Comparison between ITO and FTO Substrates on CdS Thin Films Prepared by Chemical Bath Deposition Method

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Abstract

The effects of substrate type were investigated by modifying crystal and optical properties. The CdS thin films were prepared by chemical bath deposition method. The glass, ITO and FTO were used to the substrates of CdS thin films. For the preparing CdS thin film, the temperature of CdS solution bath immersed in the glycerin was kept at 80 °C. The deposition time was used for 5 min. X-ray diffraction (XRD) and atom force microscopy (AFM) were used to investigate the crystallinity and the surface morphology respectively. The CdS/glass as-deposited thin film showed the amorphous structure. When the CdS/glass thin film annealed in nitrogen gas at 300 °C for 20 min, the one weaker peak (111) was seen. The (111) peak corresponded with the cubic structure. The optical transmission spectra of CdS/glass, CdS/ITO and CdS/FTO thin films showed the absorption edge at about wavelength of 460 nm. The surface morphology of CdS thin films depended on the type of the substrate.

Keywords: *CdS thin film; chemical bath deposition; substrate type*

1. Introduction

The CdS thin film can be prepared on the low-cost amorphous or polycrystalline substrate. The CdS semiconductor has been used in the various types of solar cells such as thin film solar cell, heterojunction thin film solar cells and dye-sensitized solar cell. The heterojunction thin film solar cells based on $CuInSe_2$ and CdTe has the efficiency of 14-16% [1]. CdS crystal is n-type semiconductor, and it has a direct band gap (2.42 eV) [2]. The films of CdS have been more prepared by a wide variety of methods than any other semiconductor material such as vacuum evaporation, sputtering, spray pyrolysis, electrochemical deposition, doctor blade and chemical bath deposition [3]. The electron mobility of thin film is commonly dominated by grain boundary potential barrier. The electron mobility at room temperature of CdS single crystals range from 100 to 400 $cm^2 V^{-1} sec^{-1}$, and the electron mobility of CdS thin film range from below 1 up to over 100 $cm^2 V^{-1} sec^{-1}$. The chemical bath deposition had been used in the preparation of CdS thin film since 1960s because this method has a simple, large area film, low temperature, and low cost deposition method.

CdS n-type semiconductor has been used as the window layer in thin films solar cell which it has to coat on transparent conducting substrate such as tin-doped indium oxide (ITO), fluorine-doped tin oxide(FTO) [4] and aluminium-doped zinc oxide. ITO and FTO are the promising for the substrate of CdS material because ITO and FTO have a wide energy band gap, large electron carrier mobility and good chemical stability. Normally, ITO and FTO have been used as the electrode of solar cell. The CdS/TCO window layer was popularly prepared by chemical bath deposition technique which the cadmium chloride and thiourea solution were normally used as the precursor of CdS semiconductor thin film. The temperature deposition and deposition time were the importance parameters that were used to control the crystal and optical film properties. The CdS thin films deposited on the glass substrate had the energy ban gap of 2.61 electron, and they were shown the uniform grain size and good adhesion to the substrate [5]. The presence of heavy homogeneous reaction of CdS thin film depended on diffuse scattering from the adsorbed colloids which they were the main parameter of the CdS thickness. The optical transmission range from 60 to 100 percent had to have the thickness of 0.05 to 1 micrometers [6]. Cadmium sulphate and thiourea used as Cd precursor and S precursor, respectively, showed the thickness of 95 nm that used the deposited time of 15 minutes and deposition temperature of 70 degree celsius, and there was the optical bad gap of 3.36 electron volt. The X-ray diffraction of CdS thin film that used cadmium sulphate and thiourea precurcors was shown the cubic structure with a main diffraction peak of (110) [1].

In this work, the glass, ITO and FTO were used as substrate of CdS semiconductor to study the effect of structure and optical properties and surface morphology of CdS thin film when it deposited on different substrate.

2. Experiment

CdS thin films were deposited on the various substrate. Soda lime glass, ITO and FTO commercial gradeswere used as the substrate of CdS thin film. The substrates were cleaned with de-ionized water and ethanol, respectively. The substrate temperature had effected with the flux of atoms or molecules that went to the substrate and the energetics of the incoming species. For the preparing CdS thin film, the bath contained 100 ml of de-ionized water kept under stirring at 80 °C. The stable of bath temperature was helped by immersing in the glycerine bath. The deposition time was usedas .min 5 The 1.5 g of cadmium sulphate was dissolves in de-ionized water of 10 ml, and the 0.4 g of thiourea was dissolves in de-ionized water of 10 ml. The substrate was immersed vertically in de-ionized water. When the temperature in bath as 80 °C, the cadmium sulphate solution and the thiourea solution were poured in the bath followed by the 29 ml of ammonium hydroxide, immediately. The deposited time was 20 min. The degree of crystallinity of prepared CdS thin films was examined by x-ray diffraction (XRD) model Advance D8 with copper Kα x-ray line. The surface morphology of thin films was determined by atom force microscopy (AFM) model SPA400 of Sieko Instruments. The optical transmission of thin film was examined by UV-visible spectrophotometer.

3. Results and discussion

The crystal structure of as-deposited and annealed CdS thin films was shown in figure 1. The CdS thin film was prepared by chemical bath method which the glass was used as the substrate. The as-deposited film showed the amorphous structure. When the CdS thin films were annealed in nitrogen gas at 300 °C for 20 min, the one weaker peak (111) that corresponded with the cubic structure was seen. The x-ray diffraction patterns of CdS thin films prepared by chemical bath method were shown in figure 2. The effect of CdS crystal structure was studied when it was coated on the different substrate. The glass and commercial transparent conducting oxides (ITO and FTO) were selected as the CdS substrate. The as-deposited condition was used to measure the CdS structural property. For the glass substrate, the amorphous structure of CdS thin film was seen. For the ITO substrate, the diffraction peaks of (222) and (440) were seen that corresponding with the ITO substrate peak, For FTO substrates, the diffraction peaks of (110), (101), (200), (211), (220), (310), (112), (202), and (321) corresponded with the FTO substrate peak. The diffraction peak of CdS semiconductor could not see because of the amorphous structure of CdS thin film.

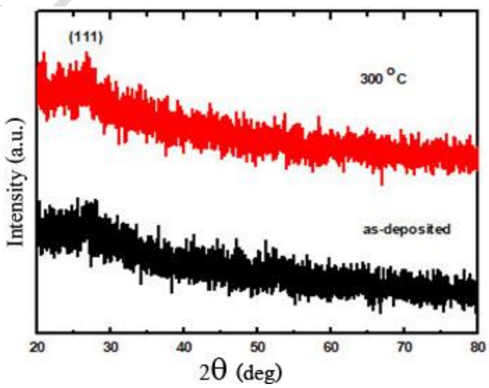


Figure 1 XRD patterns of as-deposited and annealed of CdS thin films prepared by chemical bath method on glass substrate.

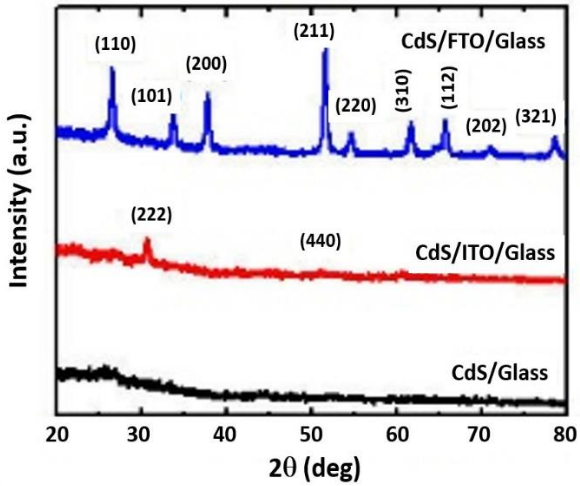
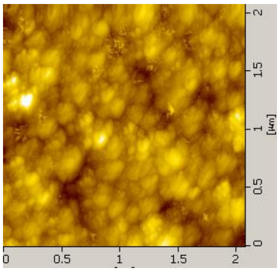
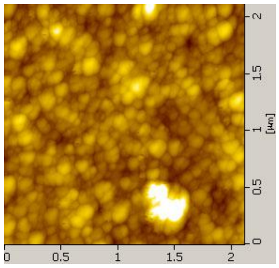


Figure 2 XRD patterns of CdS thin film prepared by chemical bath method on various substrates.

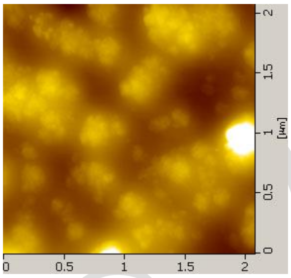
Atom force microscopy is the technique to study the surface morphology of thin films. AFM consideration of these CdS thin films clearly revealed their surface structure. The effect of CdS surface morphology was studied when the CdS was coated on different substrate. From picture 3, the deference of the CdS grain size confirmed that the substrate has the effect with surface morphology. For the glass substrate, there are two shape of grain size that is the circle shape and oval shape which the oval shape came from the fusion of circle shape grain. The smallest grain size has the grain size in the range of 0.05 – 0.1 μm. The grain size was shown the biggest grain size about 0.15 μm and the low porosity. For the ITO substrate, the surface morphology of films CdS showed the homogenous of the small circle grain size that the circle grain size has the size about of 0.05 μm. For the FTO substrate, the surface morphology showed the aggregation of small grain size that there are both the big cluster and the small cluster. However, the high porosity was shown in this case because the deposition time (5 min) of CdS thin film was not enough for the flux of atom or moleclues of CdS to surface of FTO substrate.



(a)



(b)



(c)

Figure 3 Surface morphology of CdS thin films on different substrate, CdS/Glass (a), CdS/ITO (b), and CdS/FTO (c).

The optical transmission versus wavelength of CdS thin films that various substrate was shown in figure 4. The wavelength was used for measuring transmission provided in the range of 300 – 800 nm. The optical transmission spectrum of CdS thin film depends on the uniform of CdS that deposited on the substrate. The uniform or the homogeneous of CdS thin films effects with the scattering at the textured front surface and at the voids and grain boundaries with in the film. The electromagnetic wave was absorbed in the range of 200 – 460 nm then the percent transmission was increased immediately, and transmission was occurred in the range of 461-800 nm. The optical transmission spectra of three samples was shown the absorption edge at about wavelength of 460 nm that corresponded with the band gap energy of CdS semiconductor. The temperature and the stirring rate were fixed then the type of the substrate was the effect of the homogeneous surface of CdS thin film. From the AFM result, CdS/glass and CdS/ITO films showed the high homogeneous surface that the high percent transmission was seen in these conditions, about 85%, by using the equation

$$\%\overline{T} = \frac{\sum \%T}{n} \qquad (1)$$

$\%\overline{T}$ is the average transmission in visible region

$\%T$ is the transmission in visible region

n is the number of data

The CdS/FTO film showed the low percent transmission which there was two reason for the low percent transmission. The first one was nonhomogeneous of CdS thin film, and the second one was electromagnetic wave passing the big cluster of CdS grain that has the highest thickness when compared with other path of film surface.

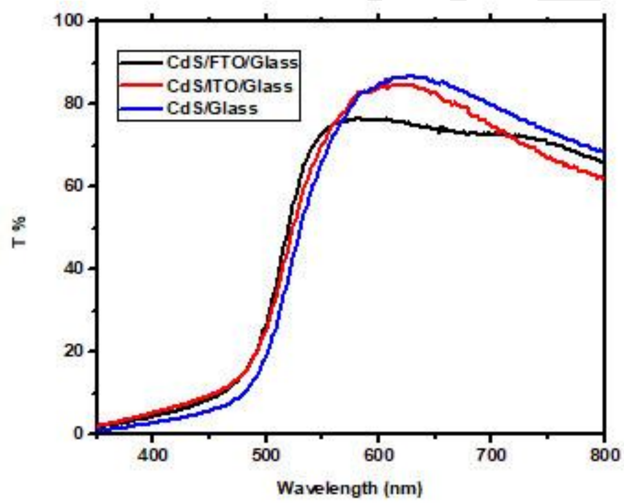


Figure 4 Optical transmission of CdS thin film coated on various substrates.

4. Conclusions

The comparison of CdS thin film on deferent substrate was studied in this work. The cadmium sulphate and the thiourea solution were used to Cd and S ions precursors, respectively. The CdS solution was fixed the temperature at 80 °C, and the solution bath was immersed in glycerine for the stable of bath temperature. The magnetic bar was used to stir the CdS solution by using the constant rate for 1 RPM.

The crystal structure of as-deposited and annealed CdS thin films prepared by chemical bath method which the glass used as the substrate was shown the amorphous structure. The CdS thin film annealed in nitrogen gas at 300 °C for 20 min the one weaker peak (111) was seen that peak corresponded with the cubic structure. The commercial transparent conducting oxides (ITO and FTO) selected as the CdS substrate the diffraction peaks of (222) and (440) was seen that corresponding with the ITO substrate peak with CdS/ITO thin film. The diffraction peaks of (110), (101), (200), (211), (220), (310), (112), (202), and (321) corresponded with the FTO substrate peak with CdS/FTO thin film.

AFM was used to study the surface morphology of CdS thin films. The CdS surface morphology was studied when the CdS was coated on different substrate. For the glass substrate, there are the circle shape and oval shape, and the oval shape came from the fusion of circle shape grain. The smallest grain size and the biggest grain size have the size in the range of 0.05 – 0.1and about of 0.15 μm, respectively. For the ITO substrate, the CdS film surface morphology showed the homogenous of the small circle grain size that has the particle size of 0.05 μm. For the FTO substrate, the big cluster and the small cluster was occurred from the aggregation of small grain size.

The wavelength was used for measuring transmission provided in the range of 300 – 800 nm. The CdS thin films was absorbed the electromagnetic wave in the range of 200 – 460 nm, and transmission was occurred in the range of 461-800 nm. The all conditions were shown the absorption edge at about wavelength of 460 nm that corresponded with the band gap energy of CdS semiconductor. The temperature and the stirring rate were fixed then the type of the substrate was the effect of the homogeneous surface of CdS thin film. CdS/glass and CdS/ITO films showed the high percent transmission about of 85%. The CdS/FTO film showed the low percent transmission.

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