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Laser Pulses Dependent Thickness and Properties of the Cds Buffer Layer

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ABSTRACT

Report demonstrates pulse laser dependence CdS thin films thickness variation and properties. Variable thickness properties like; surface morphology, cross sectional view, EDS with elemental mapping, AFM surface roughness parameter, Raman spectrum, photoluminescence, UV-Visible range FT-IR, I-V and R-V characteristics is discussed. It has been noticed with increasing laser pulses thickness, structure, surface morphology, Raman spectra, FT-IR band, I-V and R-V characteristics are changed. With the increasing number of laser pulses, the increase in surface roughness parameter, shift in FT-IR band tail toward the lower wave number side and higher current growth with lower resistance is observed for the thicker films.

Introduction

Cadmium sulfide (CdS) has received wide attention due to its important role as the best heterojunction buffer layer for CIS, CdTe, CIGS photovoltaic solar cells [1-3]. A thin CdS intermediate buffer layer is would deposit to improve the interface properties with the other layers; like active and ZnO thin layers. The buffer layer can also serve as an optical window with higher and lower optical energy band gaps and refractive index for the increasing coupling of light into the absorber [1-3]. In practice performance of the buffer layer in multilayer solar cell depends on theses parameters; i) charge carrier diffusion length $L_m=(D_m t_m)^{1/2}$ in absorber layer (here L_m – diffusion length, D_m- diffusion constant and t_m- life time); it has suggested reduction in diffusion content D_m result of the reduction in diffusion length L_m: ii) reduction in L_m results an exclusive drop in life time τ_m : iii) buffer layer key function to block the minority charge carriers motion through the barrier and allow majority carriers free flow across obstacle [4]. Therefore the prime benefit of buffer layer it can essentially remove the contact which may come from the higher minority-carrier recombination losses in the absorber. Such optical enhancement of the buffer layer can be reduced the absorption and reflection losses, this can result enhanced open-circuit voltages (VOC) due to reduction in carrier mobilities. Thus optimization of the buffer layer thickness is a crucial parameter [1,4]. The several techniques including electrodeposition [5], spray pyrolysis [6], vacuum evaporation [7], and chemical bath deposition CBD [8] CdS thin layer properties have been reported by the investigators. But a very few reports on CdS layer thickness optimization or properties with pulse laser deposition (PLD) technique. Therefore goal of this work, to present CdS thin films thickness dependence study like surface morphology, cross sectional view, EDS with elemental mapping, AFM surface roughness parameter, Raman spectra, photoluminescence, UV-Visible range FT-IR, I-V and R-V characterizations, under an applied voltage range 0 – 10 V with the varying laser pulses.

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Experimental Details

To make a PLD target the proper amount (around the 4-5 g) of the CdS (50:50%) composition was taken. CdS material 2 inch circular PLD target pellet was made by employing the 10 ton load; after that, it was sintered at temperature 2000C to harden the surface. The made material PLD target and ITO coated 3.0 × 3.0 mm substrates were mounted in a high vacuum chamber for the film deposition under the pressure 4×10^{-2} Torr. The excimer pulse laser energy, current and frequency were used 300 mJ, 10 Hz/sec respectively. The PLD deposited thin films crystallographic structure, surface morphology, cross sectional view, energy dispersive X-ray patterns and elemental mapping, roughness and depth profile, Raman spectrum, photoluminescence (PL), Fourier Infrared Transmission Radiation (FT-IR) spectrum, I-V and R-V characteristics were characterized by employing the relevant

Results and Discussion

X-ray crystallographic structure of the 1000, 2000 and 3000 laser pulses deposited thin films, in respect to the JCPDS CdS data is given in Fig.1. CdS prominent 2θ value peaks 26,

30, 43 and 52 0, corresponding to (111), (200), (110) and (112) crystallographic planes are appearing in the laser deposited thin films. Additionally laser deposited CdS thin films are also showing 2θ peaks at 25 and 480 corresponding to (100), (103) crystallographic planes. Here it is noticed with the increasing thickness of the film, the (100) and (112) crystallographic plane peaks intensities in increasing order, while, the (103) crystallographic plane seems to remain unchanged. Thus, the varying pulse laser deposited CdS thin films crystallographic structures are altered with the increasing thickness.

CdS buffer layer surface morphology can also play substantial role in determination of its working performance. Usually the CdS buffer layer even surface morphology would have required for higher performance photovoltaic solar cell [9].

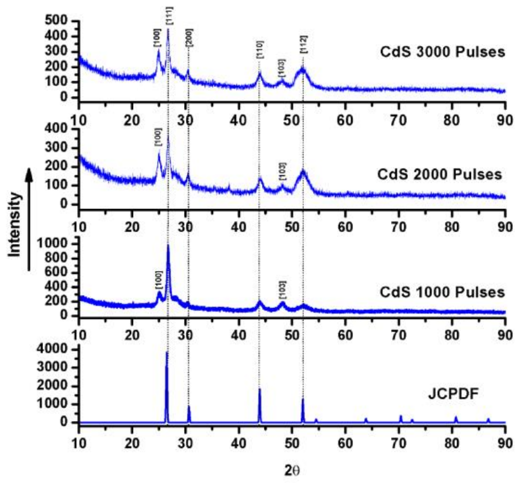

Figure 1. XRD patterns for the 1000, 2000 and 3000 pulses deposited CdS thin films

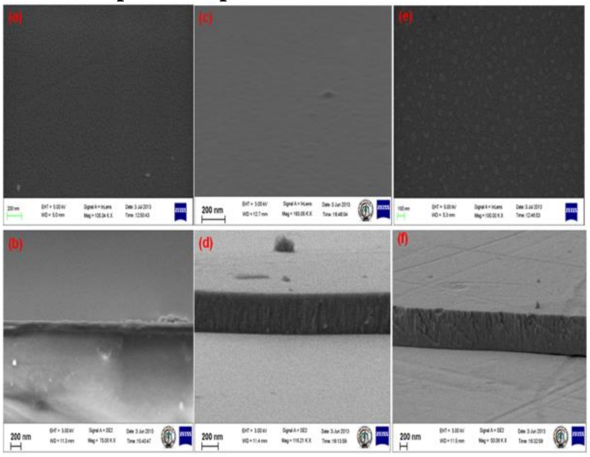

Figure 2. (a b, c d, e f). FESEM morphologies and cross sectional view for the 1000, 2000 and 3000 laser pulses deposited CdS thin films

The FESEM surface morphologies and cross sectional view of the 1000, 2000 and 3000 laser pulses deposited CdS thin films is exhibited in Figure 2 (a- f). The 1000 laser pulses deposited thin film surface morphology appears smoother (see Fig. 2 a) with the thickness around 82 nm (see Fig. 2 b), while, the 2000 laser pulses deposited film seems to fewer homogenous (see Fig. 2 c) and thickness around 230 nm (see Fig. 2 d). However, 3000 laser pulses deposited thin film has developed a distinct surface morphology (see Fig. 2 e) with the thickness around 730 nm (see Fig. 2 f). During the morphological analysis it has observed 3000 pulses deposited thin film exhibited the sharp cracks at the several places. With the smooth surface morphology the stiochimetric presence of the elements is also an important parameter [10]. Therefore, Fig. 3 (a - i) exhibits EDS mapping and EDS patterns for the 1000, 2000 and 3000 laser pulses deposited thin films. The varying laser pulses deposited thin films have exhibited almost homogenous distribution of the Cd and S, while, the respective film EDS patterns confirms the presence of elements in compositional amount.

AFM surface morphological view of the developed thin films could provide the valuable information about formed grains; however, AFM 3D view can provide the roughness of the respective films. The relevant depth profile peak can be related to the percentage of the developed minimum and maximum size grains within the thin films. Figure 4 (a- i) represents AFM surface grains morphologies, roughness and depth profile for the varying laser pulses deposited CdS thin films. It is noticed with the increasing films thickness (or laser pulses) the fine grains formed in the morphology. A slightly larger grain sizes are appearing for the 3000 pulses deposited thin film (see Fig. (a, d, g)). With the additional information 3000 laser pulses thin film has several sharp cracks within the surface morphology. The 3D view of the corresponding thin films gives roughness parameter in increasing order with the increasing thickness, it obtains highest (0.391 to 1.10) for the thicker film (see Fig. 4 (b, e, h)). The average size particle distribution for the 1000 and 2000 laser pulses deposited thin films seems to identical. But 3000 laser pulses deposited thin film particle distributions are wider than other two discussed thin films (see. Fig. 4 (c, f, i)).

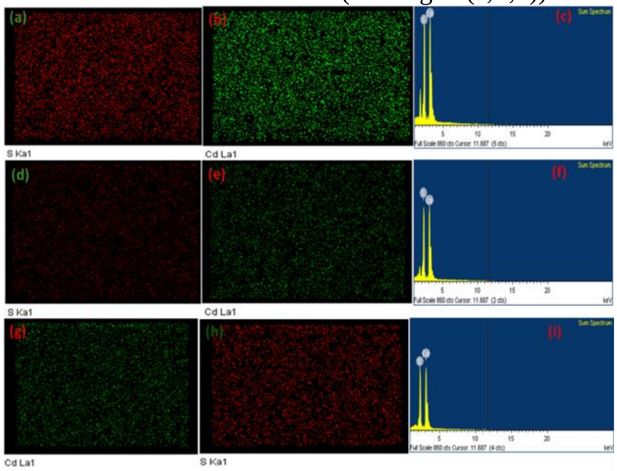

Figure 3. (a b c, d e f, g h i). EDS Mapping and EDS patterns for the 1000, 2000 and 3000 pulses deposited CdS thin films

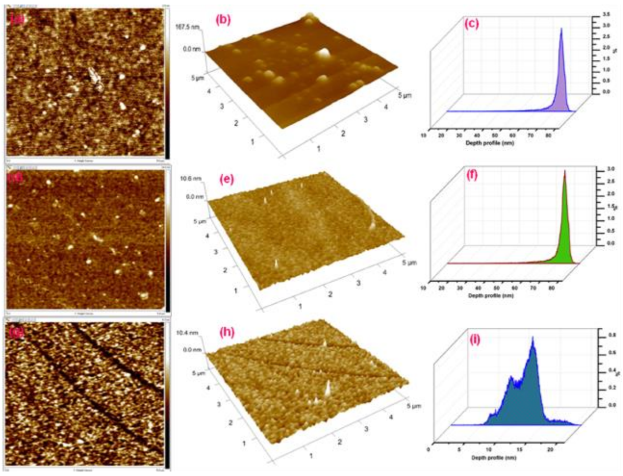

Figure 4. (a b c, d e f, g h i). AFM surface morphology, roughness parameter and depth profile for the 1000, 2000 and 3000 pulses deposited CdS thin films

Hence AFM morphological view of the developed CdS thin films reveals with the increasing thicknesses roughness of the surfaces are also increased. The appearance of cracks in thickest film surface morphology may be due larger grain size and a reduction in adherence between the element Cd and S.

Raman spectroscope can also provide structural changes in these laser pulses varying thin films. The recorded Raman spectrum of the CdS thin films is given in Fig. 5. It is evident, with the increasing thin films (or increasing laser pulses) thicknesses the spectral peak counts value is also increased. The lowest and highest counts values are obtained for the 1000 and 3000 pulses films, while, 2000 laser pulses deposited thin film counts value fall in-between. The CdS prominent Raman peaks 302 cm^{-1}, 603 cm^{-1} with other low intensity peaks at 150 $cm^{-1}$and 389 cm^{-1} are appeared in each film. The thicker CdS films higher counts values can be directly correlated to the existence of large numbers of Raman active modes [11] in comparison to thinnest film. Thus with the increasing laser pulses or thickness of the CdS films there is no sharp structural change has observed except obvious enhancement in peak counts value for the thicker films. Moreover, a good buffer layer material should have high order incident light transmission property toward the active layer with the minimal optical loss. By mean buffer layer material should have high order intrinsic optical transmission. Photoluminescence optical property can reflect a large number of sub bands formation within the optical forbidden gap in buffer layer material [12]. The existence of such a large number of sub layers makes the efficient transmission of the incident photon from top to bottom in a buffer layer.

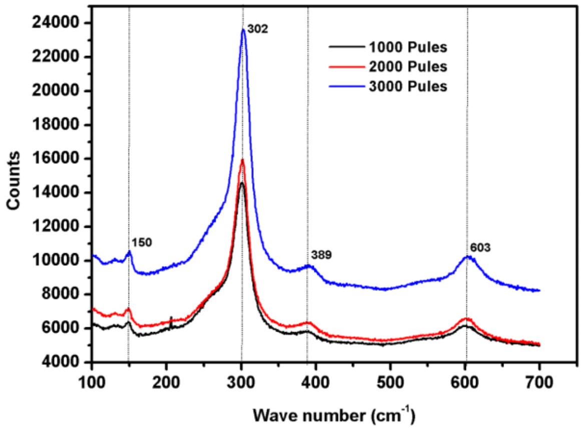

Figure 5. Raman spectra for the 1000, 2000 and 3000 pulses deposited CdS thin films

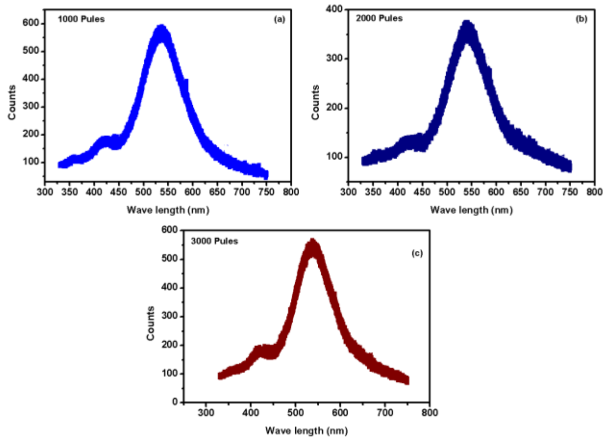

Figure 6. (a, b, c). Photoluminescence profile for the 1000, 2000 and 3000 pulses deposited CdS thin films

The thickness dependence photoluminescence optical property of the CdS thin films is given in Fig. 6 (a, b, c). The 1000, 2000 and 3000 laser pulses deposited thin films are exhibiting a strong photoluminescence signal in the wavelength range in between the 450 nm to 650 nm. It is noticed with the increasing films thicknesses the photoluminescence peak position seems to unaffected.

The FT-IR transmission property in optical wavelength range could be useful to define the optical properties of the buffer layer. Cause we have received on earth a large amount (~ 65%) of sun energy in IR range [13]. Therefore, it is worth to explore the CdS buffer layer material IR light transmission ability in UV/Visible optical range. The CdS thin films recorded FT-IR transmission spectra in UV/Visible range is exhibited in Fig. 7. The obtained spectrum is showing band tail thresholds shifted toward the higher wave number side. This is higher and lower for the 1000 and 3000 pulses deposited thin films. This means the optical energy band gap for the 1000 deposited thin film is slightly lower than other two films.

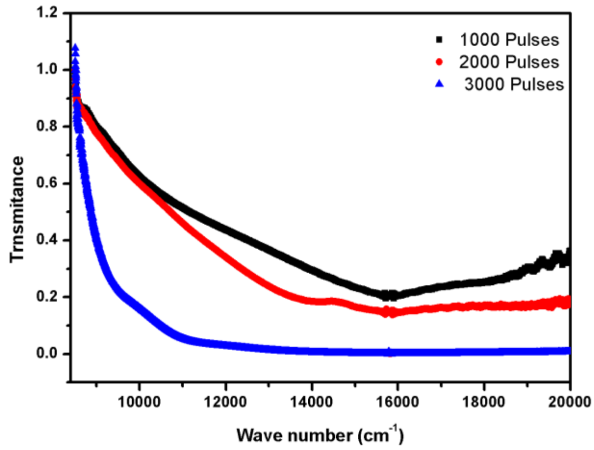

Figure 7. UV/Visible range FT-IR spectrum for the 1000, 2000 and 3000 pulses deposited CdS thin films

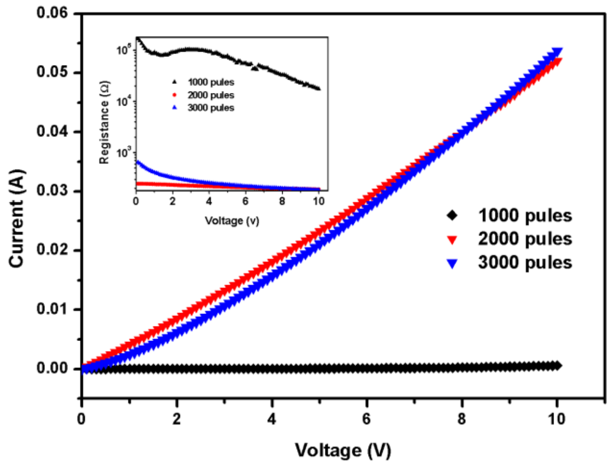

Figure 8. I-V and R-V for the 1000, 2000 and 3000 pulses deposited CdS thin films in the applied voltage range 0-10V

I-V and R-V characteristics of the 1000, 2000, 3000 laser pulses fabricated CdS/ITO/substrate devices is given in Fig. 8. It is evident; with the increasing CdS thin films thickness the current growth and resistance in increasing and decreasing order. Almost nearly identical current growths and resistance drops are appearing for the 2000 and 3000 laser pulses deposited devices, while, least current growth and resistance drop is observed for the 1000 laser pulses device, under the applied voltage range 0-10 V. This reflects upto certain thickness charge carrier creation in CdS thicker film increases afterward it become approximately constant (see I-V profile 2000 and 3000 pulses). Thus free charge carrier creation centers in a CdS thin film is would affect upto certain thickness limit but not beyond that.

Conclusions

In conclusive remarks, this study has demonstrated the pulse laser dependent thickness and structural, optical and electrical variations of the CdS/ITO/substrate devices. Specifically alteration in structure, surface morphology and cross sectional view, alloying elements existence and their distribution throughout the configuration for the CdS thin films have verified. Further, in view of possible use of the developed CdS thin films for the buffer layer in multi layers photovoltaic cells the AFM surface grain morphology, roughness parameter and average particle size depth profile have been examined. It has observed the lowest and highest roughness parameter and depth profile for the 1000 and 3000 laser pulses deposited thin films. With an additional feature 3000 film has several sharp cracks within the surface morphology. The increasing laser pulses deposition of CdS thin films also affected the Raman active vibration mode, which has appeared in the form of low and high intense peaks. The strong photoluminescence has appeared in these thin films. This is one of the essential requirements for a buffer layer material. The FT-IR transmission spectra in the UV/Visible range can reveal the buffer layer material interaction of the IR light. The outcome revealed developed CdS thin films have a strong IR transmission ability with the band tail shifting lower wave number side for the thicker films. To explore the critical parameters for the buffer layer material this report also includes alteration in I-V and V-R electrical properties, in the crucial voltage range (0- 10 V). This result has given with the increasing thicknesses of the films current growths and resistance drops in these films. The electrical parameters have obtained lowest and highest visa versa for the 1000 and 3000 laser pulses deposited thin films. Thus, structural, surface morphological and cross sectional view, roughness parameter, optical and electrical properties of the developed CdS/ITO/substrate devices has revealed 1000 laser pulses suitable for the buffer layer fabrication.

References

[1] K. Orgassa, U. Rau, Q. Nguyen, H. W. Schock and J. H. Werner, "Role of the CdS buffer layer as an active optical element in Cu(In,Ga)Se_2 thin-film solar cells" Prog. Photovolt: Res. Appl, vol. 10, pp. 457–463, 2002.

[2] R. Naciri, H. Bihri, A. Mzerd, A. Rahioui, M. Abd-Lefdil and C. Messaoudi, "Revue des Energies Renouvelables CER'07 Oujda", pp. 165 – 168, 2007.

[3] L. C. Olsen. P. Eschbach and S. Kundu, "Role of buffer layers in CIS-based solar cells" IEEE 10.1109/PVSC.2002.1190649

[4] B. V. Roedern and G.H. Bauer, "Material Requirements forBuffer Layers Used to ObtainSolar Cells with High OpenCircuit Voltages" Material Research Society' Spring Meeting San Francisco, CA April 6-10, 1999, NREL/CP-520-26363

[5] K.L. Choy and B. Su, "Growth behavior and microstructure of CdS thin films deposited by an electrostatic spray assisted vapor deposition (ESAVD) process" Thin Solid Films, vol. 388, pp. 9-14, 2001.

[6] S.J. Castillo, A. M. Galvan, R. R.Bon, F.J. E. Beltran, M. S. Lerma, J. G.Hernandez and G. Martinez, "Structural, optical and electrical characterization of In/CdS/glass thermally annealed system" Thin Solid Films, vol. 373, pp. 10-14, 2000.

[7] U. Pal, R. Gonzalez, G. M.Montes, M. G. Jimenez, M.A. Vidal and S. Torres, "Optical characterization of vacuum evaporated cadmium sulfide films" Thin Solid Films, vol. 305 pp. 345-350, 1997.

[8] M.T.S. Nair, P.K. Nair, R.A. Zingaro and E.A. Meyers, "Conversion of chemically deposited photosensitive CdS thin films to n-type by air annealing and ion exchange reaction" J. Appl. Phys, vol.75, pp. 1557, 1994

[9] T.P. kumar, M. J. Kim, H. Jeong, S. Hwang, N.L.Tarwal, Y. K. Jeong and J. H. Jang, Interface Stoichiometry Control in ZnO/Cu2O Photovoltaic Devices, IEEE 978-1-4799-3299-3/13/$31.00 ©2013

[10] A. K. Singh, "Microscopic Study on the Se-Te-Ge Alloy and Its Composite with Carbon Nanotubes and Graphene" J. Adv. Micro. Res, vol. 7, pp. 270-276, 2012.

[11] I.O. Oladeji, L. Chowa, J.R. Liu, W.K. Chu, A.N.P. Bustamante, C. Fredricksen and A.F. Schulte, "Comparative study of CdS thin films deposited by single, continuous, and multiple dip chemical processes" Thin Solid Films, vol. 359 , pp. 154-159, 2000.

[12] S. Shirakata, K. Ohkubo, Y. Ishii and T. Nakad, "Effects of CdS buffer layers on photoluminescence properties of Cu(In,Ga)Se2 solar cells" Solar Energy Materials & Solar Cells vol. 93, pp. 988–992, 2009.

[13] M. Zayat, P. G. Parejoa and D. Levy, " Preventing UV-light damage of light sensitive materials using a highly protective UV-absorbing coating" Chem. Soc. Rev. vol. 36 , pp. 1270-1281, 2007.