Volume 66, Issue 4, 2022

Journal of Scientific Research

of

The Banaras Hindu University

Optoelectronic properties and Effect of annealing on structural of Zn mixed CdS thin film by SILAR method

Naman Shukla*[1], Lokesh Kumar Sahu[2], Vaishali Soni[3], Sweta Minj[4], Harsh Singh[5], Dr. Sanjay Tiwari[6]

*[1] Naman Shukla naman.shukla43@gmail.com
[2] Lokesh Kumar Sahu sahulucky14@gmail.com
[3] Vaishali Soni vaishalisoni2310@gmail.com
[4]Sweta Minj sweta21minj@gmail.com
[5] Harsh Singh imcool.harshsingh@gmail.com
[6] Dr Sanjay Tiwari drsanjaytiwari@gmail.com
[1,2,3,4,5,6] Photonics Research Laboratory, School of Studies in Electronics and Photonics, Pt. Ravishankar Shukla University Raipur

Abstract: **In this research, the zinc mixed cadmium sulfide thin films were synthesized on the glass substrate by simple and easy successive ionic layer adsorption and reaction (SILAR) process. The thin films were prepared by different mixing percentage of Zinc with cadmium sulfide. The Zn-CdS films have been characterized by X-Ray diffraction (XRD), field-emission scanning electron microscopy (FESEM) and optical properties were investigated by ultraviolet-visible spectrophotometer. X-Ray studies show the hexagonal crystal structure of CdS film. The surface morphology is found different in both annealed and unannealed structure from FESEM image. It is smooth, dense and uniform in structure in case of unannealed condition. And it is non-uniform structure when annealed. The absorbance spectra of pure CdS and Zn mixed CdS has compared and it is observed that Zn-mixed CdS have greater absorbance than pure CdS.**

Index Terms: **SILAR, Thin film, Surface morphology, annealing.**

I. INTRODUCTION

Over the past few years, the installation and disassembly of cadmium sulfide semiconducting films has yielded significant results due to their potential use in the field of electronics and optoelectronic manufacturing. Cadmium sulfide (CdS) is a semiconductor with good absorption properties in a wide range of visible light. For this reason, cadmium sulfide has been used in many photonic devices such as photovoltaic, photo detectors, laser and light emitting diodes. Therefore, Cadmium sulfide is modified to suit the application [1].

Polycrystalline CdS thin films with good visual transmission, wide band-gap (2.43 eV) and electrical structures make it one of the most suitable for their use in solar cell fabrication [2]. There are a variety of strategies available fabrication of CdS film such as chemical bath deposition (CBD), spray pyrolysis, pulsed laser deposition, but more recently, the installation of CdS thin films has been done in the form of new chemicals, successive ionic layer adsorption and reaction(SILAR). SILAR's method of preparing small films is attractive, easy to control growth rate, cost effective, less time consuming compared to other methods [3]. It is based on immersion in the substrate in separately cationic and anionic precursors rinsing between every immersion with ion-exchange moisture to avoid uniform viscosity [4].

In past few years, CdS thin film research has many ways to learn and develop to improve the performance of the thin film. Doping is an exciting way to increase the efficiency of thin cadmium sulfide films. CdS thin films are used as an ETL (electron transport layer) instead of a regular TiO_2 thin film layer in new 3rd generation perovskite solar cells [5]. CdS thin film is one of the potential and frequently used window material and a hole blocking layer in cadmium telluride (CdTe)-based solar cells and perovskite solar cells, respectively [6,7].

It is well-known that many of the toxic effects of cadmium (Cd) action are due to interactions with important substances, including zinc (Zn). Exposure to Cd leads to Zn environmental degradation on the one hand, while on the other hand Zn has a significant effect on Cd absorption, accumulation and toxicity [8]. In this research, we studied the optical properties and morphology of Zn-mixed CdS thin films. Here, cadmium sulfide is used as a precursor which is mixed with zinc and then deposited on glass substrates using SILAR method. The preparation of the Zn-mixed CdS sensitized thin films were optimized by mixing percentage of zinc with cadmium sulfide precursors [9-11].

II. MATERIALS AND METHODS

We have prepared the thin film using successive ion layer adsorption and reaction (SILAR) method. The cationic solution was prepared by taking 0.1M of cadmium nitrate tetra hydrate ($CdH_8N_2O_{10}$) in a beaker containing ethanol and DI water in 1:1 ratio. The anionic solution was prepared by taking 0.1M of sodium sulfide (Na_2S) and mixing it in a beaker containing methanol and DI water in 1:1 ratio. 0.01M of zinc (Zn) was then mixed in the anionic solution to study the effect in properties of cadmium sulfide (CdS). Both the solutions were stirred on the magnetic stirrer for 24 hr. Pure ethanol & methanol were taken separately in two beakers.

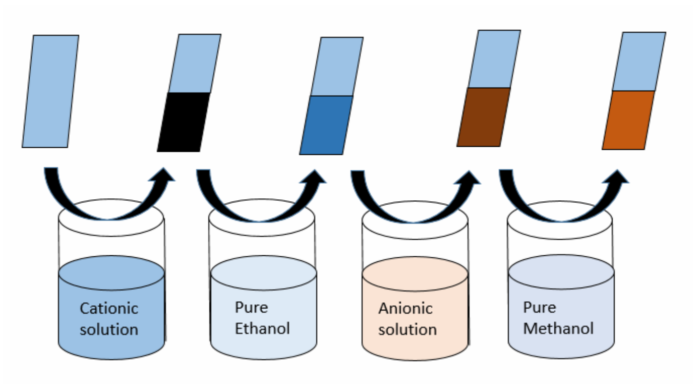

Figure 1- SILAR technique for CdS thin film

The glass substrate was first dipped in the beaker containing the cationic solution for 30 sec and was allowed to dry for 30 sec and then it was rinsed in beaker containing pure ethanol for 30 sec and was left to dry for 30 sec. The substrate was again dipped in the anionic solution for 30 sec and was rinsed in pure methanol for 30 sec. This whole process was continued for another 30 cycles until the thin yellowish color cadmium sulfide was deposited on the glass substrate. Dry duration of 30 sec has taken for the sample. So that it can be mixed with other solutions by the SILAR method before drying. The thin film was dried at room temperature for 1 hr duration.
Thin films were characterized by means of XR) to investigate crystalline phases of deposited thin film. The surface morphology was studied by SEM instrument. UV-Vis spectrophotometer in the range from 350-800 nm was used to measure its optical properties [12-15].

III. RESULTS AND DISCUSSION

The morphology and elemental analysis of thin films were investigated by field- emission scanning electron microscopy (FESEM).

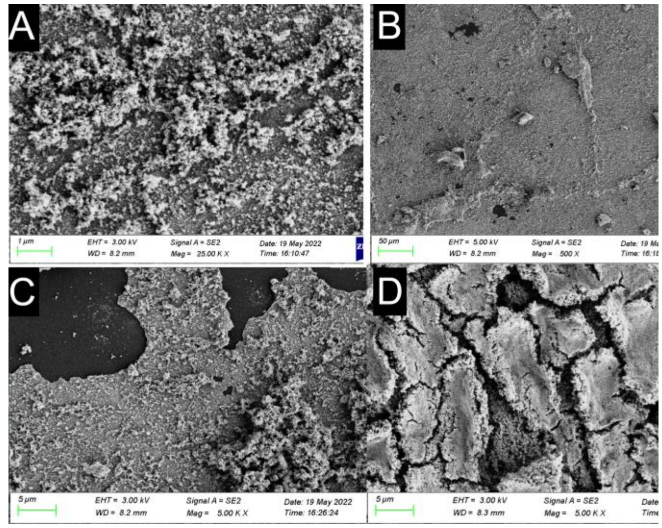

Figure 2. FESEM images of annealed Zn-CdS thin film

Figure 2 (A) FESEM image of the Zn-CdS thin film, has shown that the non-uniform distribution of the cadmium (Cd), sulfur (S) and zinc (Zn) elements in the Zn-CdS film, figure 2(B) Zn-CdS thin film image at 50 um distance, figure 2(C) represent Zn-CdS thin film image at 5 um distance. In this figure, black part shows that the glass slide, the film is removed from this region because of annealing, the cracks seen in Figure 2(D) are also due to annealing and excess thickness. Thin films were annealed at 200 °C in muffle furnace for 30 minutes.

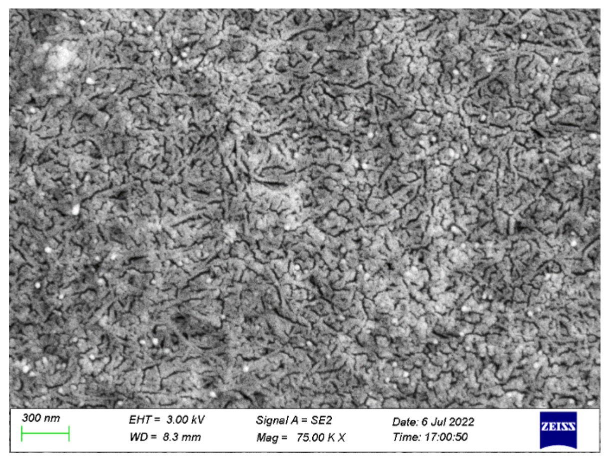

Figure 3- FESEM image of Zn-CdS thin film without annealing

Figure 3 is the FESEM image of Zn mixed CdS thin film without annealing, showed that uniform distribution of the cadmium (Cd), sulfur (S) and zinc (Zn) elements in the Zn-CdS film.

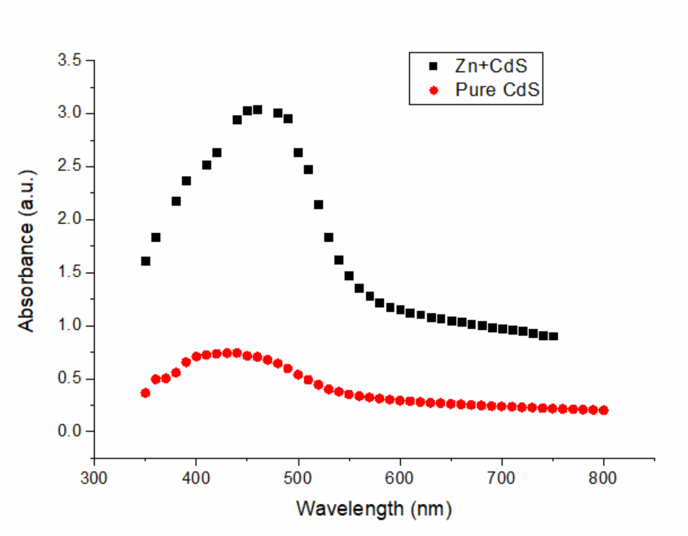

Figure.5 - Absorbance spectra of pure CdS and Zn-CdS thin film

The absorbance spectra of Zn-doped CdS thin films were measured at room temperature by ultraviolet-visible spectrophotometry (UV-Vis) as shown in figure 4. Clearly seen in this figure, increases the absorbance when Zn mixed with CdS.

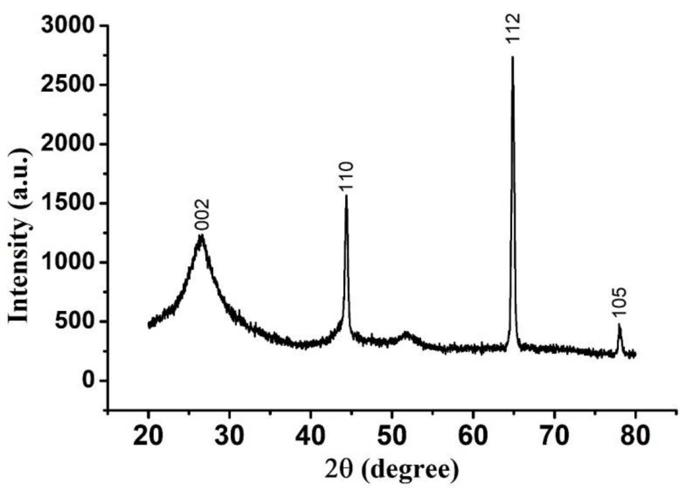

Figure.6 - XRD pattern of Zn mixed CdS thin film

Figure 5 shows the XRD pattern of deposited film. The XRD pattern of Zn mixed CdS deposited the thin film is of amorphous nature and consists of multiple grains. Zn mixed CdS film shows the well resolved peaks justifying improvement in crystallinity. Zn mixed CdS structure exhibiting lattice planes (002), (001), (112) and (105) confirmed to standard data. The Zn mixed CdS film deposition by SILAR method confirmed the hexagonal crystal structure.

IV. Conclusion

The zinc mixed cadmium sulfide thin films were produced on glass substrates using successive ionic layer adsorption and reaction (SILAR) method. The thin films were prepared by different mixing percentage of zinc with cadmium sulfide precursors. The optical properties were investigated by UV-Vis spectrophotometer shown that Zn-mixed CdS thin films were found to have the higher absorbance with compare to pure CdS. The morphology and elemental analysis were measured by field-emission scanning electron microscopy and X-Ray diffraction.

Acknowledgment

The authors gratefully acknowledge Photonics Research Laboratory, School of Studies in Electronics and Photonics, Pt. Ravishankar Shukla University Raipur, Chhattisgarh and Central Instrumentation Facility, Indian Institute of Technology, Bhilai, Chhattisgarh for provided the fabrication and characterization facility.

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