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Optical Properties of Bamboo Doped Cadmium Sulfide Thin Film for Industrial Applications

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Abstract

Thin films of bamboo doped cadmium sulfide were deposited on glass substrates using chemical bath method. The effect of deposition time on the optical properties of the films were studied. Cadmium chloride ($CdCl_2 2½H_2O$) and ammonium thiocynate (NH_4CNS) were used as the sources of Cd^{2+} and S^{2-} ions respectively. The dopant, bamboo fibre extract was whittled down using top down approach and sieved. The optical properties of the deposited bamboo doped CdS thin films were analyzed using UV/VIS Spectrophotometer in the range of 200-1100 nm. The result of the analysis indicated that the absorbance, transmittance, refractive index, extinction coefficient, optical conductivity and band gap energy were dependent on deposition time. The reflectance of the films was generally low despite deposition time. The transmittance decreased in the visible region but increased in the infrared range. This showed that the materials grown can be used in solar energy applications. The band gap values for different deposition times of the deposited films were found to be 2.75 eV for 3 hours, 2.80 eV for 6 hours and 2.70 eV for 9 hours, 2.75 eV for 12 hours and 2.65eV for 15 hours deposition times. This showed that materials grown have wide band gap and can be used in high temperature technology, electronics and opto-electronic applications.

Keyword: *Cadmium sulfide, Bamboo doped, Deposition time and Chemical bath.*

1. INTRODUCTION

Doping of binary or ternary semiconducting thin films is of great importance in semiconductor industries as many materials of great interest in industrial applications are been discovered through this process. Doping of semiconducting compounds with any foreign material is either aimed at raising Fermi level to the bottom of the conduction band or lowering the Fermi level to the top of the valence band of the parent materials. This process will give rise to either n-type or a p-type (extrinsic semiconductor), which is of great interest for many industrial applications. Beside zinc oxide and zinc sulphide, cadmium chalcogenides are the prototypical systems of the II–VI semiconductor compounds. Already for many years, cadmium sulphide (CdS) has been used as a pigment because of its colour. Solid CdS is a yellow material, due to its band gap of 2.58 eV. It provides useful properties for optoelectronic devices, such as photosensitive and photovoltaic devices or as photo resistors.

The efficiency of CdS semiconductor film has been noted to improve by changing its optical and/or electrical properties through doping with some foreign elements such as Copper, Gallium, Erbium and many other elements, Petre *et al.* (1999). Tin (Sn) doped CdS films, produced by using tartaric acid as the complexing agent, showed low transparency, Roy and Srivastava (2009). Since the transmittance of light is the most important requirement of the window layer in a thin film structured solar cell, the search for methods to form very high transparent CdS films by doping Sn is highly warranted. The Al-doped CdS thin films were used to remove methylene blue dye from an aqueous solution in presence of UV light, Bharat *et al.* (2011).

Although, CdS is commonly reported to grow as an n-type semiconductor, some reports have demonstrated p-type grown CdS, Sebastian *et al*. (1993). Furthermore,, doping the CdS films with other chemical elements during the CBD process has affected the resulting physicochemical properties of the doped CdS films, such as the electrical resistivity, band gap energy and crystalline structure. Sebastian et al. (1993) reported a decrease on the CdS band gap energy, as low as 2.0 eV, by using Cu as a doping element during the CBD process. Similar results for the band gap energy were reported by Portillo-Moreno et al. (2006) but using different chemical reagents when doping CdS with Cu. Lee *et al*. (2000) used boron as CdS doping element and reported an increase on the boron-doped CdS electrical resistance. They also reported changes on the crystalline structure of the boron-doped CdS after carrying out an annealing process under different gas environments. To date, several elements such as aluminum, Khallaf *et al.* (2008), tin, Roy and Srivastava **(2006**) and erbium (Davila-Pintle et al. (2007), have been reported to decrease the band gap energy and electrical resistivity of the CdS when used as doping elements.

Hamid and Taha (2013) studied the effect of percentage of indium doping on the structural and optical properties of CdS nanoparticle thin films prepared by CBD technique. Optical properties studies revealed that CdS or CdS thin films have transmittances that depended on the doping ratio with allow direct transition of the optical band gap, which varied from 3.84 eV for un-doped CdS to 3.79 eV for 5% In doped CdS.

A survey of literature reviewed that most of the materials used as dopant to alter the properties of CdS thin films were conventional elements/material while no effort have been made to utilize our local materials like bamboo and others.

2.0 MATERIALS AND METHOD

The cadmium sulfide thin films for the experiment were synthesized by simple, cheap and cost effective chemical bath deposition method of thin film deposition. Empty microscope slides of sizes 25.4 x 76.2m and thickness range of 1mm-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

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reagents/reactants used for the experiment were: 0.2 molar solution of cadmium chloride hemihydrate ($CdCl_2 2½H_2O$), 0.1 molar solution of ammonium thiocynate (NH_4CNS), 5.6M (33%) of ammonium hydroxide solution, carbonated bamboo and grinded sundried bamboo stem fibres. The $CdCl_2.2½H_2O$ was used to serve for Cd^{2+} source, 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 sundry bamboo fiber (uBx) which was topped down to the particle sizes of 180µm-250µm is use as dopants. The reaction mechanism upon hydrolysis is of the form.

$$2CdCl_2 2½H_2O \longleftrightarrow Cd^{2+} + 4Cl^- + 5H_2O \qquad 2.1$$

$$NH_4CNS + OH^- \longleftrightarrow S^{2-} + NH_4CN^- + H_2O \qquad 2.2$$

$$NH_4OH \longleftrightarrow NH_4^+ + OH^- \qquad 2.3$$

$$uBx + H_2O \longleftrightarrow uBx_{solution} \qquad 2.4$$

The bamboo doped cadmium sulfide formation takes the form

$$Cd^{2+} + S^{2-} + uBx \longrightarrow CdS/uBx \qquad 2.5$$

Table 2.1: Time variation for Bamboo doped CdS

Reaction Baths	pH	Dip Time	$CdCl_2 2½H_2O$		NH_4CNS		NH_4OH	uBx/ Bx	Distilled H_2O
		(hrs)	Conc (M)	Vol (ml)	Conc (M)	Vol (ml)	Vol (ml)	Vol (ml)	Vol (ml)
E3	8.4	3	0.2	10	0.1	5	5	5	70

E6	8.4	6	0.2	10	0.1	5	5	5	70
E9	8.4	9	0.2	10	0.1	5	5	5	70
E12	8.4	12	0.2	10	0.1	5	5	5	70
E15	8.4	15	0.2	10	0.1	5	5	5	70

3.0 RESULTS AND DISCUSSIONS

The Optical Properties

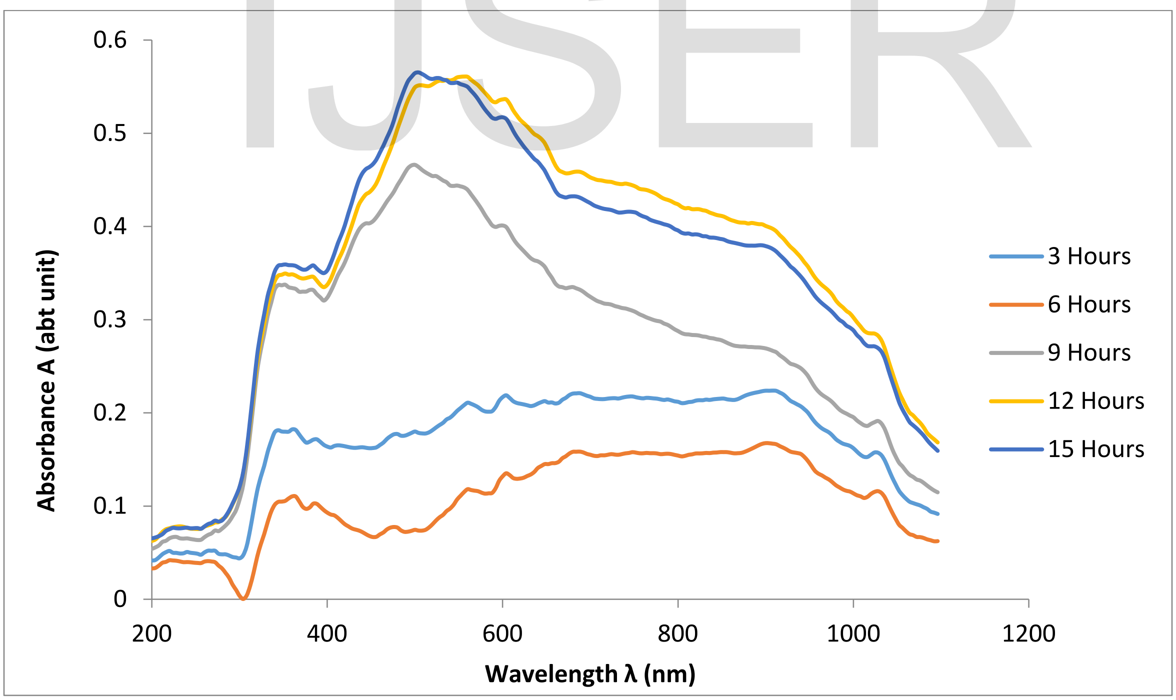

Figure 1: Plot of Absorbance against wavelength for the sundried bamboo doped CdS thin films.

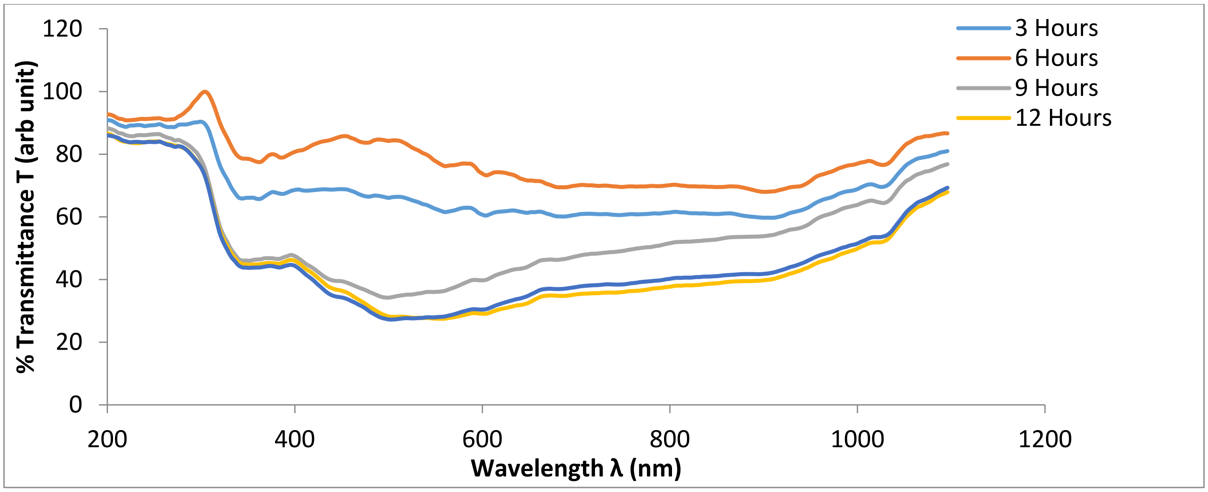

Figure 2: Plot of % Transmittance against wavelength for the sundried bamboo doped CdS thin films.

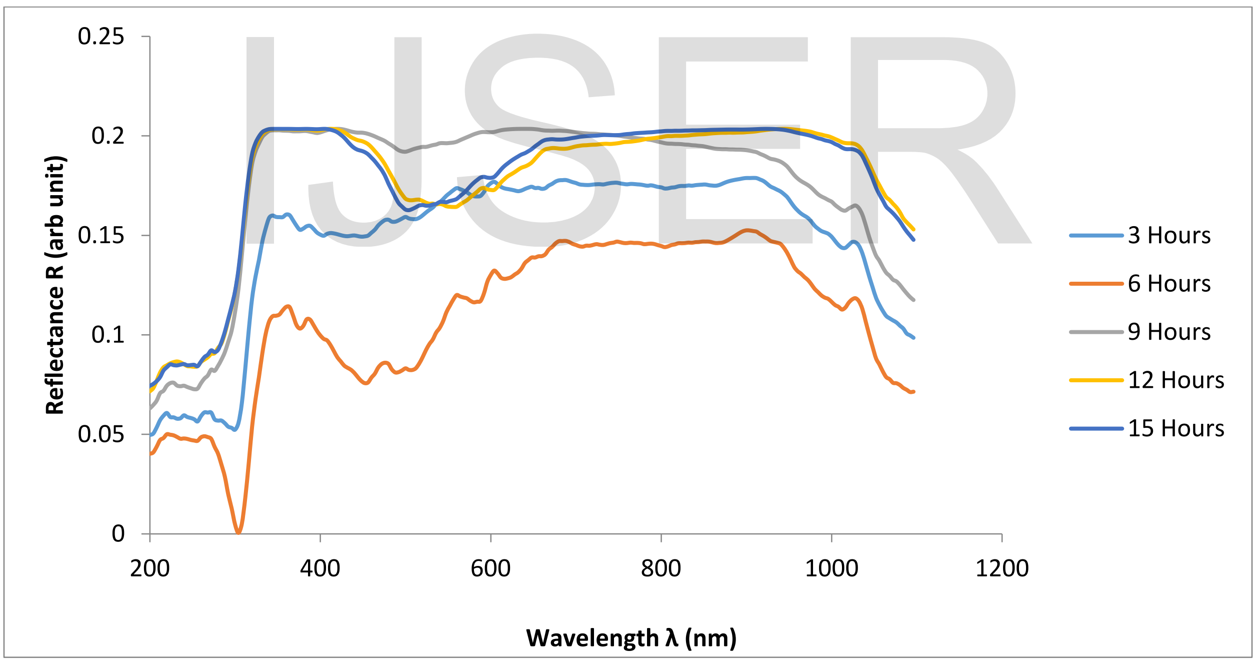

Figure 3: Plot of Reflectance against wavelength for the sundried bamboo doped CdS thin films.

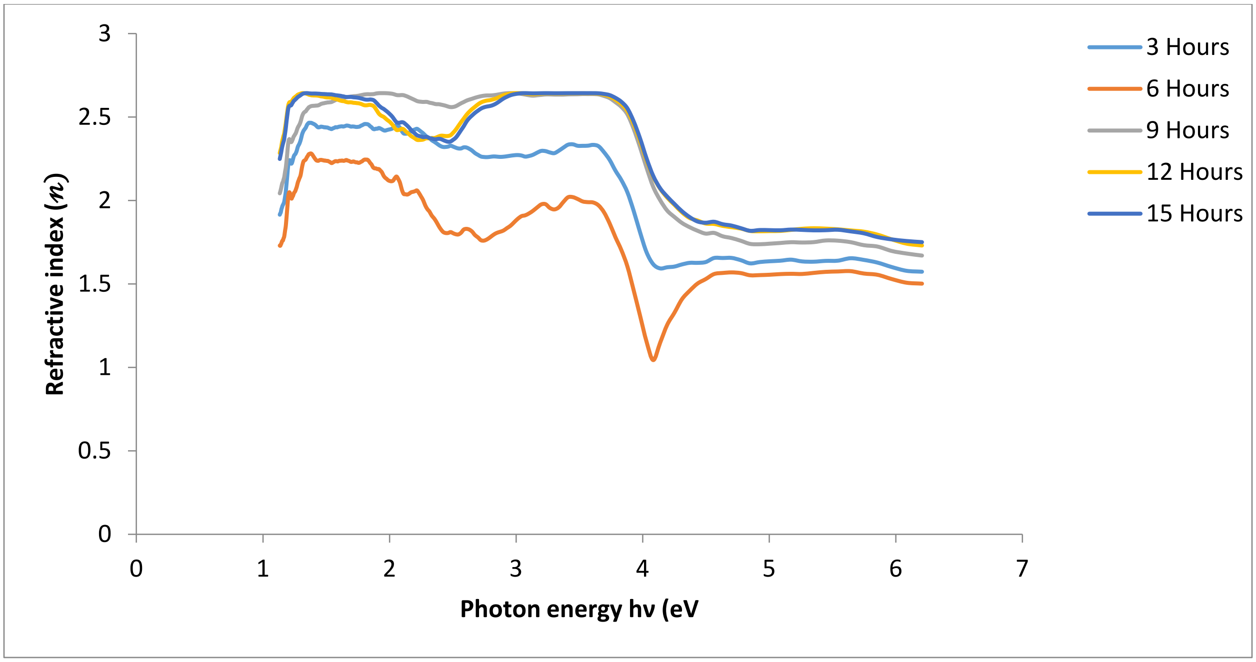

Figure 4: Plot of refractive index (n) against Photon energy (hv) for the sundried bamboo doped CdS thin films.

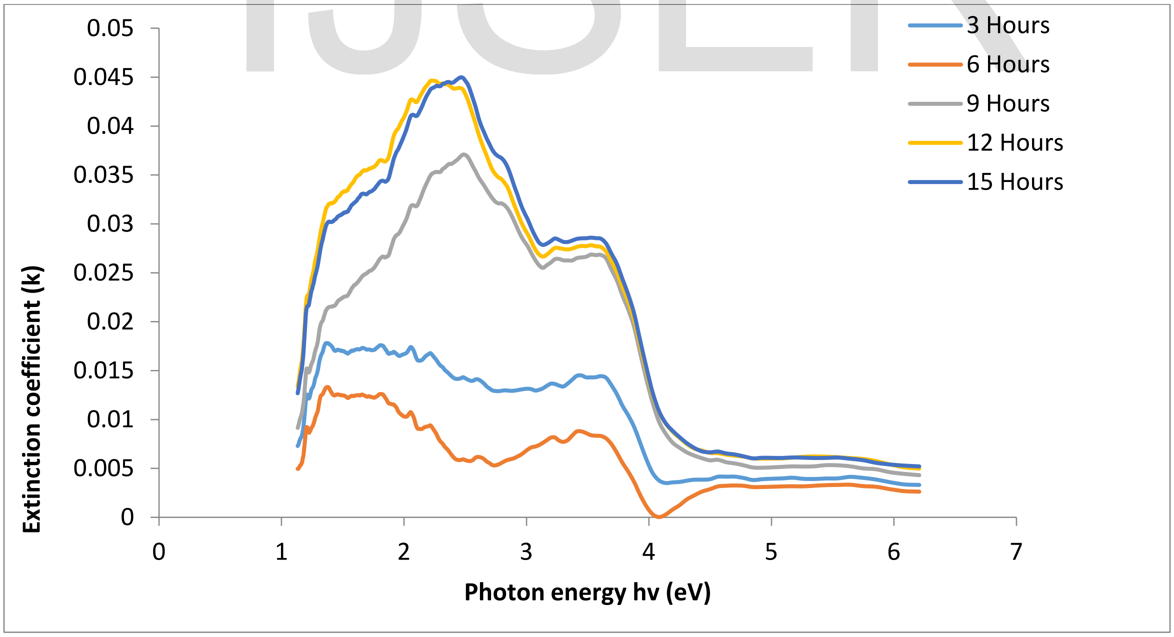

Figure 5: Plot of Extinction coefficient (k) against Photon energy (hv) for the sundried bamboo doped CdS thin films.

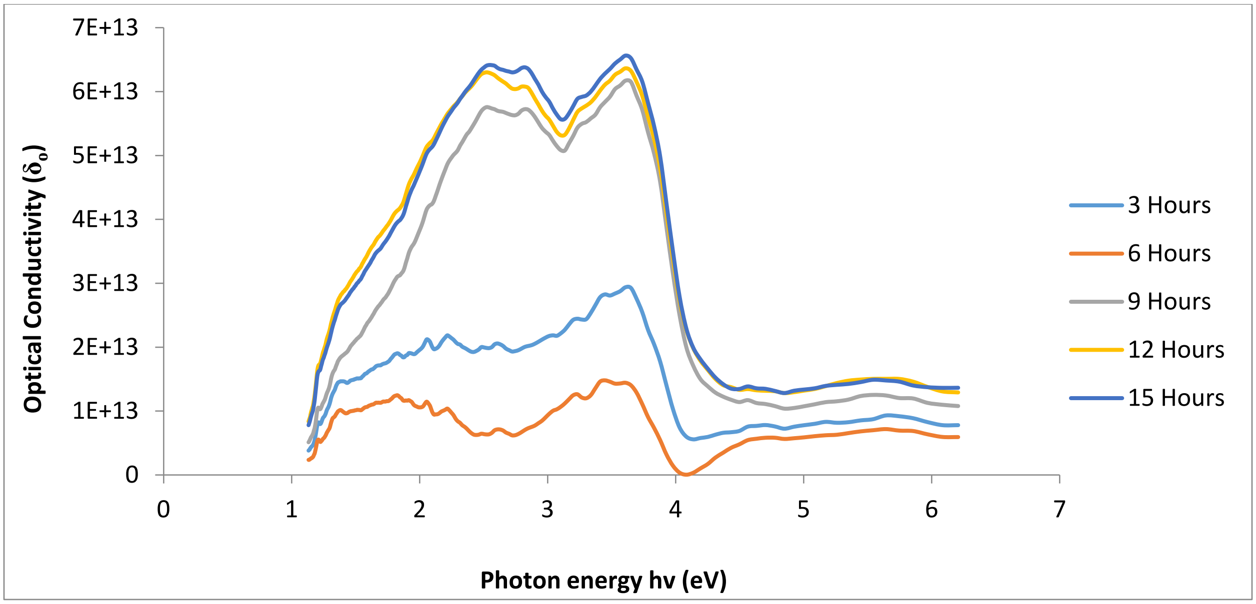

Figure 6: Plot of Optical conductivity (δ_o) against Photon energy (hv) for the sundried bamboo doped CdS thin films.

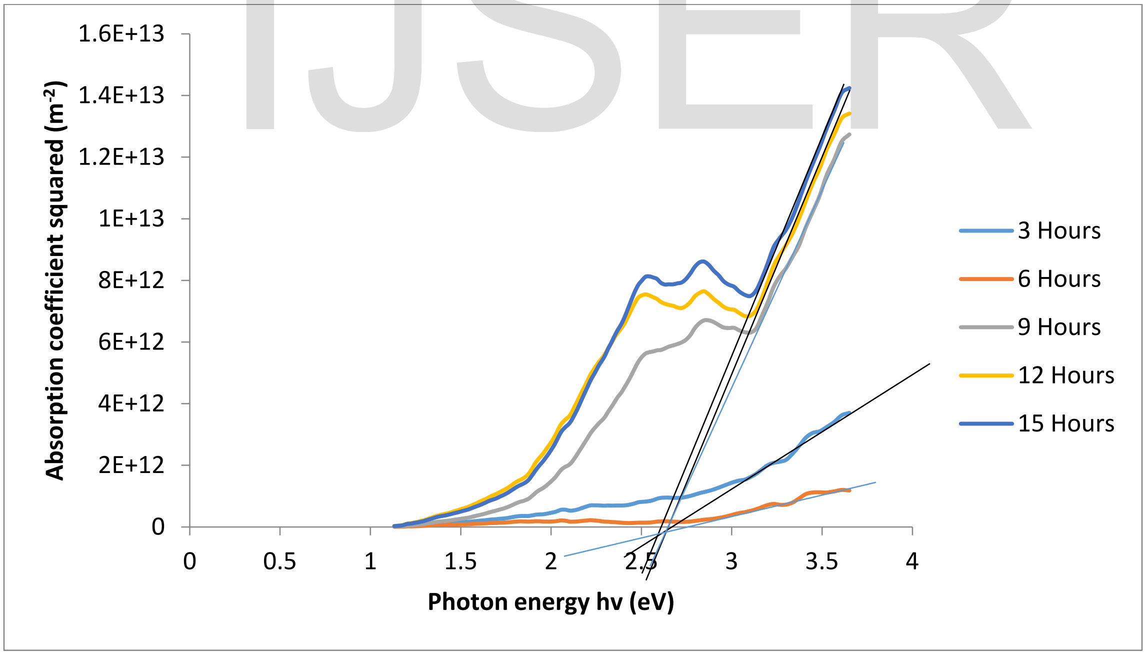

Figure 7: Plot of square of absorption coefficient $(\alpha hv)^2$ against Photon energy (hv) for the sundried bamboo doped CdS thin films.

4. DISCUSSIONS

The plot of absorbance of the film against wavelength is shown in figure 1. It was observed that the absorbance of the bamboo doped CdS films increased as the deposition time increased. The absorbance of the films deposited in the longer deposition times of 9 to 15 hours showed high value in the range of 50 to 60% in the visible region while those deposited in the shorter deposition times of 3 and 6 hours displayed lower absorbance values of 20%. The absorbance of all the films decreased to 10% no matter the deposition time in the near infrared region of electromagnetic spectrum. In figure 2, the transmittance decreased in the visible region and increased in the infrared region. In figure 3, the reflectance value of the films is small (only in the range of 10 to 20%) throughout the UV, VIS and NIR regions of electromagnetic spectrum. The plot of refractive index against photon energy is displayed in figure 4. From the figure, it was observed that the refractive index was high in the range of 2.0 to 2.6 in the photon energy range of 1.0 to 4.0eV but decreased to 1.5 as photon energy increased. The plots of the extinction coefficient and optical conductivity against photon energy were shown in figures 5 and 6 respectively. Both figures showed that the extinction coefficient and optical conductivity increased as deposition time increased. It was observed that both values were high in the photon energy range of 1.0 to 4.0eV but decreased as photon energy increased beyond 4.0eV. Figure 7 is a plot of square of absorption coefficient against photon energy (hv). The band gap values were determined by extrapolating straight line portion of the photon energy axis of the graph. The band gap values for different deposition times of the deposited films were found to be 2.75eV for 3hours, 2.80eV for 6hours, 2.70eV for 9hours, 2.75eV for 12 hours and 2.65eV for 15 hours deposition times. The samples grown were wide band gap materials and as such can be used in high temperature, high power and high frequency materials; solar energy and electronic technologies, Okpala et-al. (2012).

CONCLUSION

Bamboo doped cadmium sulfide thin films have been deposited on glass substrate using chemical bath deposition method. The optical properties of the thin films were analyzed in the wavelength range of 200 to 1100nm using UV/VIS Spectrophotometer. The results of the analysis showed that the optical properties; absorbance and transmittance were dependent on the deposition times of the bamboo doped CdS thin films. The reflectance of the films was generally low and independent of the deposition time. The films have wide band gap in the range of 2.65eV -2.80eV and as such were good materials for high temperature, high power and opto-electronic applications. The materials were highly transmitting from near infra-red to the infra-red region and as such are good materials for poultry and solar energy applications, Okpala (2013).

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