Optical band gap tuning in $Cd_{1-x}Zn_xS$ thin films grown by chemical bath deposition

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***Abstract*— Cadmium Zinc Sulphide, being direct band gap semiconductor material, has gained significant interest in the photovoltaic energy industry because of their use as buffer layer in thin film solar cells. Addition of zinc to cadmium sulphide enhances electrical and optical properties of optoelectronic devices such as thin film solar cells. Here, we report deposition of cadmium zinc sulphide thin-films grown on commercial glass substrate by Chemical Bath Deposition method (CBD). Cadmium sulphate, zinc sulphate and thiourea were used as precursors. Structural and optical properties were investigated by Raman spectroscopy and UV-Visible spectra respectively.**

***Index Terms*— Chemical bath deposition, Raman Spectroscopy, Optical band gap**

I. INTRODUCTION

Along with consistently increasing conversion efficiency of thin film solar cells with development of new photovoltaic materials, it is also desirable to lower the production cost. A buffer layer of cadmium sulphide (CdS) has been found to be advantageous for enhancing efficiency of thin film solar-cells. Because of its lower band-gap, the CdS layer has to be very thin and uniform which requires great control over the deposition parameters and is difficult to achieve. By adding zinc in CdS, we can increase the band-gap of the film which allows the deposition of relatively thicker and consequently uniform film for the thin film solar-cell [1]. A variety of deposition techniques had been employed for deposition of CdZnS thin films like vacuum evaporation [2], spray pyrolysis [3] and chemical bath deposition (CBD) [4].

In present study, $Cd_{1-x}Zn_xS$ thin films are grown by CBD technique which does not require sophisticated instruments like vacuum system. Good quality thin films were obtained using simple instruments and low temperature in the CBD method. The present manuscript demonstrates that increasing Zn content in the CdS films, tuning of the structural properties and optical band gap have been achieved.

II. EXPERMENTAL

Cadmium zinc sulphide ($Cd_{1-x}Zn_xS$, x=0, 0.2, 0.4, 0.6, 0.8, 1.0) thin films were grown on soda-lime glass slides by the CBD method. The glass substrates were cleaned by Methanol, Acetone, Trichloroethylene and distilled water prior to deposition. The chemical bath contained cadmium sulphide as cadmium source, zinc sulphate as zinc source, Thiourea as sulphur source and Ammonia as complexing agent. Six samples were prepared by varying quantity of cadmium sulphate and zinc sulphate in the chemical bath. Sample codes for thin film prepared with precursor combination of zinc and cadmium ions in bath are shown in Table 1.

TABLE 1: Thin films deposited with various precursor concentration combinations in the chemical bath for 30 minute.

Sample code	Cadmium sulphate (ml)	Zinc sulphate (ml)
S1	10.0	-
S2	7.2	1.8
S3	5.4	3.6
S4	3.6	5.4
S5	1.8	7.2
S6	-	10.0

The glass substrate was inserted perpendicularly in bath for deposition of thin film. The Chemical bath temperature was maintained at temperature of 90 °C < T < 95 °C for 30 minute. After deposition, films were taken out of bath and rinsed with distilled water to remove loosely bound atoms on the film. The films were dried in air and characterized using Raman spectroscopy (JOBIN YVON HR800 spectrometer) and UV-visible spectroscopy (Perkin Elmer made LAMBDA 19) to study its structural and optical properties. Raman scattering measurements have been performed in the back scattering configuration.

III. RESULTS AND DISCUSSION

Cadmium zinc sulphide ($Cd_{1-x}Zn_xS$, x=0, 0.2, 0.4, 0.6, 0.8, 1.0) thin films were excited by wavelength of 514.5 nm for the measurement of Raman shift. Figure 1 shows the Raman spectra of $Cd_{1-x}Zn_xS$ thin films. CdS and ZnS exhibit a peak at 305 cm^{-1} and 1097 cm^{-1} respectively in the Raman spectrum [5, 6]. The sample S1 depict strong peak at 305 cm^{-1} corresponding to the first order scattering of longitudinal optical (LO) phonon mode of CdS. For sample S2 a strong peak at 307 cm^{-1} with broad peak at 1097 cm^{-1} is also observed, indicating the presence of ZnS in the film. As amount of zinc ions increases in the bath, the intensity of peak at 305 cm^{-1} reduces and at 1097 cm^{-1} increases. With increase of zinc content in CdS, the peak width becomes wider, which is related to their poor crystallinity, shape variation and even increase in compositional and structural disorder. Intense peak

at 1097 cm^{-1} observed in S6 film signifies the presence of longitudinal optical mode of zinc sulphide.

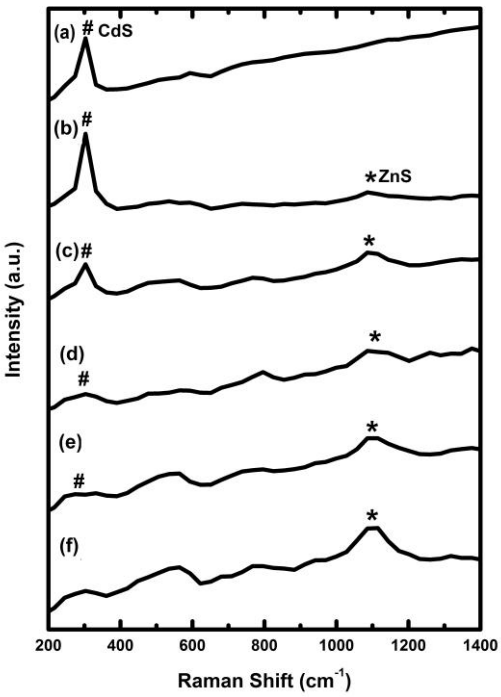

FIGURE 1. Optical Raman spectra of sample (a) S1 (b) S2, (c) S3, (d) S4, (e) S5 and (f) S6.

The optical band gap of $Cd_{1-x}Zn_xS$ thin films were calculated using Tauc plot by measuring the absorption spectra of the thin film in the wavelength range of 300-900 nm. Figure 2 shows the optical band gap variation with respect to change in the concentration of Cd and Zn ions in the $Cd_{1-x}Zn_xS$ thin films.

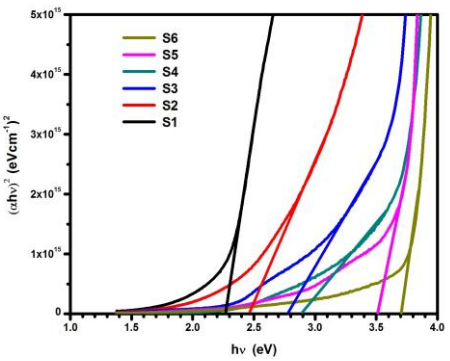

FIGURE 2. The Tauc plots for thin film (a) S1, (b) S2, (c) S3, (d) S4, (e) S5 and (f) S6.

For the thin film prepared with only cadmium ions in the CBD CdS thin film (sample S1) the optical band gap value evaluated is 2.27 eV [3]. Similarly, for only zinc ions in the CBD (sample S6) the Optical band gap of ZnS is 3.71 eV [3]. Optical band gap values for $Cd_{1-x}Zn_xS$ thin films are shown in Tables 2.

TABLE 2: Band gap of thin films obtained from Tauc plot.

Sample Code	Optical Band gap (eV)
S1	2.27
S2	2.47
S3	2.77
S4	2.89
S5	3.51
S6	3.71

The optical band gap energy value is higher for the films grown with higher amount of zinc ions compared to cadmium ions in the chemical bath. The increment of the bandgap with increased concentration of Zn ions in the solution clearly suggests good control of Zn incorporation in the films during the deposition. It is evident that the bandgap of the films can be tuned as per the requirement of the applications.

IV. CONCLUSION

We have prepared $Cd_xZn_{1-x}S$ thin film films using chemical bath deposition method for tuning of the optical energy band gap. We have tuned the optical band gap by varying the amount of cadmium and zinc ions in the chemical bath for the range of 2.27 eV to 3.71 eV. The analyzed Raman and optical results reveals that $Cd_xZn_{1-x}S$ thin films can be used in thin film based solar cells as a buffer layer.

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