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SYNTHESIS AND CHARACTERIZATION OF CHEMICAL BATH DEPOSITED CdCoS THIN FILM

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Thin film of ternary CdCoS has been deposited on microscopic glass substrate using the Chemical Bath Deposition (CBD) technique. The film was characterized using UNICO UV-2102 PC spectrophotometer in the UV – VIS – NIR region. The optical and dielectric properties of the film show that it has high transmittance in the VIS – NIR range (>50%) which was moderate at the UV range (<50%) with markedly low reflectance (3.52 – 20.57%) which declined albeit exponentially within the entire wavelength range. The band gap energy of 2.10eV for film deposited for 14h and 2.53eV for that deposited for 17h with other studied properties show that this film is a good material for optical window layers for photocells; fabrication of solar cells; antireflective coating material and coating for poultry houses.

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1. Introduction

There has been increased interest in the properties of metal – metal chalcogenide materials [Chopra and Das 1983; Mane and Lokhande 2002; Petkov *et al* 2004; Mahmoud *et al* 2002; Sedeek *et al* 1994; Hidenori *et al* 2008], due to their efficient solar energy conversion ratio, and as such a potential candidate for photo – electrochemical solar cells fabrication [Lee *et al* 2003; Pentia *et al* 2004]. Of paramount technological importance is that micro-crystallites of the mixed CdCoS have high optical and mechanical properties that can be harnessed for possible application as filter materials; temperature sensors; optical waveguides etc [Ezema and Osuji 2007; Stageman and Seaton 1985; Sifuentes *et al* 2000].

The chemical bath deposition technique has been used in this analysis not necessary due to its relative cheapness (and as such the most available for research in developing countries where other highly expensive and technically advanced methods are not readily available) but because it is a simple way to deposit and fabrication large area metal chalcogenide thin films [Kale and Lokhande 2005; Ezema 2005; Bindu *et al* 2005], easy coating process of complex shaped substrates and possibility of using high purity starting materials for the growth of the thin film. The CBD method also offers wider choices of materials to be used (insulators, semiconductors or metals) since it is a low temperature process which avoid oxidation and corrosion of substrates; facilitates better orientation of crystallites with improved grain structure [Mane and Lokhande 2002].

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2. Experimentation

The Cadmium Cobalt Sulphide (CdCoS) thin film was deposited on glass slides using the Chemical Bath Deposition (CBD) technique at room temperature (300K) which is basically an ion – by – ion exchange. The slides were initially degreased in HCl for 24h, cleaned in cold water with detergent, rinsed in distilled water and dried in open air. The reaction bath for the deposition of CdCoS contained 1M 2mL $CdCl_2$; 0.25M 3mL $CoCl_2$; 1.0M 10 mL thiourea; 14M 5mL NH_3 and 35 mL of distilled water which were carefully added in that order and allowed for 14 and 17h deposition time respectively. The mixtures were carefully stirred to maintain homogeneity and constant pH which was close to 9.0. The kinematics of the reaction of the complex ion formation and subsequent film deposition process are:

$$CdCl_2 + 2NH_3 \rightarrow Cd(NH_3)_2 Cl_2$$

$$CoCl_2 + 2NH_3 \rightarrow Co(NH_3)_2 Cl_2$$

$$CS(NH_2)_2 + OH^- \rightarrow CH_2N_2 + H_2O + SH^-$$

$$SH^- + OH^- \rightarrow H_2O + S^{2-}$$

$$Cd(NH_3)_2 Cl_2 + Co(NH_3)_2 Cl_2 + CS(NH_2)_2 + 2OH^- \rightarrow CdCoS + CH_2N_2 + 6NH_3 . \tfrac{1}{3} Cl_2 + H_2O$$

Observe that the Sulphide ions are released from the hydrolysis of thiourea ($CS(NH_2)_2$) while the Co^{2+} and Cd^{2+} ions formed complexes: Cobalt diamine chloride ($Co(NH_3)_2 Cl_2$) and Cadmium diamine chloride ($Cd(NH_3)_2 Cl_2$) respectively by reacting with NH_3. These two complexes adhered firmly to the substrate surface forming a heterogeneous nucleation and subsequently growth by ions exchange of S^{2-} ions, a process which have come to be known as ion – by – ion exchange. The deposited film (CdCoS) was yellowish in colouration, transparent, homogeneous and adhered firmly to the glass slide. It was also observed to be insoluble in water but readily dissolves in dilute HCl.

The deposited film was characterized using UNICO UV-2102 PC spectrophotometer in the UV – VIS – NIR region and the solid state and optical properties calculated. The optical properties investigated were Absorbance (A); Transmittance (T) and Reflectance (R) which were subsequently used to calculate other properties: Extinction coefficient (k); Refractive index (n); Dielectric constant (ε); Optical conductivity (σ) and the band gap energy (E_g) which were deduced from their various relations already well established in literature [Singh 2006; Pankove 1971; Okujagu 1991].

3. Results and discussion

The results of the various properties of the thin film (deposited at 14 and 17h) respectively at room temperature are as shown in figures 1 – 9.

The spectral absorbance of the film (see fig. 1) indicates that the film has low absorbance in the UV region which decreased with increasing wavelength up to the NIR region. It can be observed that the film generally exhibited poor absorbance throughout the UV – VIS – NIR region.

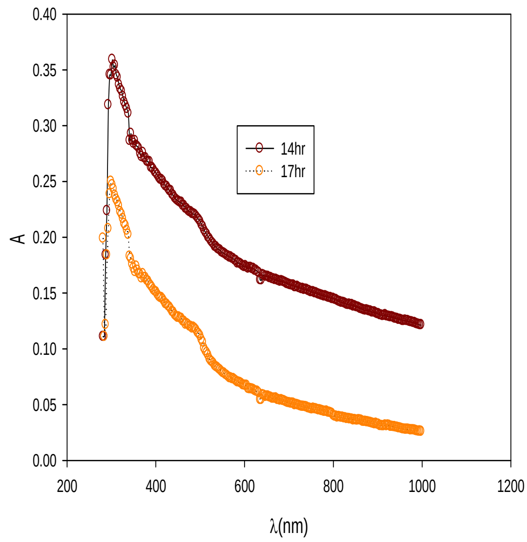

Fig. 1. Absorbance (A) as a function of wavelength (λ) for CdCoS thin film.

Figs. 2 and 3 respectively show the transmittance and reflectance as function of photon wavelength. It will be inferred that the film showed moderate transmittance in the UV region and high transmittance in the VIS – NIR regions of the electromagnetic spectrum. Conversely from fig. 3, it will be observed that the film exhibited low reflectance (3.52 – 20.57%) within the same wavelength range which declined exponentially. The observed high transmittance and low reflectance exhibited by the film makes it good candidate for solar thermal application in flat plate collectors, fabrication of antireflective coating materials, material for coating poultry roofs and walls. The moderately lower transmittance exhibited by the film in the UV region suggests that they can be harnessed for possible application in screening off UV portion of the electromagnetic spectrum which is known to be harmful to humans and domestic animals.

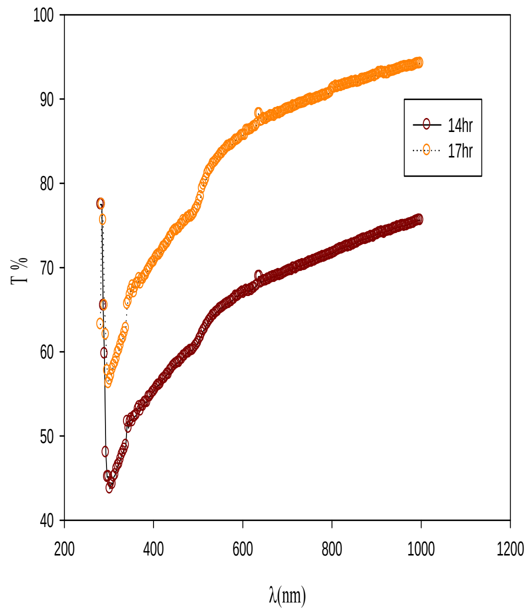

Fig. 2. Transmittance (T) as a function of wavelength (λ) for CdCoS thin film.

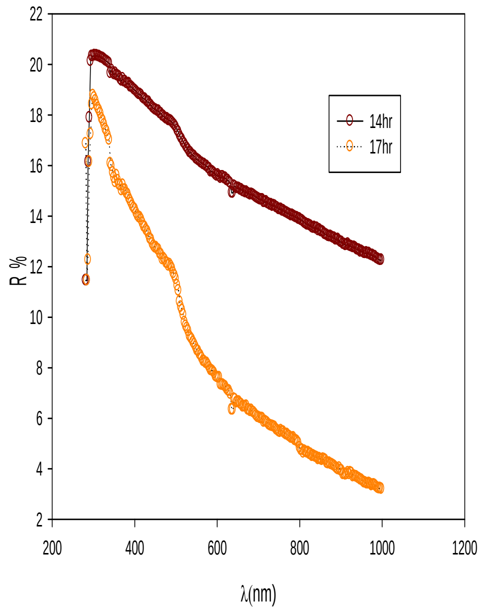

Fig. 3. Reflectance (R) as a function of wavelength (λ) for CdCoS thin film.

Fig. 4 shows the plot of the refractive index as a function of photon energy; fig. 5 is that of absorption coefficient against photon energy which though increased but very low coefficient values while fig. 6 is that of extinction coefficient (*k*) also as a function of photon energy. The average value of *n* is in the range 1.65 – 2.20 and was found to increase within the entire photon energy being studied. The behaviour of *k* for the samples needs to be pointed out. For film deposited for 14h, it was almost linear while for 17h, it had minimum at $5.26x10^{-3}$ and a maximum at $13.56x10^{-3}$.

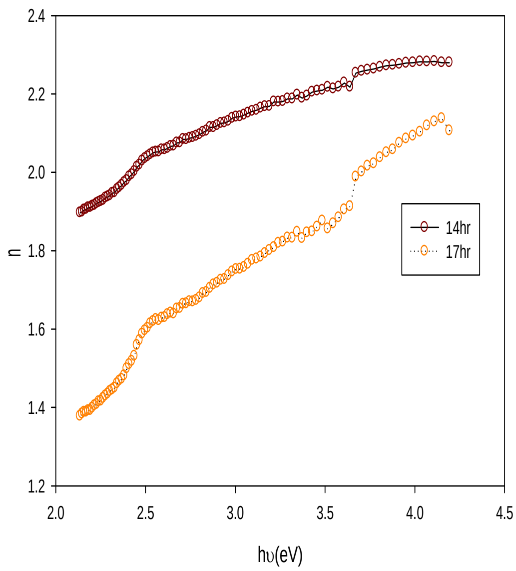

Fig. 4. Refractive index (n) as a function of photon energy (hv) for CdCoS thin film.

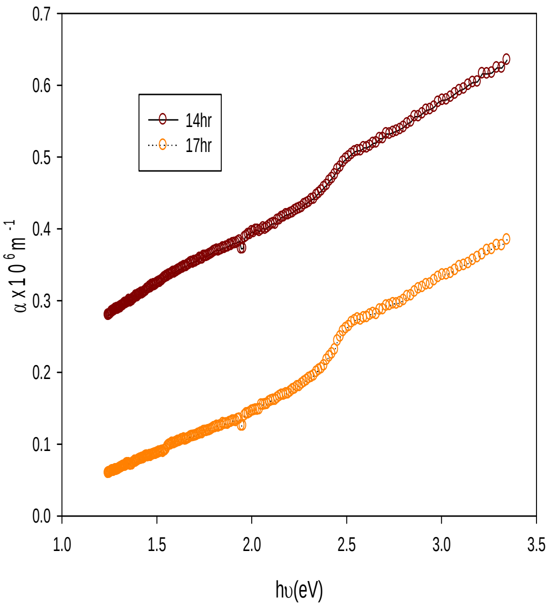

Fig. 5. Absorption coefficient as a function of photon energy (hv) for CdCoS thin film.

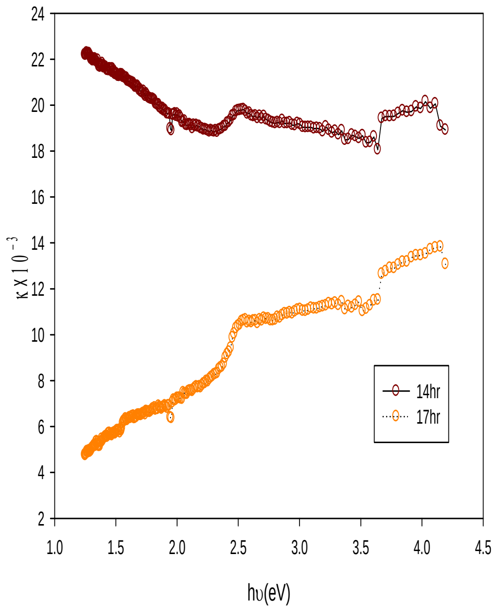

Fig. 6. Extinction coefficient (k) as a function of photon energy (hv) for CdCoS thin film.

The plots of the dielectric constants (ε_r and ε_i) are as shown in figs. 7 and 8. The real (ε_r) and imaginary dielectric constant (ε_i) increased steadily within the entire photon energy for both samples. Same is observed for the optical conductivity of the films (see fig, 9).

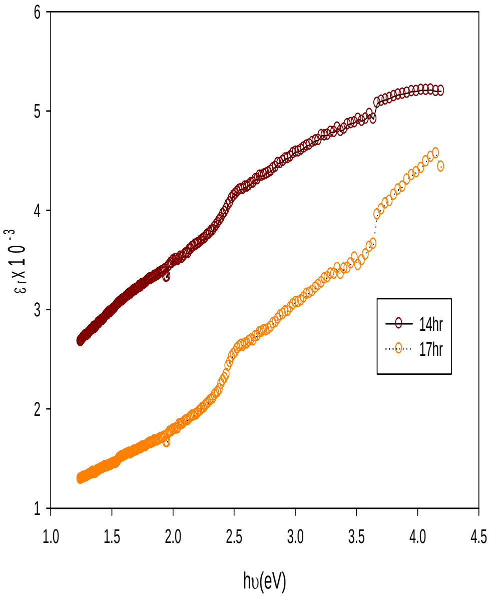

Fig. 7. Real dielectric constant as a function of photon energy (hν) for CdCoS thin film.

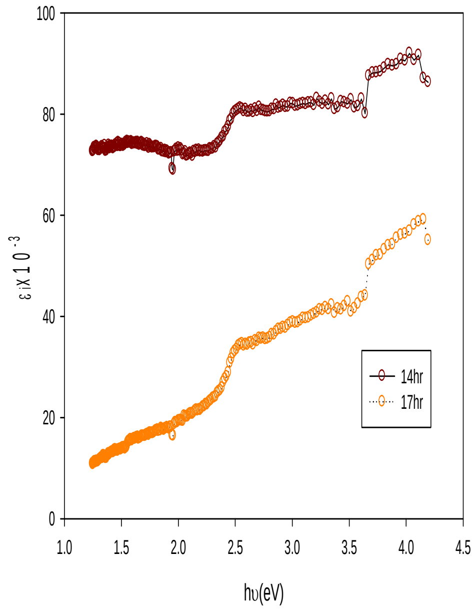

Fig. 8. Imaginary dielectric constant as a function of photon energy (hν) for CdCoS thin film.

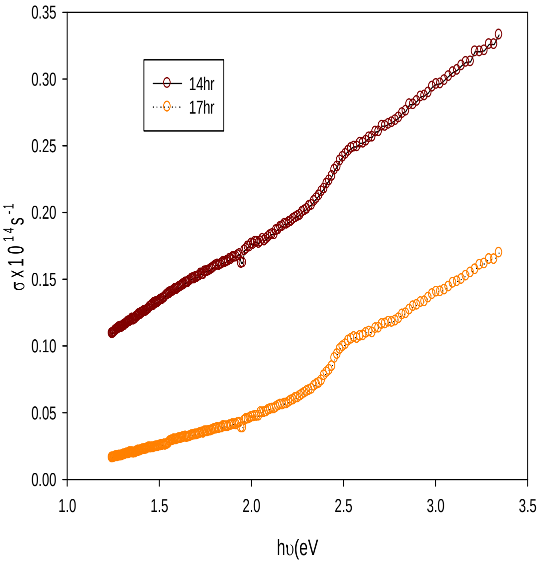

Fig. 9. Plots of conductivity (σ) as a function of photon energy (hv) for CdCoS thin film

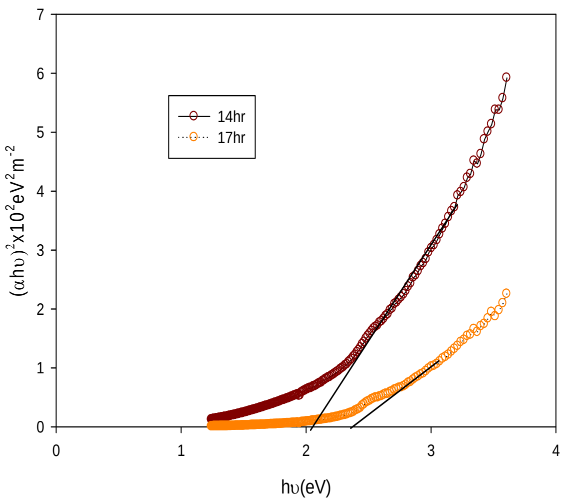

Fig.10. Plots of $(\alpha hv)^2$ as a function of photon energy (hv) for CdCoS thin film.

From fig. 10, the band gap is shown to be 2.10eV for film deposited for 14h while that deposited for 17h is 2.53eV. This value is close to the value of ~2.50eV found by George *et al* (1996); decrease from 2.43eV to 2.37eV with increasing Cobalt found by Bacaksiz *et al* (2008) using spray pyrolysis method. Suffice to note that the band gap of CdCoS found here is between that of CoS with E_g of 3.20eV (Zhenrui *et al* 2002) and CdS with E_g range of 2.38eV – 2.43eV (Ates *et al* 2007; Yu *et al* 1995; Badawi *et al* 1998; Mahanty *et al* 1999). The important remark that can be made from this is that the deposited film had lower E_g due to the formation of Cadmium rich layer. This enhanced band gap due to Cadmium rich layer makes the films good material for solar cell fabrication.

4. Conclusion

The synthesis and characterization of Cadmium Cobalt Sulphide deposited by the Chemical bath deposition (CBD) technique has been carried out. The optical and dielectric properties studied from the *T* and *R* values show that the film has interesting properties ranging from high transmittance, generally low reflectance and moderate band gap energy etc. These properties make this film of high technological applications in the fabrication of solar cells; as antireflective coatings; harnessed for possible application in screening off UV portion of the electromagnetic spectrum; could be effective material as coatings for poultry houses and even as window layers for photocells etc.

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