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Morphological and Optical Study of Sol-Gel SpinCoated Nanostructured CdSThin Films

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Abstract: *Nanostructured CdS thin films of different thicknesses were deposited on a cleaned glass substrate using sol-gel spin coating technique. CdS thin films were prepared using cadmium acetate as cadmium source and thiourea as sulfur source. The Morphological, chemical composition, and optical properties of the spin- coated CdS thin film were studied using field emission- scanning electron microscopy (FE-SEM), Energy dispersive X –ray (EDX) spectroscopy, and a UV-Vis-NIR spectrophotometer.The morphological results revealed that the films consist of agglomerated spherical CdS nanoparticles with diameter < 20 nm, which distributed uniformly on the substrate surface.The films show high transmittance > 90% and very strong absorption edge at 295 nm.The absorption edge shifts towards longer wavelength as the film thickness increased.*
Keywords*: CdS film, EDX, FE-SEM, optical properties, and Spin coating*

I. Introduction

Among the II–VI semiconductor compounds, CdS, CdSe, and CdTe are of great interest because they are potential candidates in many practical applications [1-3].CdS is used as a window material for heterojunction realization of p-type CdTe and CuInSe solar cells because it has a relatively wide band gap of 2.42 eV at room temperature.CdS thin films are used as n-type window layer with CdTe to produce 14.6% solar cell [4] and with ZnO and CuInGaSe2 to produce 19.2% solar cell structure [5]. Also, CdS thin film has a broad range of application in important technical fields such as laser materials, photo-sensors, photo-conducting cells, optical waveguides, transducers, light emitting diodes, large screen liquid crystal devices, gas sensors, and field effect transistors [6-11]. CdS thin films have been deposited by various methods, e.g. spray pyrolysis, successive ionic layer adsorption and reaction (SILAR) method, evaporation, sputtering, molecular beam epitaxy (MBE) technique, chemical bath deposition (CBD)photochemical deposition, and sol-gel spin coating method [12- 20]. Among them, spin coating deposition technique is simple, fast, and produce uniform deposition over large areas at relatively lower temperature. It also does not limit the choice of the substrate material [21]. Here, the deposition is carried out based on ammonia-free precursors by employing an inexpensive, simplified sol- gel spin coating technique on glass Substrate. In addition, the optical, morphology, and chemical composition of the nanostructured CdS film are studied.

II. Experimental Details

2.1 Film preparation

The nanostructured CdS thin film was grown onto a cleaned glass substrate using sol-gel spin coating method. a precursor solution of cadmium acetate (CdAc), 2-methoxy ethanol, thiourea, and polyethylene glycol (PEG 200) was used to deposit CdS. 2-Methoxy ethanol and PEG were used as the solvent and the stabilizer, respectively.The glass substrate was degreased with an organic solvent, rinsed with deionized water and dried in air. Two solutions have been prepared. 0.0186M of CdAc was dissolved in 10ml of 2-methoxy ethanol and stirred (solution 1). A volume of 0.4ml Polyethylene glycol was dissolved in 10ml of 2-methoxy ethanol (solution 2). Solution 2 was mixed to solution 1 and stirred again. Then, 1582 x 10^5M of Thiourea was dissolved in 5ml of 2-Methoxy ethanol and added drop wisely to the mixture under stirring which was continued for 1 hour. The sol solution was dropped onto the glass substrate about 5and 10 cycles at speeds of 5000 and 7000 rpm for 1min for each cycle. After deposition, the films were dried in air at 300 °C for 20 min to remove the solvent and residual organics.

2.2. Film Characterization

The surface morphology of the films was characterized by a scanning electron microscope with field emission gun (FE-SEM, model: Quanta 250) and provided with EDX Unit (Energy Dispersive X-ray Analyzes). The optical transmission studies are carried out in the wavelength range of 300–1200 nm, using UV–Vis–NIR double beam spectrophotometer model(LAMBDA – 35).

III. Results and discussion

3.1. Morphological analysis

The morphological properties of the deposited nanostructured CdS film on the glass substrate are studied. Figure 1 shows top view FE-SEM images at two different magnifications These images show a relatively high density of tiny CdS nanoparticles that are agglomerated to form a nanostructured thin film. These nanoparticles are assembled to uniformly covering the overall surface of the substrate with a good adherence. These CdS nanoparticles are spherical in shape with a particle diameter less than 20 nm.

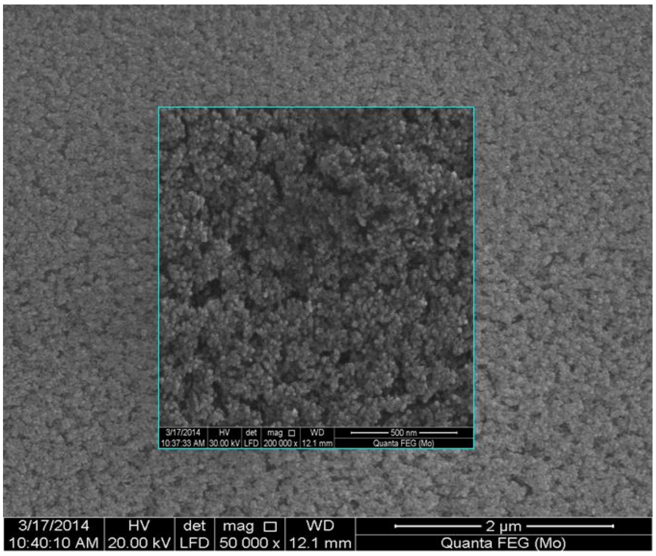

Figure 1. Top view FE-SEM images of the nanostructured CdS thin film deposited onto a glass substrate.

3.2. Chemical Composition

Figure 2 shows the energy dispersive X-ray (EDX) spectrum of the deposited CdS nanostructured film on the glass substrate. This EDX spectrum clearly shows two peaks relevant to Cd at 3.13 and 3.3 keVand a peak relevant to S at 2.307 keV.Because EDX has a large interaction volume (≥ µm in SEM), thus, we detect Si, O, Na, C, and Mg signals from the glass substrate because the thicknesses of the CdS film is less than the interaction volume.The quantitative EDX analysis of the nanostructured CdS film is shown in Table 1. The quantitative analysis of the CdS is 91.8 wt% (66.4 At%) Cd and 8.2 wt% (23.6 At%) S. These ratios indicate Sulphur deficiency in the film. This may be ascribed to the higher sulphur affinity towards oxygen, so it might have converted to SO_2 and then evaporated. Also, this may be a result from the conversion of CdS to CdO during the drying at 300 °C. This may be confirmed by the existence of the strong O signal. However, EDX result reveals that the deposited films are close to the nominal composition of CdS.

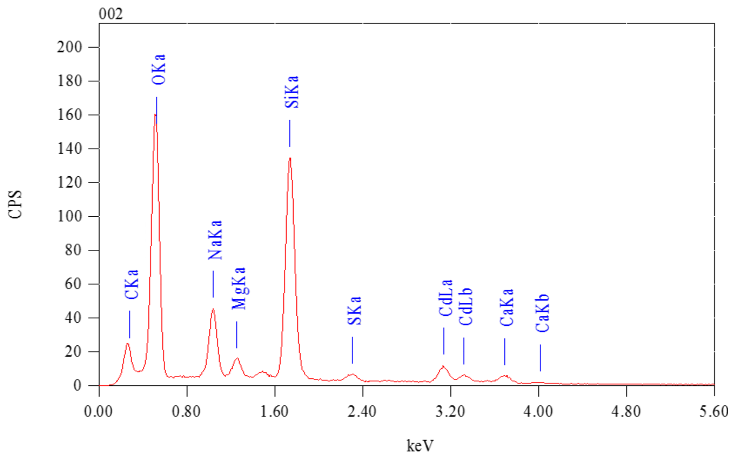

Figure 2. EDX spectra of spin coated nanostcturedCdS thin film.

Table 1. Quantitative analysis of EDX spectrum

Element	(keV)	Mass%	Error%	Mol%
S K	2.307	1.20	1.29	1.75
Mg K	1.253	2.09	0.58	4.04
Ca K	3.690	3.22	2.01	3.77
Na K	1.041	6.94	0.42	7.09
C K	0.277	8.80	0.23	34.40
Cd L	3.132	13.56	2.69	5.66
Si K	1.739	25.89	0.92	43.27
O		38.30		
Total		100.00		100.00

3.3. Optical properties

The optical transmission of the CdS films of different thicknesses were measured in the wavelength range of 300–1200 nm using the UV-Vis -NIR spectrophotometer at room temperature. These films showhightransparency>80% in the visible range for the films of high thickness (10 cycles) which enhanced to 95% for the films of small thickness. For IR range, almost the transmission % is constant and very close to unity. In addition, below 400 nm there is a sharp fall in the T of the films and very strong absorption band centered around 350 nm for all films. The transmission edge of this band is shifted toward longer wavelengths (red shifted) and the bandwidth increased as the film thickness increased, as shown in the inset ofFigure 3.The sharpness of this band confirms the good optical band edge property. The absorption bands of these nanostructured films show strong blue shift (>100 nm) compared to that of the bulk CdS films that previously deposited using ultrasonic spray pyrolysis technique and sol-gel spin coating method[20, 22], in addition, these films show higher transmittance than the previously reported data. This suggests that the fabricated nanostructured films can be used efficiently in different applications including photovoltaic devices.

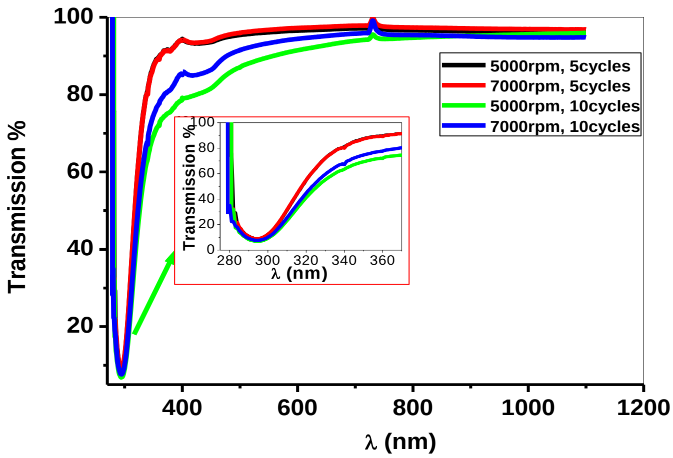

Figure 3. Transmittance spectra ofnanostructuredCdS thin films with different thicknesses.

IV. Conclusions

Cadmium sulphide thin films of different thicknesses were deposited onto glass substrates by the sol-gel spin coating technique. The morphological studies reveal the self-agglomeration of spherical CdS nanoparticles with a diameter less than 20 nm to form nanostructured CdS thin film with high quality. The density of the nanoparticles is very high and uniformly covering the overall glass surface with good adherence.EDS spectrum confirms the presence of 91.8 % Cd and 8.2% S in the prepared sample.The high optical transparency (> 90%) of the deposited spin coated CdS films make them a potential candidate for window material in solar cell applications.

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