Analysis and Structural Investigations of CdS/Quartz Nanostructures

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Abstract. CdS nanostructures deposited on quartz substrates with spin coating speeds 1000, 3000 and 5000 rpm and annealed at 800 °C are prepared by sol-gel spin coating technique. Ratio of cadmium to thiourea molar is 0.1:0.05 as an indication of nanostructured CdS formation with a grain size of 3.83 nm CdS nanostructures have been characterized by scanning electron microscopy (SEM) to research the morphology, respectively. Also, they have been analyzed using X-ray diffraction (XRD); the grain size, full width half maxima, miller indices, lattice constant $a$ and $c$. The measured and calculated results showed a good agreement with other experimental and theoretical data.

Introduction

Cadmium sulfide (CdS) is direct band gap material has unique properties of nanomaterial and it is structures have received much attention in recent years due to their potential applications and is of significant interest for both fundamental and applied research, in many fields such as optoelectronics devices, catalysis, single electron transistors, light emitters, photoelectrochemical and nonlinear optical devices [1]. A better understanding of matter at then a no scale has led to a number of advances in materials science having novel optical and electronic properties. The formations of high strength materials have wide scale applications. Semiconductor nanoparticles of II-VI compounds are an example of a low dimensional structure with their unique electronic and optical properties that have been extensively investigated for a wide variety of applications. Dramatic modification of their electronic and optical properties takes place due to the three dimensional quantum confinements of electrons and holes when the size of the particle approaches the Bohr radius of exciton [2,3]. The luminescent CdS nanocrystals have wide potential applications in optical switches, sensors, electroluminescent devices, lasers and biomedical tags [4].

Using polymers is a common method to modify the surface chemistry of the crystals and the concentration of solublespecies for crystal growing. This is due to the fact that the polymer matrices offer advantages like easy processability, solubility and control of the growth and morphology of the nanoparticles thermal stability and hydrolyzation properties, which make it more environmentally friendly and the possibility of obtaining CdS nanocrystals with much smaller diameters [5].

Lahewil et al. [6] have presented the structural and optical investigations of cadmium sulfide nanostructures for optoelectronic applications, where CdS nanostructures were deposited on quartz substrates by sol-gel spin coating technique. They have investigated the grain size, dislocation density, strain, interplanar distance, miller indices, number of crystallites per unit area, lattice constants and bulk modulus 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 speeds and annealing temperature on structural, morphological, thermal and optical properties of CdS nanostructures deposited on quartz 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 technique 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 15 ml ethanol accompanying at 60 °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 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 quartz substrates at spinning coating speeds 1000, 3000 5000 rpm for 30sec. The precipitate collected from centrifugation was dried on hot plate at 110 °C and annealed using Muffle Furnace at 800 °C.

The dried and annealing temperature for CdS nanostructures are used to be characterized and analyzed by X-ray diffraction pattern (XRD) (JEOL-JSM-6460 LA analytical), (Philips PW 1710 X-ray diffractmeter).

Results and Discussion
X-ray diffraction XRD Analysis

The XRD of CdS nanostructures deposited on quartz 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 Fig. 1, that the peaks are found at 2θ = 26.78°, 29.38°, 36.18°, 39.64°, 43.54°, 47.58° and 48.58° correspond to the CdS (202), CdS (203), CdS (006), CdS (106), CdS (311), CdS (313) and CdS (321) planes.

All the miller indeces mentioned peaks are exactly matched with the hexagonal (wurtzite) structure of CdS corresponds to standard (JCPDS Data Card no. 020563) with lattice constants \( a = 4.142 \) Å, \( c = 6.724 \) Å, 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). 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 [6]:

\[
D = K \frac{\lambda}{\beta \cos \theta} \quad (1)
\]

where \( K \) is a constant taken to be 0.94, \( \lambda \) is the wavelength of X-ray used (\( \lambda = 1.54 \) Å), \( \beta \) is the full width at half maximum of XRD pattern, and \( \theta \) is Bragg's angle, around 26.51°. The crystallites sizes are found to be within the range 1.81 to 4.35 nm prepared on quartz substrates and spin coating speeds 1000, 3000 and 5000 rpm. But as the spin coating speeds increases, the crystallites size increases.

where \( h \) is a constant equals to one. The lattice constants \( (a) \) and \( (c) \) were deduced via [6]:

\[
a = \sqrt{\frac{1}{3}} \frac{\lambda}{\sin \theta} \quad (2)
\]

\[
c = \frac{\lambda}{\sin \theta} \quad (3)
\]
Fig. 1, shows the X-ray diffraction XRD of cadmium sulfide (CdS) nanostructures deposited on Quartz substrates at 1000 and 5000 rpm spin coating speeds.

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

<table>
<thead>
<tr>
<th>Peak 2θ (°)</th>
<th>Grain Size (nm)</th>
<th>Full width half maximum (FWHM)</th>
<th>Lattice constants a and c (Å)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.78</td>
<td>4.35</td>
<td>0.36</td>
<td>a=1.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.015^c</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.35^b</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.1^c</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>c=3.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6.545^f</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7.04^g</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6.7^f</td>
</tr>
<tr>
<td>29.38</td>
<td>3.83</td>
<td>0.42</td>
<td>a=1.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>c=3.13</td>
</tr>
</tbody>
</table>


Scanning Electron Microscopy (SEM)

Fig. 2, shows the scanning electron microscopy (SEM) micrographs CdS nanostructures deposited onto quartz substrates at different spin coating speeds and annealed at 800 °C, the morphology of CdS nanostructures is found to be continuous and dense. The crystallinity of the films is improved and the crystallite size becomes larger and uniform.
Conclusion

Cadmium Sulfide (CdS) nanostructures have been prepared by sol-gel spin coating technique deposited onto quartz substrates at different spin coating speeds and temperature of 800 °C. 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 3.83 to 4.35 nm. In addition, the analysis and characterizations studies recommended CdS nanostructures for photovoltaic and optoelectronic application.
References


