Properties of CdS:In Thin Films according to Substrate Temperature

G-C Park*, J Lee*, H-D Chang*, W-J Jeong*, J-Y Park*, Y-J Kim*, H-H Yang*, J-H Yoon*
H-R Park**, K-S Lee***, H-B Gu****
Department of Electrical Engineering and Electronics, Mokpo Natl University *
Department of Phisics Mokpo Natl University **
Department of Electrical Engineering and Electronics, DongShin Natl University ***
Department of Electrical Engineering and Electronics, ChonNam Natl University ****

Abstract

Cubic CdS thin film with the strongest XRD peak (111) at diffraction angle (Θ) of 26.5 was well made at substrate temperature of 150 ℃. At that time, lattice constant a of the thin film was 5.79 Å, grain size of that was more over 1 ㎛ and it's resistivity was over 10^3 Ωcm. And the peak of diffraction intensityat miller index (111) of CdS:In thin film with dopant In of 1 atom% was shown higher about 20 % than undoped CdS thin film. Also, CdS:In thin film had in part hexagonal structure among cubic structure as secondary phase. Lattice constant of a and grain size of secondary phase of the film with dopant In of 1 atom% was 5.81 Å and around 1 ㎛ respectively. The lowest resistivity of 5.1×10^{-3} Ωcm was appeared on dopant In of 1.5 atom%.

Optical band gap of undoped CdS thin film was 2.43 eV and CdS:In thin film with dopant In of 0.5 atom% had the largest band gap 2.49 eV.

KeyWords: Cubic, Lattice Constant, Resistivity, Dopant, Hexagonal, Band gap

1. Introduction

Cadmium Sulfide (CdS) has a direct band gap that can be used for the fabrication of optoelectronicdevices such as solar cells, laser diodes and photoconductors. It is very desirable window layer for many photovoltaic solar cells because of its optical and electrical properties. Also, CdS has been the subject of intensive research because of its band gap, high absorption coefficient, reasonable conversion efficiency, stability and low cost. In particular, CdS thin films are the most commonly used window material for high efficiency CdTe and $CuInSe_2$ polycrystalline thin film solar cells.

CdS thin films can be fabricated using the methods such as vacuum evaporation, spray pyrolysis, chemical solution growth, cathodic pulverization, sputtering, sintering and screen printing.

Among these techniques vacuum evaporation is a simple, convenient and accurate controllable for optoelectronic film devices with high efficiency.

While when CdS is deposited, substrate

temperature has affected greatly the formation (adhesion, surface uniformity etc.) of CdS thin films.

Also undoped CdS thin films generally have high electrical resistivity. An good way to produce less resistive thin films is doping In into CdS (CdS:In) thin films.

So, In this study, CdS:In thin films were prepared at various substrate temperatures and dopant In quantities by E-beam evaporation. And structural, electrical and optical properties of fabricated CdS:In thin films were investigated for solar cell.

2. Experiment

CdS:In thin films were made on substrate slide glasses by co-deposition method of CdS and In by E-beam evaporator with two heating boats in vacuum of 10^{-6} Torr. At this time sodalime slide substrate glasses were heated at temperature ranging from 50 ℃ to 300 ℃. Table 1 described sample numbers of CdS:In thin films by dopant In. The thickness of CdS thin film was about 1.0㎛ which was enough to obtain over 90% of transmittance and to grow polycrystalline thin film.

Table 1. Sample numbers of CdS:In thin films by dopant In ratio.

Sample number	Composition condition [atom%]		Area [cm^2]
	CdS	In	
L	100	0	1.65 × 1
M	99.75	0.25	
N	99.5	0.5	
O	99.0	1.0	
P	98.5	1.5	
Q	98.0	2.0	

Thickness of CdS:In thin film was measured by Interferometer(Å-Scope, Varian) and Surface profiler(-step 200, Tencor).

Microstructural studies were carried out by XRD (D/MAX-1200, Rigaku Co.) and SEM (JSM-5400, Jeol Co.). Electrical properties were measured by Hall Effect Measurement System (HL5500PC, Accent Optical Technology Ltd.), while the optical absorbance was measured by UV-VIS-Spectrometer (CARY 1, Varian Co.).

3. Results and Discussion

3.1 Structural property

Fig 1 showed XRD patterns of CdS thin films by substrate temperature. Cubic CdS thin film with the strongest diffraction peak (111) at diffraction angle (Θ) of 26.5 was well made at substrate temperature of 150 ℃. At that time, lattice constant a of the thin film was 5.79 Å. Fig 2 showed XRD patterns of CdS:In thin films at substrate temperature of 150 ℃ by dopant In. And the peak of diffraction intensity at miller index (111) of CdS:In thin film with dopant In of 1 atom% was shown higher about 20 % than undoped CdS thin film. But the peak (111) intensity of over dopant In of 1.5 atom % inversely decreased thanthat of undoped CdS thin film. Also, from miller index (002) of XRD patterns, CdS:In thin film had in part hexagonal structure among cubic structure as secondary phase. Lattice constant of a of CdS:In thin film with dopant In of 1 atom% and 1.5 atom% was 5.81 Åand 5.84 Å respectively.

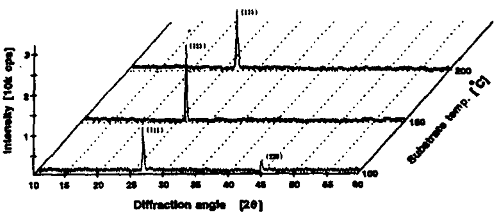


Fig. 1. XRD patterns of CdS thin films by substrate temperature.

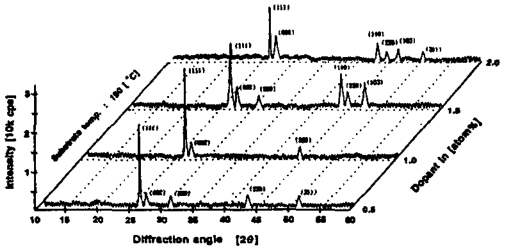


Fig. 2. XRD patterns of CdS:In thin films by dopant In.

Photol described SEM photographs of undoped CdS thin film and CdS:In thin films by In ratio. The grain size of undoped CdS thin film was more over 1 ㎛and it's surface was very smooth. As dopant In doped more, secondary phase on surface of CdS:In thin film increased, and the grain size of secondary phase of CdS:In thin film with dopant In of 1atom% was around 1㎛.

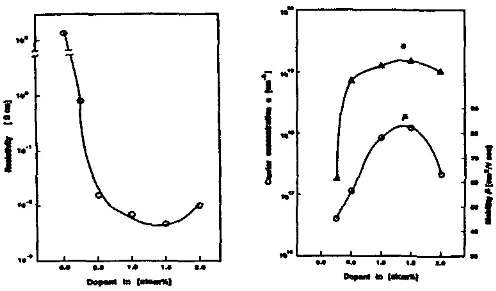
Photo 1. SEM photographs of CdS:In thin films by In ratio.

3.2 Electrical property

Table 2 showed electrical properties of CdS:In thin films by dopant In. Fig 3(a) represented resistivities and Fig 3(b) showed carrier concentrations and mobilities obtained from Hall Effect analyses to convince the variety of resistivities of the CdS:In thin films. Resistivity of undoped CdS thin film was over 10^3 Ωcm. But the lowest resistivity of 5.1×10^{-3} Ω?cm was appeared on CdS:In thin film with dopant In of 1.5 atom%. So, electron carrier concentration and mobility was the highest value 1.487×10^{19} cm^{-3} and 82.41 cm^2 /V?sec respectively on dopant In of 1.5 atom%.

Table 2. Electrical properties of CdS:In thin films by In ratio.

Sample No.	Carrier con. [cm^{-3}]	Mobility [cm^2/Vsec]	Resistivity [Ω cm]	Hall coefficient	Conduction type
L-15	*	*	> 10^{-3}	*	n
M-15	1.780×10^{17}	45.17	7.8×10^{-1}	-3.511×10^{-1}	n
N-15	6.975×10^{18}	56.21	1.6×10^{-2}	-8.960×10^{-1}	n
O-15	1.241×10^{19}	78.11	6.6×10^{-3}	-5.140×10^{-1}	n
P-15	1.487×10^{19}	82.41	5.1×10^{-3}	-4.203×10^{-1}	n
Q-15	1.010×10^{19}	63.23	9.8×10^{-3}	-6.180×10^{-1}	n



(a) (b)

Fig. 3. Electrical properties of CdS:In thin films by dopant In. (a) resistivities, (b) carrier concentrations and mobilities

3.3 Optical property

The optical transmittance spectra of CdS:In thin films by dopant In were shown at Figure 4 at room temperature. Undoped CdS thin film had 90% of transmittance and CdS:In with dopant In 1.5 atom % had 84%.

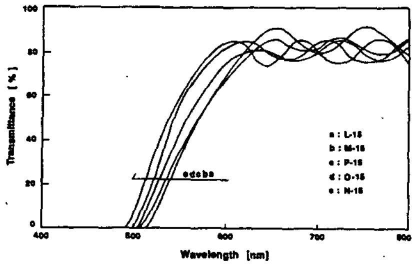
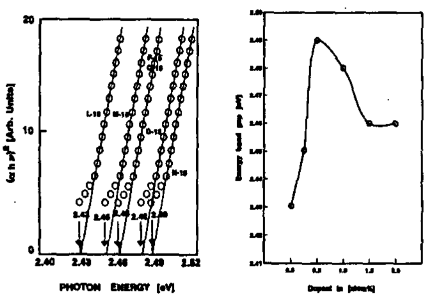


Fig. 4. Optical transmittance spectra of CdS:In thin films by dopant In.

Figure 5 (a) showed plots of $(?h?)^2$ versus the incident photon $h?$ for CdS:In thin films at various dopant In ratios by extrapolation methods for getting energy band gap.

Figure5(b) showed optical energy band gaps of CdS:In thin films by dopant In ratio. Optical band gap of undoped CdS thin film was 2.43 eV and CdS:In thin film with dopant In of 0.5 atom% had the largest band gap 2.49 eV.



(a) (b)

Fig. 5. Optical properties of CdS:In thin films by dopant In. (a) Plots of $(h)^2$ versus the incident photon h, (b) Optical energy band gap

4.Conclusion

Cubic CdS thin film with the strongest XRD peak (111) at diffraction angle (Θ) of 26.5 was well made at substrate temperature of 150 ℃. At that time, lattice constant a of the thin film was 5.79 Å, grain size of that was more over 1 ㎛and it's resistivity was over 10^3 Ω?cm.

And the peak of diffraction intensity at miller index (111) ofCdS:In thin film with dopant In of 1 atom% was shown higher about 20 % than undoped CdS thin film. Also, CdS:In thin film had in part hexagonal structure among cubic structure as secondary phase. Lattice constant of a and grain size of secondary phase of the film with dopant In of 1 atom% was 5.81 Å and around 1 ㎛ respectively. The lowest resistivity of 5.1×10^{-3} Ω?cm was appeared on dopant In of 1.5 atom%.

On the other hand, optical band gap of undoped CdS thin film was 2.43 eV and CdS:In thin film with dopant In of 0.5 atom% had the largest band gap 2.49 eV.

We found that n-type CdS:In thin film was well made at substrate temperature of 150 ℃ and properties of the thin film were appropriate for window layer of compound solar Cell.

References

[1] F.Atay, V.Bilgin, I. Akyuz & S.Kose, Materials Science in Semiconductor Processing, 6(2003) 197-203.

[2] M.Y.Elzayat, A.O. Saed & M.S. El-Dessouki, Solar Energy Materials & Solar Cells,71(2002)22-39.

[3] K.durose, M.A. Cousins, D.S. Boyle, J.Beier & D.Bonnet, Thin Solid Films, 403-404(2002)396-404.

[4] M.A. Contreras, M.J.Romero, B. To, F.Hasoon, R.Noufi, S.Ward & K.ramanathan, Thin Solid Films, 403-404(2002) 204-211.

[5] A.Romeo, D.L. Batzner, H.Zogg & A.N.Tiwari, Thin Solid Films, 361-362(2000)420-425.

[6] I.D. Desnica-Frankovic, U.V.Desnica, A.Stotzler & M.Deicher, Physica B, 273-274(1999)887-890.

[7] J.Lee &T.Tsakalakos, Nanostructured Materials, 8(4), (1997)381-398.