CHARACTERIZATIONS AND APPLICATIONS OF CDS THIN FILMS

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Abstract

Cadmium sulfide (CdS) thin films are the most commonly used window materials for high efficient chalcopyrite polycrystalline thin-film photovoltaic devices. Chemical bath deposition (CBD) is known to be a simple, low temperature, and inexpensive large-area deposition technique. It has been used in the deposition of CdS semiconductor thin films. The as deposited CdS thin film prepared at $80^0 C$ for 60 min had a cubic phase with homogeneous and small grains. In the **PL** spectrum of the 2900 Å thick **CdS** thin film, the broad red band around 1.7 eV. Different other optical properties are also studied by FTIR analysis.

1. Introduction

Nanocrystals and quantum dots are nanometer-scale particles that are neither small molecules nor bulk solids. Semiconductor nanocrystals, which exhibit properties different from bulk materials, are a new class of material that hold considerable promise for numerous applications in the fields of electronics and photonics. As the diameter of semiconductor crystal approaches its exciton Bohr diameter. the optical properties begin to change and quantum confinement, effects become important. Asa consequence of quantum confinement, the optical absorption onset of small semi- conductor crystals occurs at higher energies (blueshift) versus absorption of bulk materials.

Cadmium sulfide (CdS) has been studied extensively for various applications suchas solar cells [1, 2], photovoltaic devices [3, 4], and photosensors [5] because of its intermediate band gap (2.42 eV), high absorption coefficient, electron affinity, low resistivity and easy of making an Ohmic contact. Although high-quality CdS can be produced by using vapor epitaxial growth techniques [6, 7] or sputtering [8, 9], the fabrication cost increases significantly.

2. Method of Sample Preparation

Chemical bath deposition (CBD) is an alternative approach to synthesize high-quality polycrystalline CdS thin films on large-scale wafers including flexible substrates at a low cost.

Chemical bath deposition (CBD) is a convenient and low cost technique for producing large area thin film semiconducting The basic principles underlying the chemical bath deposition of semiconductor thin films and early research work in this areais reviewed by Chopra et. which has inspired many researchers to initiate work in this area. Consider CdS thin film formation. The basic mechanism of CdS thin film formation was supposed to be either

(1) an ion-by-ion condensation of cd2+ and s2- on the substrate from an aqueous basic medium, containing thiourea and cadmium ions in the form of a complex species as indicated in the following equation,
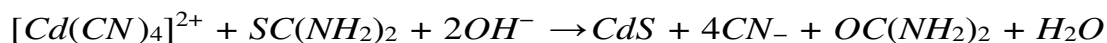
$$Cd(L)^{2+} \rightarrow Cd^{2+} + nL$$
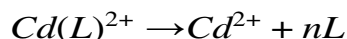
or, (2) the result of the adsorption of colloidal particles of CdS onto the substrate surface. CdS film formation may be achieved using one of the following three complex methods.
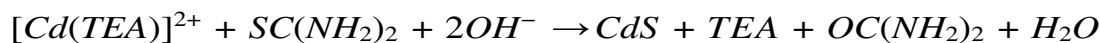
[1] The tetra mine complex method in which the film formation follows the reaction represented below.

$$[Cd(NH_3)_4]^{2+} + SC(NH_2)_2 + 2OH^- \rightarrow CdS + NH_3 + OC(NH_2)_2 + H_2O$$
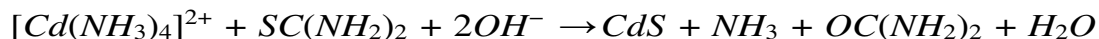
[2] The cyano complex method based on the reaction

$$[Cd(CN)_4]^{2+} + SC(NH_2)_2 + 2OH^- \rightarrow CdS + 4CN_- + OC(NH_2)_2 + H_2O$$

[3] The triethanolarnine complex method (TEA), in which film formation is basedon the reaction,

$$[Cd(TEA)]^{2+} + SC(NH_2)_2 + 2OH^- \rightarrow CdS + TEA + OC(NH_2)_2 + H_2O$$

Due to the fascinating color tunability as a function of the size of semiconductor nanocrystals such as XdSe, CdTe and CdS most studies have been on undoped rather than doped semiconductor nanocrystals. Growth rate dependence on the Cd salt. The latter, ranked the Cd salts based on the least film thickness, obtained from the lowest to the highest, in the following order: CdI_2, $CdSO_4$, $Cd(NO_3)_2$, $Cd(CH_3COO)_2$, $CdCl_2$. Other than film thickness, however, very few details were mentioned in both studies about the effect of Cd source on other film properties.

3. Characterization of CdS Thin films

The films of different thicknesses were deposited on to glass substrate. The deposition parameters such as speed of rotation of substrate, temperature of chemical bath, pH of solution and deposition time were optimized.

Structural Characterization

The structural surface morphology of as-deposited CdS thin films were characterized by XRD, SEM. The material was confirmed as single cubic phase. The average grain size obtained of CdS in the film was 10 nm to 22 nm. The physical conditions were kept identical while growing the samples. The investigation of the effect of the synthesis method on the grain size and the effect of grain size on the properties of semiconductor is under consideration.

The as deposited CdS thin film prepared at 80^0C for 60 min had a cubic phase with homogeneous and small grains.

Optical Properties

In the **PL** spectrum of the 2900 Å thick **CdS** thin film, the broad red band around 1.7 eV and the broad high-energy band around 2.7 eV are attributed to the S vacancy and the band-to-band transition, respectively. As the deposition time increases to over 90 min, the PL intensity from the band-to-band transition significantly increases. The temperature dependence of the PL intensity for the CdS thin films was studied from 16 to 300 K. The EA and EB activation energies are obtained by fitting the temperature dependence of the PL intensity. The EA and EB are caused by the deep trap and shallow surface traps,

respectively. From the FTIR analysis of the CdS thin films, a broad absorption band of the OH stretching vibration in the range $3,000^{-3}, 600cm^{-1}$ and the peak of the CN stretching vibrationat $2,000cm^{-1}$ were found.

Wide-gap chalcopyrite CuInS$_2$ ("CIS")-based thin film solar cells are far behind their low-gap counterparts in terms of photovoltaic performance. To date, most chalcopyrite-based devices include a CdS layer, which is deposited in a chemical bath(CBD). In order to shed light on the effects induced by the interface formation, the buried CdS/CIS interface was investigated by X-ray emission spectroscopy. By com- paring the CdS/CIS interface with a CdS/Si reference heterostructure, we find that the properties of the substrate determine the chemical structure of the heterointer- face. In particular, we find that the formation of the CBD-CdS on Si substrates is delayed compared to that on CIS absorbers.

4. Applications and Disscussion

CdS TFT's prepared by using Chemical Bath deposition method is used to deposit CdS channel layers.

Fabricating CdS TFTs using chemical bath deposition (CBD) to deposit CdS channel layers. Device analysis of an enhancement-mode CdS metal-insulator-semiconductor field effect transistor (MISFET) with a field-effect mobility of ~ 1.5 $cm^2V^{-1}s^{-1}$ and a threshold voltage of $V_T \sim 14V$ is also prepared. A large drain current about $\sim 10^6$ on-to-off ratio is achieved which indicates that this device will function well as a switch. Scanning electron microscopy of the CdS film morphology indicates that the films deposited by CBD are dominated by a particle sticking growth mechanism which is very useful for current device fabrication. Atomic force microscopy characterizations and real-time quartz crystal microbalance growth curve are also supported the particle sticking growth mechanism. Denser CdS films can be obtained by different bath condition. A selected-area electron diffraction pattern indicates that the CdS thin film deposited by CBD has a hexagonal structure with an optical band gap of 2.4 eV as determined by UV-Vis absorption.

The Structure of CdS films were in polycrystalline hexagonal phase as studied by X-Ray diffraction. The films exhibited high optical transmittance T $50-100$ percent and low reflectance in the wavelength (500-900)nm which make them useful as a

transparent window in solar cells. The refractive index constant and extinction constant are also calculated in the same spectrum region. The absorption spectra is of direct band gap type in quantum mechanical sense. The energy band gap for the CdS films was in the range (2.35-2.43) eV. Crystalline structure of the films has been improved by Vacuum annealing at $(200, 300)^o C$.

During chemical bath deposition process if Ultrasonic agitation process has applied produces remarkable changes. Ultrasonic agitation changes surface morphology, deposition time and optical characteristics. Surface roughness calculated by Atomic Force Microscopy was reduced by two factor.

Ultrasonic agitation was applied during the chemical bath deposition of CdS thin films. Ultrasonication resulted in a dramatic difference in surface morphology, growth rate, and optical properties of CdS films. There were virtually no colloidal particles adsorbed on the surface. The surface roughness measured by atomic force microscopy was reduced by a factor of two. Band gap energy increased from 2.37 eV to 2.39 eV. X-ray patterns showed that the preferred orientation changed from hexagonal 002)/cubic (111) to hexagonal (101). Optical transmission curve find in the wavelength range more than 520 nm. The chemical reaction for CdS formation started at a lower temperature under ultrasonication, and thickness of films were increased when the chemical composition of the aqueous solution changed from the optimum conditions.

CdZnS thin films were prepared by chemical bath deposition method in two different ways. First is solution is prepared and kept for deposition at room temperature. The second way is solution is prepared and kept in water bath for a fix duration at constant temperature. The optical and structural properties are different for second way of CBD deposition than that of first way. X-ray diffraction analysis showed that all the peaks from the thin films prepared by second process could be assigned to diffraction lines of wurtzite (CdZn)S. The photoconductivity of the thin films was larger than the dark conductivity in the thin films prepared by second process with $[Zn]/([Cd] + [Zn]) = 0.9$ in the solution.

The nature of the deposition mechanism can be determined by measurement of activation energy of the deposition rate. We found that at low solution temperature, the growth

mechanism proceeds via the ion by ion process, and found the corresponding activation energy equal to 0.06 eV. However, at higher solution temperature, the film deposition became via the cluster by cluster process, the growth rate activation energy is equal to 0.48 eV. Structural and optical properties of the films were studied by x-ray diffraction analysis and UV-vis spectrophotometry. Structural analysis revealed that the deposited films have a cubic structure, and as the deposition temperature increases the crystallite size decreases. The transmission spectra of the film, in the visible range, show a high transmission coefficient (70) percent. Solution temperature affect the optical band gap which is revealed by transmittance data analysis. From this analysis, a direct band gap ranging from 2.21 to 2.34 eV was deduced. From the electrical characterization we inferred that CdS films are n-type and their dark conductivities reduced with increasing bath solution temperature. From the photoconductivity measurements we concluded that films deposited at low temperatures (less than $60^0 C$) or high temperatures (higher than 70^0C) have good optoelectronic properties suitable for utilization as a buffer layer in thin film solar cells.

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