

COMPARATIVE ANALYSIS OF PROPERTIES OF BAMBOO DOPED AND UN-DOPED CADMIUM SULFIDE THIN FILMS DEPOSITED BY CBD METHOD FOR POSSIBLE APPLICATIONS

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ABSTRACT

Thin films of undoped and bamboo doped cadmium sulfide (CdS) were deposited on microscopic glass substrate using chemical bath method at room temperature. 0.2 molar solution of cadmium chloride hemihydrate ($\text{CdCl}_2 \cdot 2\frac{1}{2}\text{H}_2\text{O}$), 0.1 molar solution of ammonium thiocyanate (NH_4CNS), and 5.6M of ammonium hydroxide solution were the reagents used for the deposition of undoped CdS, while grinded carbonated bamboo and sundried bamboo fibers were introduced as dopants. The $\text{CdCl}_2 \cdot 2\frac{1}{2}\text{H}_2\text{O}$ was used to serve as source of Cd^{2+} ions, NH_4CSN was used to serve for S^{2-} ion sources, while NH_4OH served dual purpose of pH adjuster (buffering agent) and complexing agent. The carbonated and sunburnt bamboo fibers which were introduced as dopant were topped down to the particle sizes of $180\text{ }\mu\text{m}$ - $250\text{ }\mu\text{m}$. The deposited films were characterized using X-ray diffraction (XRD), UV-VIS Spectrophotometer to determine the structural and optical properties of the deposited thin films respectively. The results of the analysis of the characterizations indicate that doping CdS thin film with grinded bamboo extracts have altered the various optical and structural properties. The transmittance of the bamboo doped CdS thin films were observed to decrease as a result of doping CdS with grinded sundried bamboo (CdS/uBx), while doping with carbonated bamboo extract (CdS/Bx) rather increased the transmittance value. The spectral absorbance of the doped CdS is also observed to increase for sundried (CdS/uBx) but decreased for carbonated (CdS/Bx). The values of the absorption coefficient of the samples CdS/uBx were equally observed to be highest as compared to undoped CdS and carbonated (CdS/Bx) samples. The result of the XRD analysis indicates that the crystalline structure of CdS was improved by doping with sundried bamboo extracts. These changes in the optical and structural properties of CdS as a result of doping with bamboo extract are desirable for many applications such as in solar PV cells, optical coatings and high temperature superconducting devices.

Keywords: Thin films, Chemical Bath, Bamboo, XRD, Cadmium Sulfide.

1. INTRODUCTION

Cadmium sulfide (CdS) thin film is one of the group II–VI semiconductor compounds, which is of great interest for many practical applications (Shah *et al*, 2012). CdS is used as a window layer in order to achieve hetero-junction p-type cadmium telluride (CdTe) and copper indium selenide (CuInSe) solar cells because of its relative wide band gap value of 2.42 eV. CdS has been used as n-type semiconductor window layer material with CdTe to produce 14.6% solar cell and with ZnO and CuInGaSe_2 to produce 19.2% solar cell structure (Romeo *et al*, 1999) and (Ramanathan *et al*, 2003). The optoelectronic applications of CdS thin film are found in the following devices: laser materials, photo-sensors, photo-conducting cells, optical waveguides, transducers, light emitting diodes, large screen liquid crystal devices, gas sensors, and field effect transistors (Anuar *et al*, 2008).

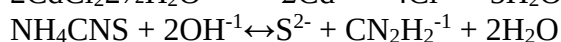
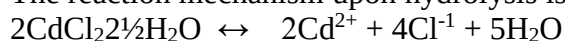
Doping of thin film materials with suitable impurities has given rise to a new class of thin film materials whose various properties have differed from those of the corresponding host materials, (Hasnat and Podder 2012). Indium doped cadmium sulfide thin film have given rise to a typical n-type CdS semiconductor with low resistivity and high optical transmittance. Effect of manganese doping percentage on band gap energy of cadmium sulphide (CdS) nanofilms prepared by electrodeposition method was reported by Okafor and Ekpunobi (2015) showed that band gap energy increased with the increase of percentage Mn dopant from 2.02 eV to 2.35 eV which is slightly lower than bulk value 2.42eV. The optical and structural properties of polythiophene(PTh) doped CdS deposited by electrodeposition method equally, reported by Sakilet *al.*, (2013) indicated that band gap energy of CdS/polythiophenenano-composite was found to decrease to a value of 1.7 eV. The band gap values for Copper, Boron and Indium doped CdS films; exhibit a band gap value of 2.52 eV for Cu and B, while the Indium doped sample possesses a band gap of 2.46 eV (Martin, 2007). Many preparation conditions (Ruby and Suman 2011) and different other deposition methods like spray pyrolysis (Meshramet *al.*, 2012; Hasnat and Podder 2013) and thermal evaporation (Torreset *al* 1996) have been used to deposit CdS thin films and their properties analyzed for different applications.

2. EXPERIMENTAL PROCEDURE

The cadmium sulfide thin films for the experiment were synthesized by cost effective chemical bath deposition method of thin film deposition. Empty microscope slides of sizes 25.4 x 76.2mm and thickness range of 1 mm - 1.2mm were degreased by soaking them in concentrated trioxonitrate(V) acid for 72 hours and washed with detergent, then rinsed with distilled water and allowed to dry in a clean environment. These clean slides served as the substrate for the pure CdS and doped CdS thin film deposition. 100ml beakers were also washed with detergent and rinsed with distilled water. These served as the reaction container. The reagents/reactants used for the experiment were: 0.2 molar solution of cadmium chloride hemihydrate ($\text{CdCl}_2 \cdot 2\frac{1}{2}\text{H}_2\text{O}$), 0.1 molar solution of ammonium thiocyanate (NH_4CNS), 5.6M (33%) of ammonium hydroxide solution, carbonated bamboo and grinded sundried bamboo stem fibers. The $\text{CdCl}_2 \cdot 2\frac{1}{2}\text{H}_2\text{O}$ was used to serve for Cd^{2+} source, NH_4CSN served for S^{2-} ion sources, while NH_4OH served dual purpose of pH adjuster (buffering agent) and complexing agent. The carbonated and sunburnt bamboo fiber which was topped down to the particle sizes of 180 μm – 250 μm were use as dopants. For the deposition of undoped CdS thin films, 10ml of 0.2M $\text{CdCl}_2 \cdot 2\frac{1}{2}\text{H}_2\text{O}$ was measured in the 100ml beaker. The cadmium ions (Cd^{2+}) were complexed by dropping 5ml of ammonia solution into the reaction bath. The mixture was stirred thoroughly for 5mins. Thereafter 5ml of 0.1M NH_4CNS was added to the reaction bath and stirred again thoroughly. The solution was topped to a total of 90ml by addition of 70ml of distilled water. The pH of the solution was measured using pH meter to be 8.4. The whole solution was stirred once again and the clean microscopic glass slide was clamped/ mounted on polyethylene block and dipped vertically into the beakers (reaction containers) at room temperature. The glass substrate was removed from the reaction bath after 15 hours, washed and hung to dry.

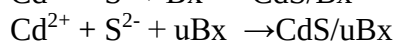
For doped cadmium sulfide thin film 5ml of solutions of the carbonated and sundried bamboo fiber were added as impurity to the mixture and processes described for undoped CdS thin film deposition.

The reaction mechanism upon hydrolysis is of the form.



The pure cadmium sulfide formation takes the form $\text{Cd}^{2+} + \text{S}^{2-} \rightarrow \text{CdS}$

The bamboo doped cadmium sulfide formation takes the form for carbonated and sundried bamboo doped samples respectively.



The effects of the bamboo dopant on the optical and structural properties of the CdS thin films were carried out using UV/VIS Spectrophotometer in the wavelength range of 200–1096 nm and GBC Emma XRD diffractometer respectively.

3. RESULT AND DISCUSSION

3.1 Optical properties

The plots of absorbance, transmittance, reflectance spectra and absorption coefficient against wavelength for as deposited thin films of pure and bamboo doped CdS are displayed in figures 3.1, 3.2, 3.3 and 3.4 respectively. The absorbance values are observed to be low throughout UV-VIS/NIR regions of electromagnetic spectrum. The absorbance is however observed to increase to maximum value of about 0.6 (60%) within the visible region for the sample (CdS/uBx) and decrease to lower value of 0.2 (20%) in the infrared regions. The transmittance of the films in the other hand is high (order of 90%) for carbonated bamboo doped (CdS/Bx) thin film, 60% for undoped CdS while 40% is accredited to sundried (CdS/uBx) but increases in the IR regions. The reflectance of the as deposited films is rather low with CdS/Bx having lowest value while undoped and CdS/uBx reflect in the range 10% to 20% throughout UV and IR regions. The absorption coefficient (α) of the films peaks at the visible regions of the electromagnetic spectrum and decreases in the NIR regions. The CdS/uBx film has highest value in the VIS region followed by undoped sample while the CdS/Bx film has lowest value in the region but all decreased towards the NIR region. The direct band gap energy of the films extrapolated from the plots of $(\alpha h\nu)^2$ against photon energy at $(\alpha h\nu)^2$ equal to zero as shown in figure 3.5 (a, b and c) indicated that undoped CdS has band gap energy of 2.15 eV, while CdS/Bx and CdS/uBx have direct band gap energy of 2.6 eV each.

3.2 Structural properties

Figures 6-7 are the x-ray diffraction (XRD) pattern of the deposited thin films for un-doped CdS, sundried bamboo doped CdS and carbonated bamboo doped CdS films respectively. The prominent peaks observed in the pattern of the un-doped CdS film confirm the crystalline nature of the CdS films. The numbers of peaks were equally observed to increase as a result of doping the CdS films with sundried bamboo extract as impurity and the peaks were broader as observed in their pattern in figure 6. In contrary the XRD pattern of the carbonated bamboo doped CdS has no peaks rather there is more of noise amorphous in nature as shown in figure 7. Hence doping CdS with sundried bamboo extract gives rise to polycrystalline films as there were increases in the broader numbers of peaks.

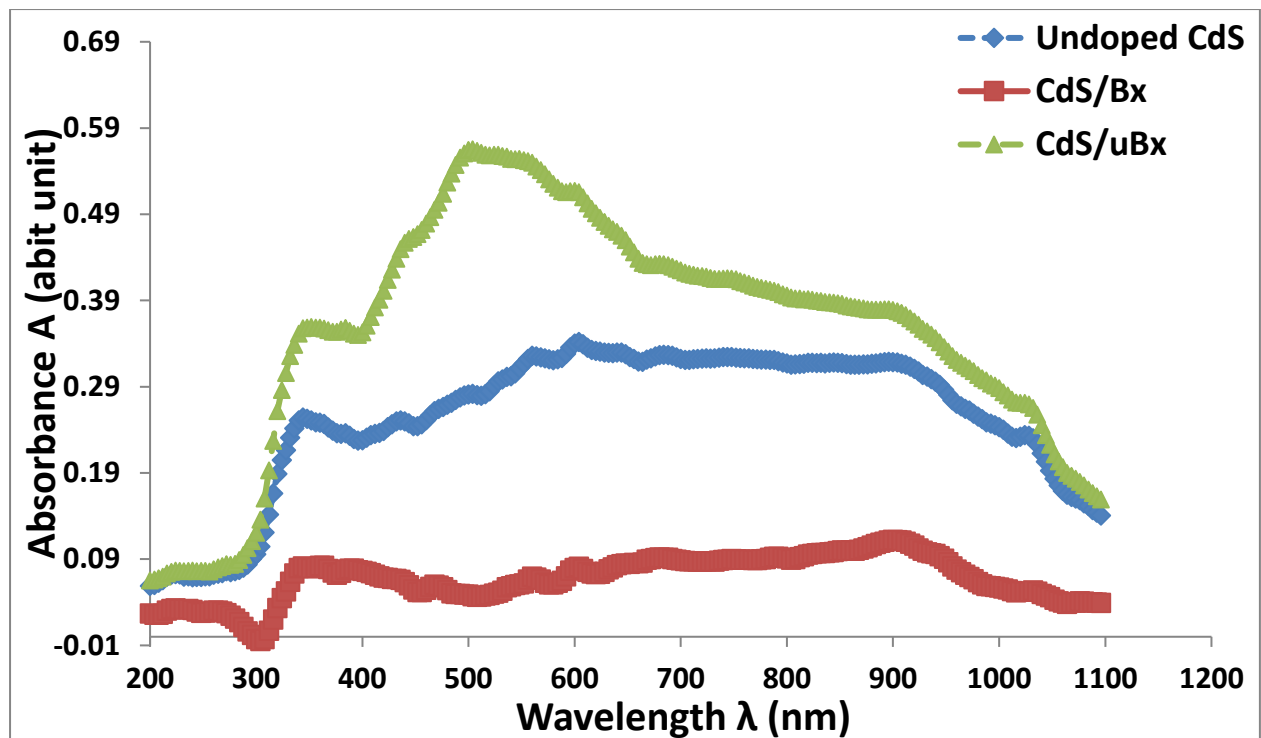


Figure 1: Plot of Absorbance against Wavelength of undoped and doped CdS thin films

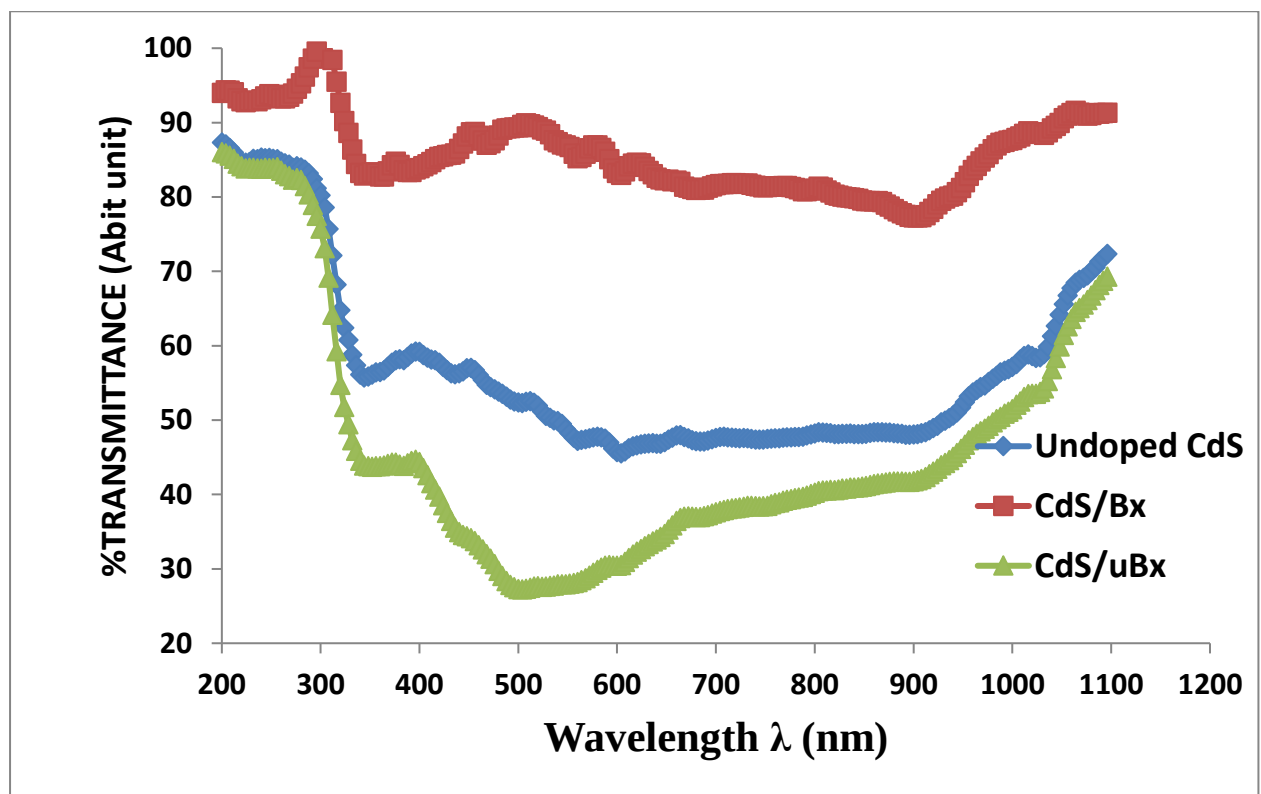


Figure 2: Plot of %Transmittance against Wavelength of undoped and doped CdS thin films

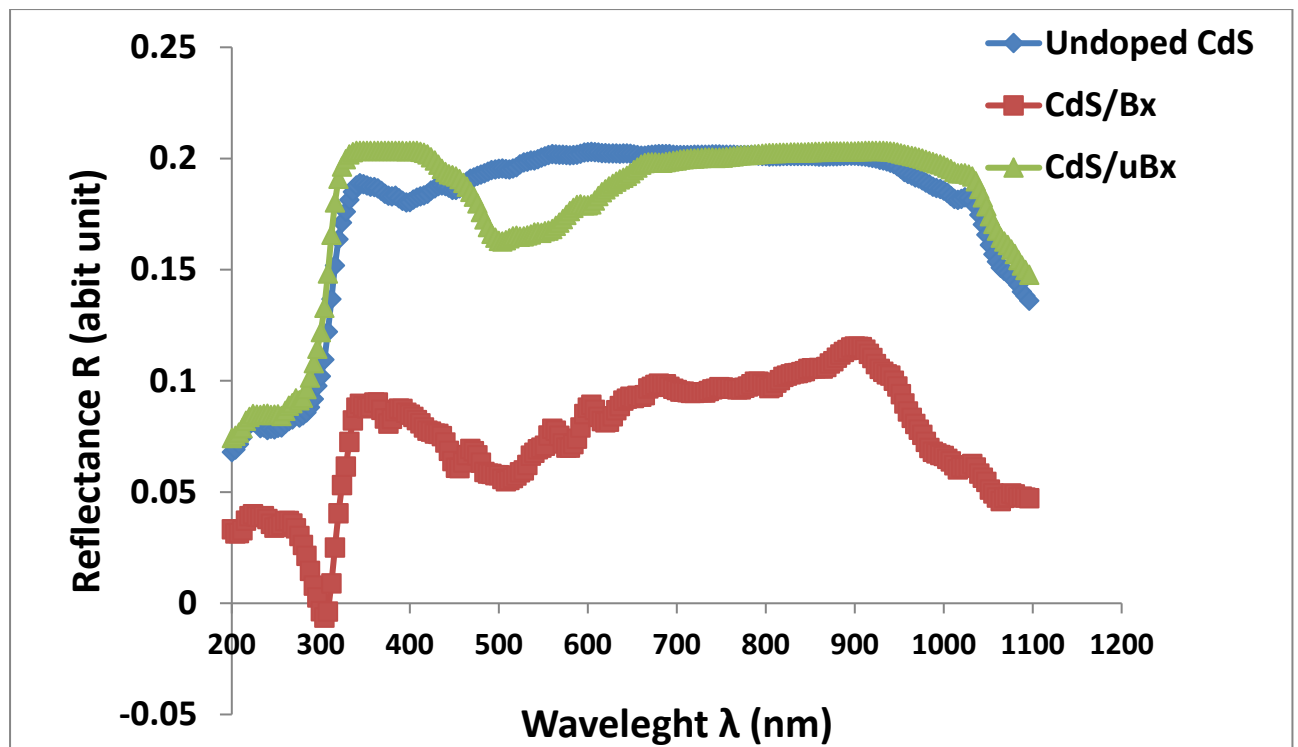


Figure 3: Plot of Reflectance against Wavelength of undoped and doped CdS thin films

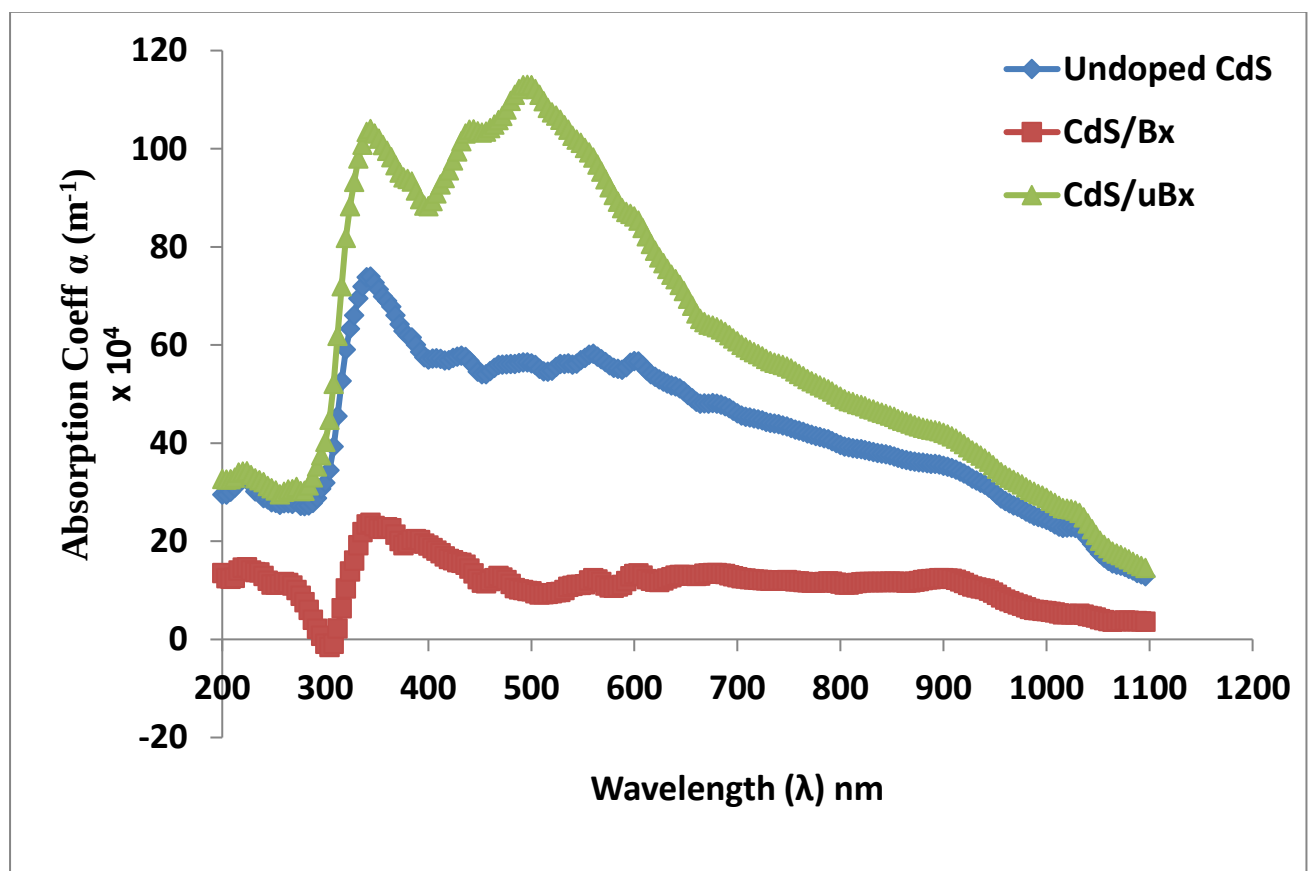


Figure 4: Plot of Absorption coefficient against Wavelength of undoped and doped CdS thin films.

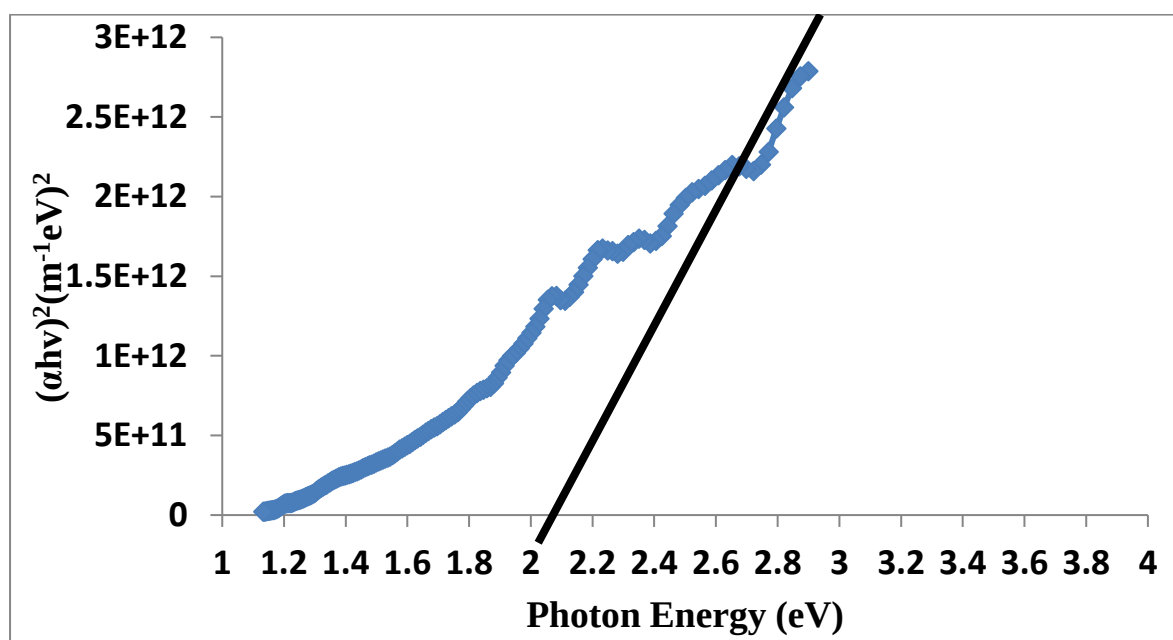


Figure 5a: Graph of $(\alpha h\nu)^2$ against Photon Energy ($h\nu$) for undoped CdS. The energy band gap for undoped CdS here is 2.15 eV.

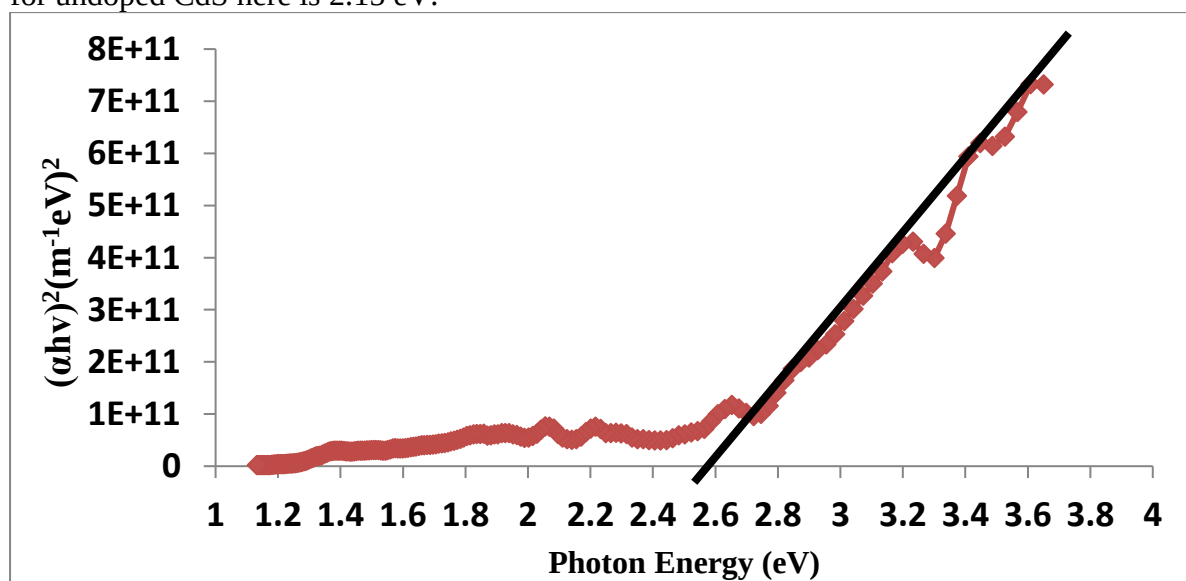


Figure 5b: Graph of $(\alpha h\nu)^2$ against Photon Energy ($h\nu$) for CdS/Bx. The energy band gap for carbonated bamboo doped CdS is 2.62 eV.

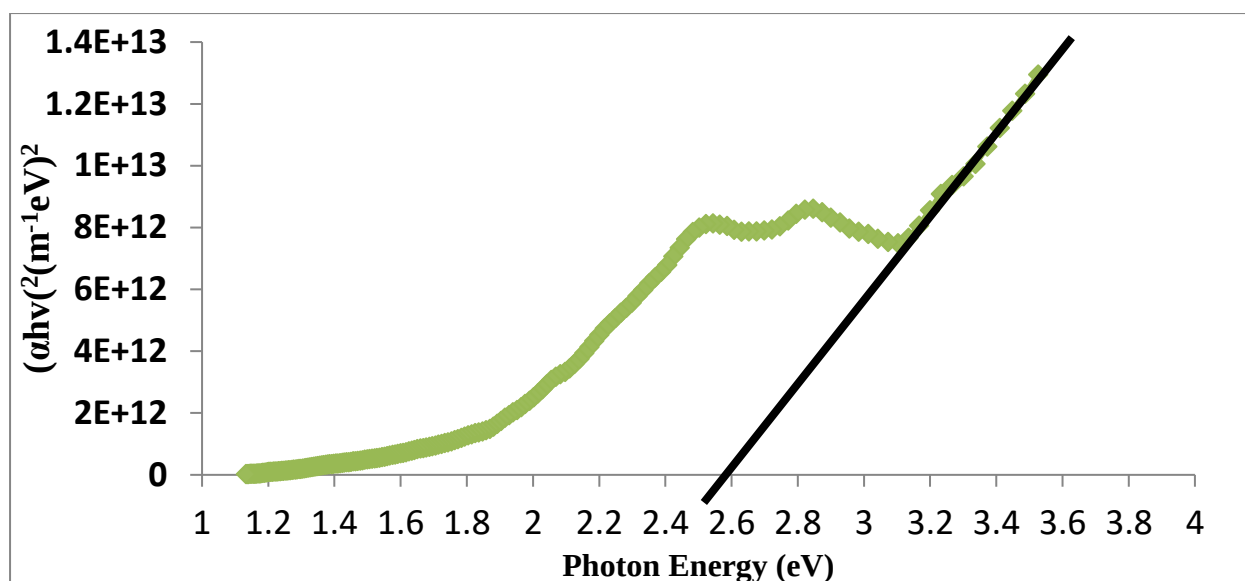


Figure 5c: Graph of $(\alpha h\nu)^2$ against Photon Energy ($h\nu$) for CdS/uBx. The band gap for the sundried bamboo doped CdS is 2.6 eV.

3.2

Structural properties

Figures 6-7 are the x-ray diffraction (XRD) pattern of the deposited thin films for un-doped CdS, sundried bamboo doped CdS and carbonated bamboo doped CdS films respectively. The prominent peaks observed in the pattern of the un-doped CdS film confirm the crystalline nature of the CdS films. The numbers of peaks were equally observed to increase as a result of doping the CdS films with sundried bamboo extract as impurity and the peaks were broader as observed in their pattern in figure 6. In contrary the XRD pattern of the carbonated bamboo doped CdS has no peaks rather there is more of noise amorphous in nature as shown in figure 7. Hence doping CdS with sundried bamboo extract gives rise to polycrystalline films as there were increases in the broader numbers of peaks.

The average grain sizes and d- spacing of the as deposited thin films of undoped CdS and bamboo doped CdS were calculated using Debye-Scherrer's formula and Bragg's equation (Nath *et al.* 2007).

$$D = \frac{K\lambda}{\beta \cos\theta} \quad 1$$

where D is average grain size, K is peak shape coefficient, = 0.85 in our case, β is the Full Weight at Half Maximum (FWHM) = 0.12 degree, λ is X-ray wavelength ($\text{CuK}\alpha = 1.54059\text{\AA}$) and θ is the Bragg's angle.

The observed and calculated parameters were used to compare with the standard powder diffraction file for CdS published by the international centre for diffraction data (ICDD) card number 00-001-0647, and presented in the Table 1.

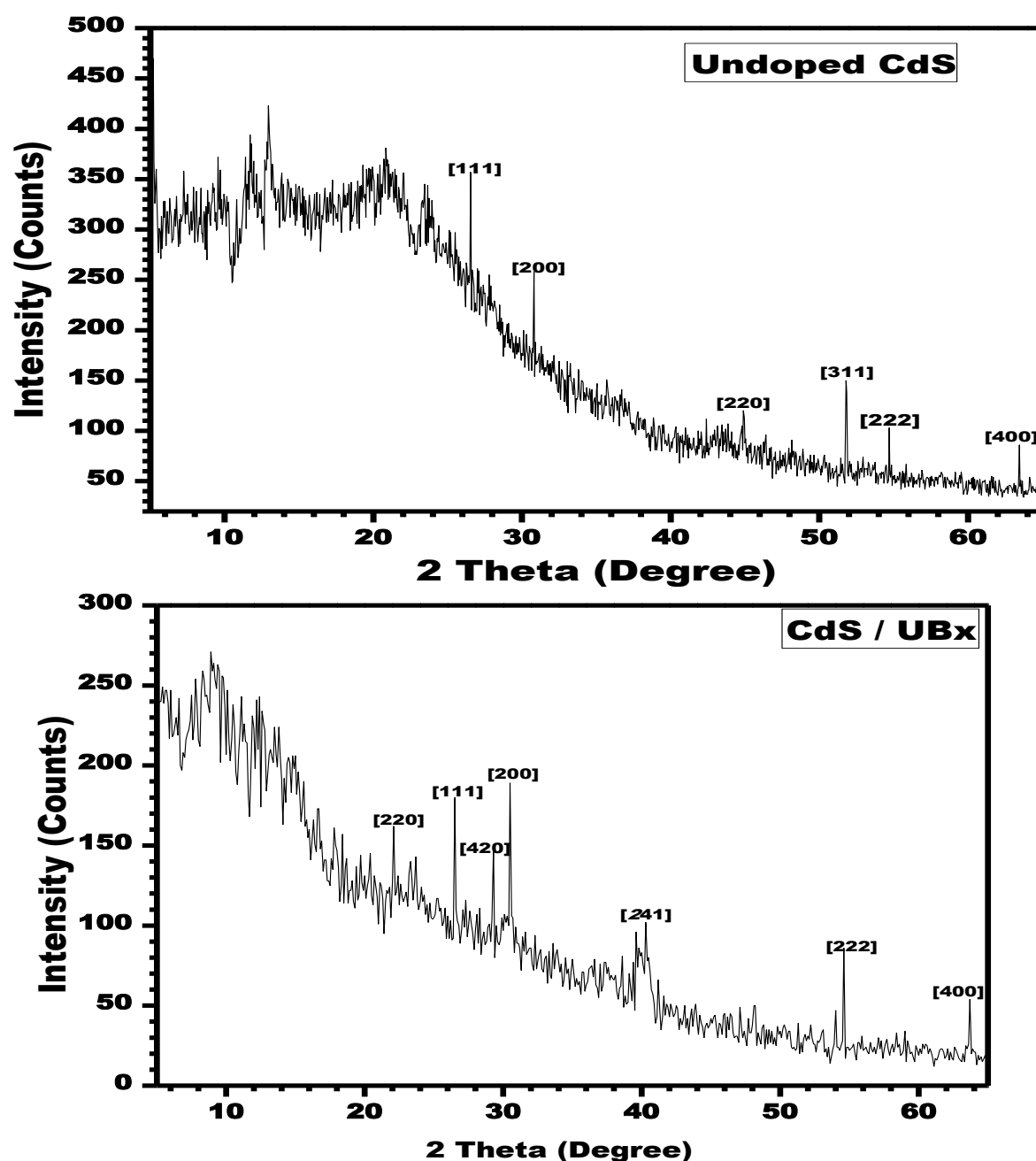


Figure 6: XRD Pattern of undoped CdS and XRD Pattern of Sun dried bamboo (CdS/uBx).

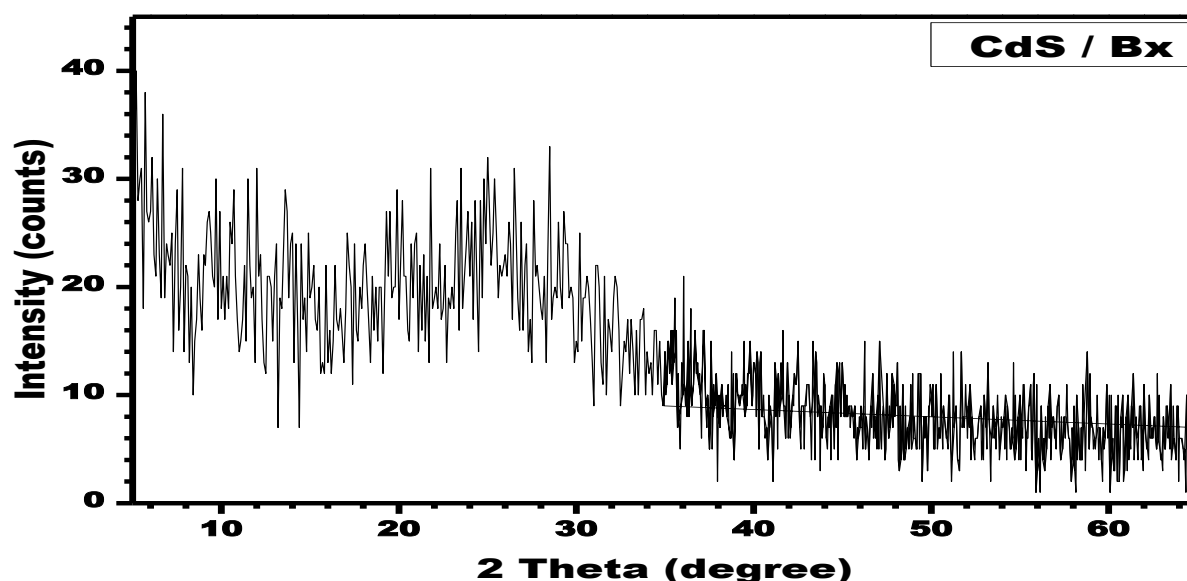


Figure 8: XRD Pattern of carbonated bamboo doped CdS (CdS/Bx).

Table 1: XRD Analysis of pure and sun-dry bamboo doped CdS (CdS/uBx)

Standard Values		Experimental Values							
CdS		Un-doped CdS		Doped CdS (CdS/uBx)		Plane (hkl)	FWHM (deg)	Crystallite Size (nm)	
2θ (deg)	d-spacing (Å)	2θ (deg)	d-spacing (Å)	2θ (deg)	d-spacing (Å)			Pure CdS	CdS/uBx
22.11	4.02	--	--	22.07	4.03	220	0.1200	--	63.70
26.50	3.36	26.55	3.35	26.55	3.35	111	0.1200	64.24	64.24
29.29	3.05	--	--	29.26	3.06	420	0.1200	--	64.62
30.81	2.90	30.54	2.93	30.55	2.93	200	0.1200	64.81	64.81
40.38	2.23	--	--	40.35	2.24	-241	0.1200	--	66.61
51.91	1.76	51.80	1.76	--	--	311	0.1200	69.51	--
54.58	1.68	54.68	1.68	54.50	1.68	222	0.1200	70.39	70.32
63.69	1.46	63.49	1.46	63.72	1.46	400	0.1200	73.53	73.61

4. SUMMARY AND CONCLUSION

Un-doped and bamboo doped cadmium sulfide (CdS) thin films were deposited on microscopic glass slides using chemical bath method at room temperature using cadmium chloride hemihydrate ($\text{CdCl}_2 \cdot 2\frac{1}{2}\text{H}_2\text{O}$) and ammonium thiocyanate (NH_4CNS), as sources of Cd and S ions respectively. Comparison of the optical and structural properties of the un-doped and bamboo doped CdS thin films were carried out. The results of the analysis done on the as deposited thin films using bamboo extracts as dopant in place of conventional material have actually altered the structural and optical properties of CdS thin films. The absorbance values un-doped CdS films are low throughout UV-VIS/NIR regions but to increases to maximum value of about 0.6 (60%) within the visible region for the sample (CdS/uBx) and decrease to lower value of 0.2 (20%) in the infrared regions. The transmittance of carbonated bamboo doped (CdS/Bx) thin films is high (order of 90%), undoped CdS has value of 60% while sundried (CdS/uBx) got value of 40% in the UV-VIS/NIR regions. The band gap energy increases from value of 2.15 eV to 2.6 eV as result of doping CdS with bamboo extract as impurity. The films doped with

sundried bamboo fiber (CdS/uBx) are polycrystalline in nature; un-doped CdS films are crystalline while carbonated bamboo doped (CdS/Bx) thin films amorphous in nature. Due these properties displayed by thin films CdS deposited under this condition, the films have good applications in the following areas: Heat Mirror Coating, Anti-reflection Coating, Solar Energy Application, High Temperature materials and High temperature Superconductor Applications.

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