technology, thin films find wide spread applications. Cadmium sulphide (CdS) is an important material which can be used to make n-type material for thin film hetero junction solar cells. Low resistivity CdS films are needed in solar cells to lower the cell series resistance. CdS is technologically interesting because of its energy band gap (2.43 eV) and lattice parameter can be varied by doping [1, 2]. It is well known that electrical and optical properties of semiconducting material depend strongly on external doping and preparation conditions. The addition of group –III elements like Gallium, Copper, and Aluminum [3,4] improve the efficiency of CdS thin film. In the past few years, the deposition and characterization of CdS thin film has been received a considerable amount of interest due to its applications in the electronic and opto-electronic device fabrications [5-8]. Doped CdS films can be deposited by several methods such as Thermal evaporation, chemical bath deposition, chemical vapour deposition, and spray pyrolysis etc [9, 10]. Spray pyrolysis method employ precursor solutions to deposit thin films. It is very easy, simple and cost effective processing method can be applied to prepare thin and thick films, ceramic coatings and powders. CdS thin film prepared by spray pyrolysis was explained by Mooney et al [11]. Spray pyrolysis does not require high quality substrate or chemicals. Multi-layer, porous and dense films can be easily prepared by this technique. This method consists of an atomizer, precursor solutions, substrate heater and temperature controller unit.

In the present case, preparation, characterization and measurement of optical and electrical properties of Zinc and Barium doped CdS thin films are communicated.

MATERIALS AND METHODS

The CdS thin film was prepared by taking the 0.1 M aqueous solutions of $CdCl_2$ and Thiourea with 1:1 Molar Proportion. The CdS & Zinc, Barium doped Thin films prepared by spraying aqueous solution of Cadmium Chloride (CdCl2) & Thiourea [(NH2)2CS], ZnO & BaCl2 in appropriate proportion on glass substrate kept at 400 ^{0}C . Zinc & Barium doped CdS films were deposited by adding ZnO & BaCl2 as a dopent source to the solution of atomic percentage 10 % each. All the thin films are of the thickness 500 nm & also show good reproducibility. When the solution is spread on the substrate the following reaction takes place,

$$CdCl_2 + (NH_2)_2\,CS + 2H_2O \rightarrow CdS + 2NH_4Cl + CO_2$$

X-ray diffraction has been used to study the structure of thin films. The resistivity was measured by LCR meter and Oven in the temperature ranges 300- 420 K. Optical band gap were studied by optical absorption spectroscopy.

RESULTS AND DISCUSSION

Characterization

A typical XRD pattern for Zinc doped CdS thin film on glass substrate is presented in Figure 1. From these patterns, it is found that all the films are polycrystalline & hexagonal. The average crystalline size is calculated by using the formula [12].

$$D = 0.9\lambda\ /\ \Delta COS\ \theta \qquad (1)$$

Where, θ = is angle of diffraction, λ= wavelength of XRD & Δ = measured in radian as a full width at half maximum of the diffraction line. It is nearly 0.05 ^{o}. The values are present in Table 1. The grain size of CdS thin films is found to be around 37.82 nm. By doping Zinc & Barium grain size becomes larger. The grain size is found to be comparable as represented earlier [13].

DC Resistivity

The electrical resistivity of all the samples was measured by two probe method. The resistivity was also measured at room temperature for all three thin films. The variation of resistivity with temperature is presented in Figure 2. From the graph it found that resistivity decreases with increase in temperature, it indicates that semiconductor behavior of the film [15].

From the slope, the activation energy of the films has been calculated and is presented in Table 1. These values are also found to be comparable with the values reported earlier [14]. The order of resistivity in the present work is suitable for solar cells [15].

Optical Studies

The variation of optical transmittance as a function of wavelength of the thin film under investigation is presented in Figure 3**.** From the graph it is observed that transmittance decreases with zinc and barium substitution it may be due increase in resistivity. The semiconductor band gap was determined by analyzing the optical data with the expression for the optical absorbance `α` and photon energy [16] by using the relation,

$$\alpha = k\,(h\nu - Eg)^{n/2} / h\nu$$

Where, k is a constant and `n` is constant which is equal to one for a direct gap material and four for an indirect gap material. The plot of absorption coefficient $(\alpha h\nu)^2$ vs photon energy (hν) is presented in Figure 4. The extrapolation of the linear portion of the plot to the energy are yielded the direct band gap values presented in table 1. These values are in good agreement with the reported values by others [15, 17, 18].

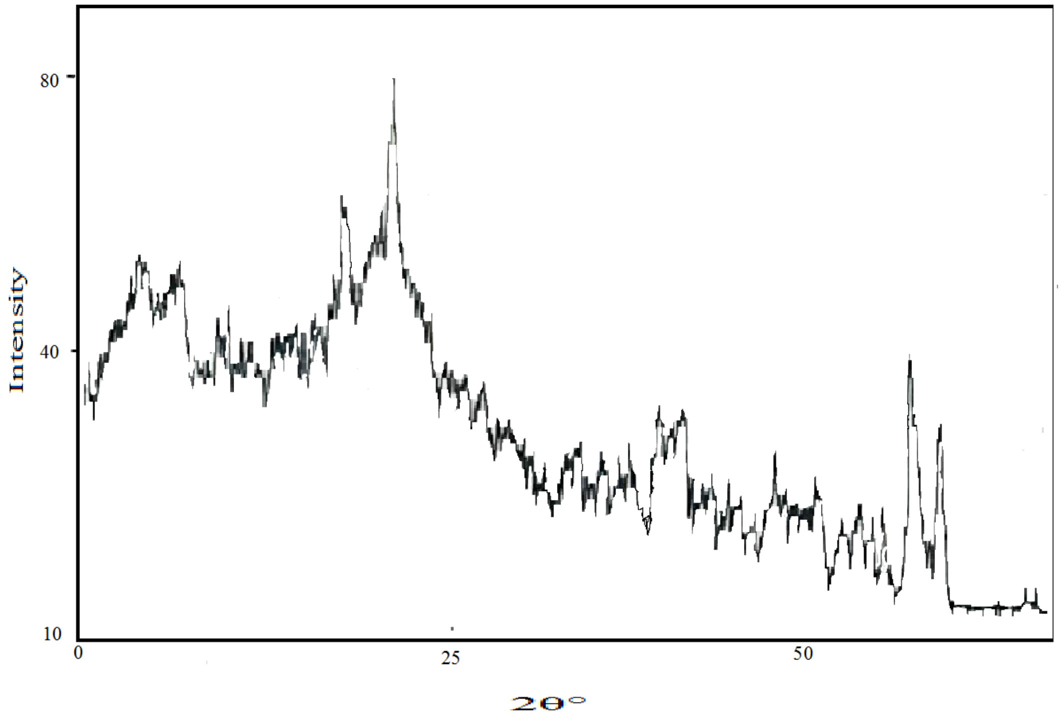

Figure 1. X-ray diffraction Spectrum of Zinc doped CdS thin film

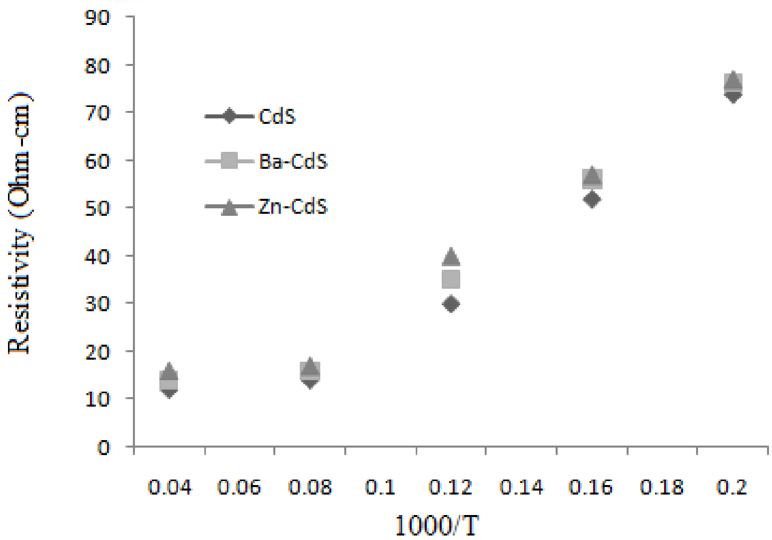

Figure 2. The variation of resistivity with temperature of CdS and doped CdS thin films

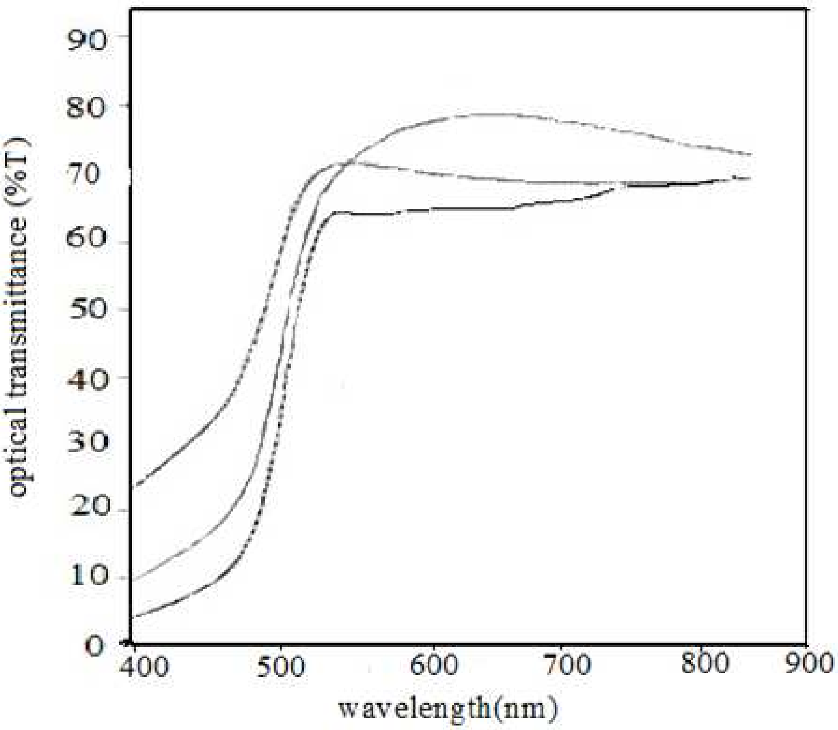

Figure 3 The variation of optical transmittance (%T) as a function of wavelength.

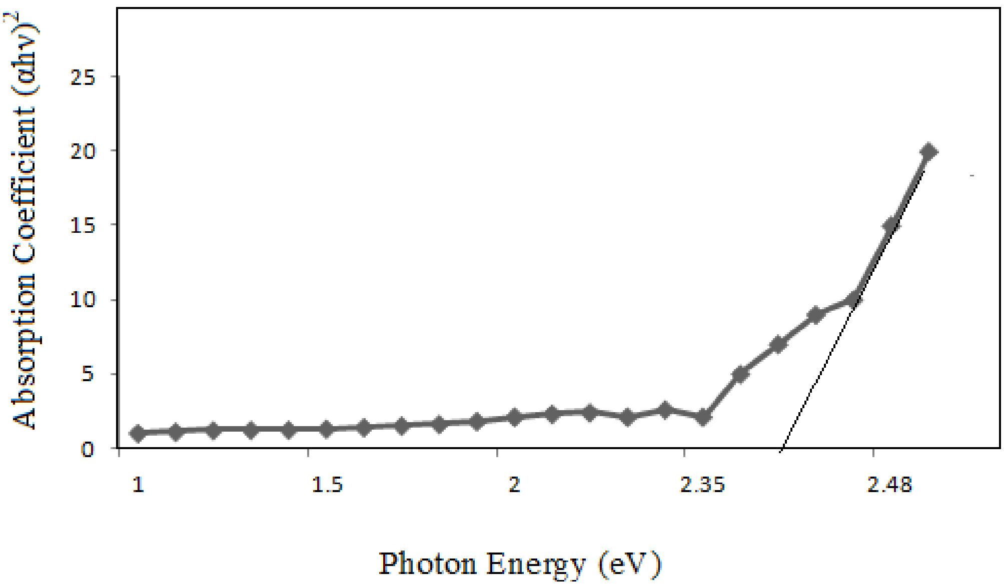

Figure 4 The plot of Absorption coefficient $(\alpha h\nu)^2$ vs Photon energy hν

Table 1. Crystallographic, Optical, and electrical parameters of the thin films

Thin Film	Grain Size (nm)	Activation Energy (eV)	Room Temp. Resistivity (Ω cm)	Energy Band Gap (eV)
CdS	35.39	0.47	2×10^5	2.41
Zn- doped CdS	39.41	0.58	7×10^6	2.48
Ba- doped CdS	38.68	0.52	5×10^5	2.44

CONCLUSION

From the obtained data we can draw following observations,

- XRD shows that formation of polycrystalline and hexagonal CdS and doped CdS thin films with average grain size 37.82 nm.
- The structural and electrical properties of CdS are found to be doping depended.
- CdS thin films are good response to the light and hence they can be employed in photo sensor applications.
- The electrical resistivity at room temperature is found to be of the order of 10^5**Ω** cm and vary with doping element.
- The films exhibited direct transition energy in range of 2.41 to 2.48 eV.
- These results suggest that the method of spray pyrolysis for the deposition of CdS thin films may be further investigated for applications of solar cells.

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