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Spin Coating Effect on Structural and Morphological Properties for CdS/Glass Nanostructures

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Keywords: CdS Nanostructures; Spin Coating; Morphology; Analysis Properties.

Abstract. CdS/glass nanostructures are prepared at 400 ^{o}C by sol-gel spin coating method without catalyst. These nanostructures have been characterized by analyzed using X-ray diffraction (XRD) and atomic force microscopy (AFM). The grin size, full width half maxima, miller indices, strain, dislocation density, lattice constant and interplaner distance. The measured and calculated results showed a good agreement with other experimental and theoretical data.

Introduction

The preparation of nanomaterials is one of the most active fields in material science, CdS nanostructures are one of the most important II-VI group semiconductors, with applications in optoelectronic devices such as tunable light emitting diodes, lasers, solar cells, photocatalysts, and electronic devices [1]. Development of morphology controlled synthesis methodologies is of great interest in materials chemistry [2]. The synthesis of binary metal chalcogenides of group II-VI semiconductors has been the focus of recent scientific research due to their important electronic, optical and catalytic properties resulting from the quantum size effect nonlinear, luminescent properties, quantum size effect and other important physical and chemical properties. Several methods exist for the synthesis of CdS nanostructures such as solvothermal route [3], a novel hydrothermal [4], sonochemical [5], and microwave assisted synthesis [6], microwave irradiation & spattering, chemical bath deposition [7], spray pyrolysis (SP) [8] and sol-gel spin coating [9].
Lahewil et al. [9] have presented the structural and optical investigations of cadmium sulfide nanostructures for optoelectronic applications, where CdS nanostructures were deposited on glass substrates by sol-gel spin coating technique. They have investigated the grain size, dislocaction density, strain, interplanar distance, miller indices, number of crystallites per unit area and lattice constants of CdS nanostructures, and analyzed the thickness and optical properties transmissions, energy band gap, refractive index and optical dielectric constant where proved distinguished results compared with other ones.
In the present work, we have used the spin coating technique to prepare CdS nanostructures. The effect of spin coating speed and annealing temperature on structural and morphological properties of CdS nanostructures deposited on glass substrates was investigated.

Experimental Procedure

All chemicals were used as received from Malaysia Sigma-Aldrich Company and prepared at Institute of Nano Electronic Engineering (INEE), in University Malaysia Perlis (UniMAP). CdS nanostructures are grown by sol-gel spin coating method at room temperature. Polyethylene glycol (PEG200) was prepared by mixing 0.6 ml of PEG200, 8.9 ml of ethanol and 0.5 ml of acetic acid under stirring for one hour. 0.05 mol/L thiourea and 0.1 mol/L cadmium nitrate as a source of S and Cd, respectively and 10 ml ethanol accompanying at 60 ^{o}C. Prepared solution was slowly added to the PEG200 with vigorous stirring for 6 hours until homogeneous solution was obtained. As the reaction was started, the reaction system is gradually changed from transparent to light yellow. The

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prepared solution was stored at room temperature for at least 24 hours. The substrates were cleaned by acetone and rinsing with distilled water. After that the prepared solution was spin coated on glass substrates at spinning coating speed 1000, 3000 5000 rpm for 30sec. The precipitate collected from centrifugation was dried on hot plate at 110 ºC and annealed using Muffle Furnace at 400 ^{o}C.

Results and Discussion
X-ray diffraction XRD

The XRD of CdS nanostructures deposited on glass substrates grown by sol-gel spin coating technique is shown in Fig. 1, the crystalline structure of CdS nanostructures is found to have hexagonal structure. It is observed from at spin coating speeds 1000 rpm the peak at $2\theta = 29.63^{o}$ correspond to the (321) plane, at spin coating speeds 3000 rpm shows the peak at $2\theta = 26.28^{o}$ correspond to (310) plane and at spin coating speeds 5000 rpm shows the peak at $2\ \theta = 29.56$ correspond to the (210) plane due to annealing temperature and different spin coating speeds. Measurement condition voltage = 35.0 (kV), current = 25.0 (mA) slits, Divergence slit = 1.00000 (deg), Scatter slit = 1.00000 (deg), Receiving slit = 0.30000 (mm) and scan range = 10.000-79.990, Scan speed = 5.0000 (deg/min), Sampling pitch = 0.0300 (deg), Preset time = 0.36 (sec) [20]. The measured structural properties of CdS nanostructures are listed in Table 1. The crystallites sizes (D) of the films are estimated using the Scherer formula:

$$D = K\lambda / \beta \cos\theta \quad (1)$$

where K is a constant taken to be 0.94, λ is the wavelength of X-ray used ($\lambda = 1.54$ Å), β is the full width at half maximum of XRD pattern, and θ is Bragg's angle, around 26.28^{o}. The crystallites sizes are found to be within the range 2.77-3.78 nm prepared on glass substrates and spin coating speed 1000, 3000 and 5000 rpm. But as the spin coating speed increases, the crystallites size increases. Also, the dislocation density (δ), defined as the length of dislocation lines per unit volume, has been estimated using [9];

$$\delta = 1 / D^{2} \quad (2)$$

The strain (ε) of CdS nanostructures was determined using [9];

$$\varepsilon = \beta \cos\theta / 4 \quad (3)$$

These parameters are given in Table 1, the small values of δ obtained in the current work confirm the good crystallinity of CdS nanostructures. The interplanar distance (d) is obtained for all sets using Bragg's formula [9];

$$d = h\lambda / 2 \sin\theta \quad (4)$$

where h is a constant equals to 1. The lattice constants (a) and (c) were deduced via [9];

$$a = \sqrt{\frac{1}{3}}\ \lambda / \sin\theta \quad (5)$$

$$c = \lambda / \sin\theta \quad (6)$$

Table 1, Measured structural properties of CdS nanostructures using XRD for different spin coating speeds correspond to experimental value.

Spin coating Speed (rpm)/(sec)	Peak 2θ	FWHM	Grain Size (nm)	Dislocaction density (δ) (10^{14} lines/m^2)	Strain (10^{-3})	Interplanar distance (d) (Å)	Miller indices (khl)	Lattice constants a and c (Å)	Thickness t (nm)
1000/30	29.63	0.82	2.77	0.1303	0.130	1.557	321	a=1.038 4.015[a] 2.35[b] c=3.12 6.545a 7.04[b]	80
3000/30	26.28	21.58	1.168	216.7498	5.3280	1.7794	310	a=1.186 c=3.558	60
5000/30	29.56	0.48	3.78	0.0699	0.0956	1.5608	210	a=1.040 c=3.121	40

Ramaiah et al. [a]Ref. [7] Exp.; Lahewil et al. [b]Ref.; [9] Exp.

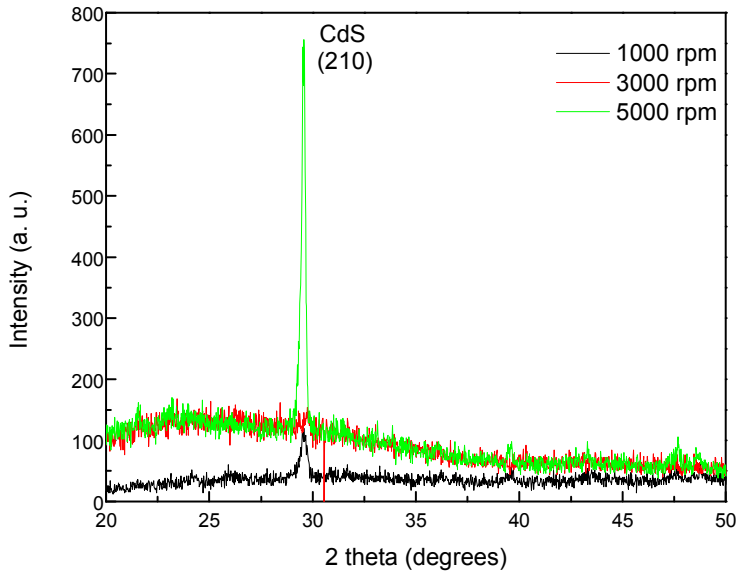

Fig. 1, X-ray diffraction XRD for cadmium sulfide (CdS) Nanostructures deposited on glass substrates at 1000, 3000 and 5000 rpm spin coating speeds.

Atomic Force Microscopy (AFM)

Figure 2, shows the atomic force microscopy (AFM) images of CdS nanostructures at various spin coating speeds. The images show the two and three dimensional to characterize the surface topography of CdS nanostructures. The thickness was measured using AFM and observed that the thickness values of CdS nanostructures deposited at 1000, 3000 and 5000 rpm are found to be 80, 40 and 20 nm, respectively, indicating that the thickness decreases as the spin coating speed increases [10].

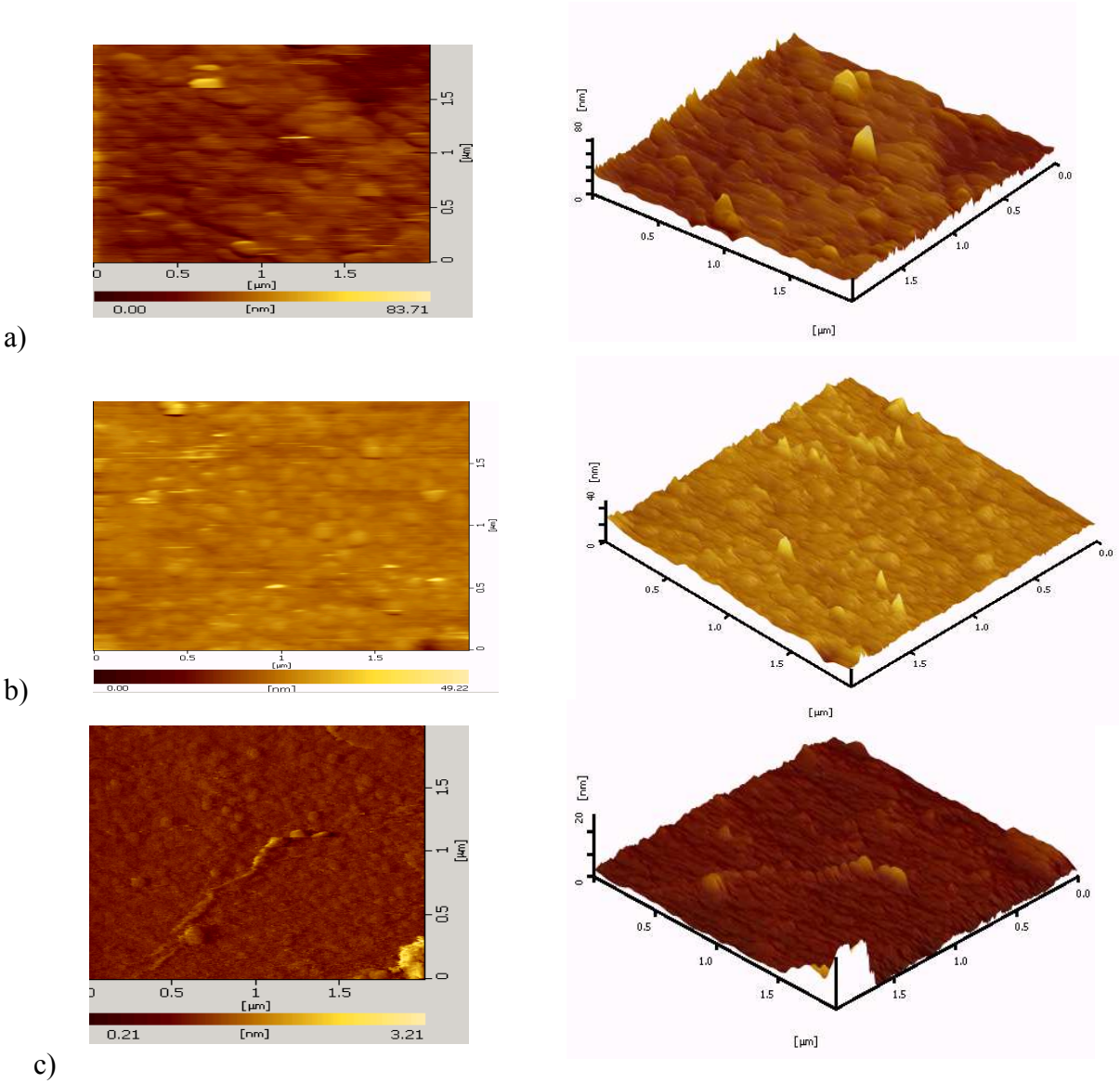

Fig. 2, Atomic Force Microscopy (AFM) for Cadmium Sulfide (CdS) Nanostructures Deposited on Glass Substrates at 1000, 3000 and 5000 rpm Spin Coating Speeds.

Conclusion

Cadmium sulfide (CdS) nanostructures have been prepared by sol-gel spin coating technique deposited onto glass substrates at different spin coating speeds, at temperature of 400 ^{o}C and different thicknesses as obtained from AFM. We determined that all samples surfaces are relatively smooth and uniform, having well defined nanosized grains with relatively small roughness values. Nanostructures of different order diameters, lengths and morphologies changes by assisting of the surfactant PEG200 with high uniformity and high yield. X-ray diffraction studies indicated that the structure is polycrystalline with the crystallite size of 1.16 to 3.78 nm. In addition, the characterizations and analysis studies recommended CdS nanostructures for photovoltaic and optoelectronic application.

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