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Electrochemical growth and characterization of iron doped cadmium sulfide thin films

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ABSTRACT

Cadmium Sulfide and Ferrous doped Cadmium Sulfide thin films have been prepared on different substrates using an electrodeposition technique. Linear sweep voltammetric analysis has been carried out to determine deposition potential of the prepared films. X-ray diffraction analysis showed that the prepared films possess polycrystalline nature with hexagonal structure. Surface morphology and film composition have been analyzed using Scanning electron microscopy and Energy dispersive analysis by X-rays. Optical absorption analysis showed that the prepared films are found to exhibit Band gap value in the range between 2.3, 2.8 eV for Cadmium Sulfide and Ferrous doped Cadmium Sulfide.

1. Introduction

Recently, II–VI group binary semiconductors have received much attention due to its wide range of applications in fabrication of so many solid state devices such as solar cells, opto-electronic devices and solar selective coatings [1–3]. Among them, CdS is found to be an excellent material with a band gap value around 2.5 eV which make them interesting for the fabrication of photoelectrochemical solar cells, because of its compatiblility of band gap with solar spectrum. CdS thin films are normally crystallized in hexagonal (wurtzite) structure (JCPDS ICDD 2003, File no.41-1049) with lattice constants (a=4.140 Å; c=6.719 Å) and in cubic (zinc blende) structure (JCPDS ICDD 2003, File no.89-0440) with lattice constant (a=5.830 Å). A number of techniques that have been reported to prepare CdS thin films such as thermal evaporation [1], electron beam evaporation [4], vacuum evaporation [5], RF sputtering [6], pulsed laser deposition [7], chemical bath deposition [8] etc. To our knowledge so many researchers have been focused the preparation and characterization of CdS thin films and fabrication of devices with better efficiency. In numerous semiconducting devices, low resistance, metal based, ohmic resistance requires the establishment of heavily doped region directly beneath the launches of metal contact. But, the doped surface layer is sufficiently heavy, the flow of current across the interface keeps principally tunneling through at fermi level. The resistivity of polycrystalline material mainly depends upon the surface scattering or grain boundary scattering effects [9,10]. Fabrication of electrodes for photoelectrochemical process has been observed to be electrochemical corrosion [9,11]. In order to obtain CdS thin films with low resistance metal contact, it is essential to dope the material with suitable donor impurity concentration,

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which can be mainly reduce the resistivity of the fabricated photoelectrode [9–11]. In recent times, large amount of attention has been given to tailor the optical and electrical properties of materials to add suitable materials as a dopant (metals or transition metals) such as In, Cu, Al, Co, Mn, Ni [12–17].

Shadia and his coworkers have been investigated the current voltage characteristics of spray deposited CdS:In thin films [13]. Photovoltaic solar cells are fabricated using vacuum deposited CdS and Copper doped Cadmium Sulfide thin films (CdS:Cu) and its solar cell parameters such as open circuit voltage, short circuit current, fill factor and efficiency are determined by Yasube Kashiwaba et al. [15]. Muthusamy et al. [14] have prepared Aluminum doped Cadmium Sulfide (CdS:Al) thin films and investigated its compositional dependent, structural, morphological and optical properties of the deposited films. Photoconductivity analysis on Cobalt doped CdS (CdS:Co) thin films have been investigated by Nitu Badera et al. [16]. Aksu et al. [17] have prepared Mn doped CdS (CdS: Mn) thin films using vacuum evaporation method and investigated its structural, optical and magnetic properties. Chandramohan and his research group have been investigated ion implantation effect on Ni doped CdS (CdS:Ni) thin films and studied its structural, morphological and optical properties [18]. The process of doping different materials which causes the broadening of intra gap impurity bands and the formation of band tails and band gap renormalization [9,19]. The presence of dopant with CdS causes considerable effect in number of host lattices [9,10]. The process of doping transition metals with CdS which has been found numerous applications in the region of visible. Measurement of magnetic properties at room temperature for Fe doped nanocrystals (CdS:Fe) was analyzed by Murali et al. [20]. Quenching effect of photoconductivity on Fe doped CdS (CdS:Fe) thin films prepared using spray pyrolysis was reported by Badera et al. [21]. To the best of our knowledge, no such report that have been focused the electrochemical growth of Fe doped CdS thin films (CdS: Fe) using a cost effective electrodeposition technique. When compared to the deposition techniques mentioned above for the preparation of CdS:Fe thin films, electrodeposition emerges to be attractive due to its simplicity, low temperature processing, low cost of synthesize, control of film thickness and surface morphology by readily adjusting the deposition parameters as well as composition of the electrolytic bath etc., mainly it is an eco-friendly technique [2,21–23]. This one is highlight of the present work, (i.e) CdS:Fe thin films are prepared using electrodeposition technique when compared with films prepared by some other techniques.

In the present work, we have prepared CdS and Iron (Ferrous) doped Cadmium Sulfide (CdS:Fe) thin films on Stainless Steel (SS) and Tin Oxide Coated Conducting glass (SnO_2) substrates using an electrodeposition technique. Growth mechanism has been analyzed using linear sweep voltammetry. X-ray diffraction analysis has been carried out to determine structural properties of the deposited films. The parameters such as crystallite size, strain and dislocation density are determined using observed X-ray diffraction data. Surface morphology and film composition have been analyzed using Scanning electron microscopy and Energy dispersive analysis by X-rays, respectively. Optical absorption analysis has been carried out to find out band gap value of the deposited films. Also, the parameters such as refractive index, extinction coefficient are determined and its dependency with wavelength are analyzed. The experimental observations are discussed in detail.

2. Experimental details

The chemicals used in the present work were of AR grade reagents. Thin films of CdS and CdS:Fe were prepared on SS and SnO_2 substrates from an aqueous electrolytic bath containing 0.25 M $CdSO_4$ and 0.0025 M $Na_2S_2O_3$ and TEA as complexing agent. The pH value was adjusted to 2.0 ± 0.1 by adding an adjustable amount of Sulfuric acid. At higher pH value such as above 4.0 ± 0.1 adherence of deposited film to the substrate was very poor. Consequently, the pH value must be fixed as 2.0 ± 0.1 to obtain films with better quality. Before used for deposition, SS and SnO_2 substrates were well cleaned with ultrasonic waves in a bath of isopropyl alcohol for 10 min and then dipped in acetone followed by water. The SCE was introduced into the solution by luggin capillary arrangement whose tip was placed as close as possible to the working electrode. All the working potential was measured with respect to SCE. The deposition potential of CdS and CdS:Fe systems were measured within the range between 0 and −900 mV versus SCE. The bath temperature was fixed as 80 °C for all the deposited films. The deposition time was found to be vary in the range between 5 and 60 min in order to obtain films with various thickness values.

2.1. Characterization

Linear sweep voltammetric analysis was carried out in a standard three compartment cell consists of Platinum electrode as anode, SS and SnO_2 substrates as cathode and Saturated Calomel Electrode (SCE) as reference electrode with the help of Potentiostat/Galvanostat Unit (SP50 BioLogic, France). Stylus Profilometric analysis was carried out using a Stylus Profilometer (Mitutoyo SJ 301, Japan) to estimate thickness value of the deposited films. An X-ray diffractometer (XPERTPRO PANalytical, Netherlands) with CuKα radiation ($\lambda = 1.540$ Å) was utilized to determine crystalline nature and phases of the deposited films. Surface morphology and film composition of the prepared films were analyzed using an Energy dispersive analysis by X-rays set up attached with Scanning electron microscope (JEOL JSM 840). Optical absorption measurement of the prepared films was analyzed using an UV–vis–NIR (Shimadzu Model 2600) spectrophotometer. The parameters such as bandgap, refractive index, extinction coefficient were calculated and its dependency with wavelength was analyzed.

3. Discussion

3.1. Linear sweep voltammetry

Linear sweep voltammetric analysis has been carried out to determine reduction, oxidation potential of individual elements such as Cd, S and redox potential of CdS,