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PHOTO-ELECTROCHEMICAL PROPERTIES OF FLASH EVAPORATED CADMIUM SULPHIDE FILMS

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Cadmium sulphide(CdS) thin films were deposited by the flash evaporation technique using the CdS powder synthesized by a chemical precipitation method in the laboratory from AR grade cadmium acetate and thiourea. The synthesized powder was characterized by x-ray diffraction technique. Peaks corresponding to single phase hexagonal CdS were observed. This powder was used as source material for the deposition of thin films on glass and titanium substrates by the flash evaporation technique. The substrate temperature was varied in the range of 30 – 250C XRD pattern indicated that the films were polycrystalline exhibiting peaks corresponding to the hexagonal phase. Optical absorption studies indicated a direct band gap of 2.39 eV. Photo-electrochemical measurements were made on the films deposited at different substrate temperatures. The as deposited films exhibited weak photo-activity, due to the annealing in argon atmosphere.

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1.Introduction

II–VI compound semiconductors have drawn considerable interest due to their potential applications in photovoltaic devices, photo-resistors, heterojunction diodes, electroluminescent layers and surface acoustic wave devices. Chalcogenides, especially of cadmium, lead and zinc have proved their potential as efficient absorbers of electromagnetic radiation [1–3]. Cadmium chalcogenides form a technically important class of materials owing to their wide spread utility in a variety of electronic and optoelectronic devices. CdS thin films are well known for their extensive applications as an optoelectronic material in solar cells [4–6] and photo-detectors [7,8]. They are also used in the fabrication of optical filters, multilayer LEDs, photodiodes, phototransistors, etc. Heterojunction solar cells with a wide band gap window and a narrowband gap absorber are currently becoming the focus of intensive research in order to develop efficient, stable and low-cost cells. Cadmium sulfide, with a band gap of 2.43 eV, is an ideal material for use as the window layer of heterojunction solar cells [9,10]. A wide variety of techniques have been employed for the deposition of CdS thin films. In this work, CdS films were deposited by the flash evaporation technique employing the CdS powder synthesized in the laboratory.

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2.Experimental techniques

CdS powder was prepared by the chemical precipitation technique using thiourea and cadmium acetate. 80 grams of cadmium acetate was dissolved in 200 ml of triple distilled water, and 50 grams of thiourea was dissolved in 250 ml of triple distilled water by gentle warming. This solution was filtered after cooling. The cadmium acetate solution was taken in a three litre round bottomed Pyrex flask fitted with ground joints, and 150 ml of fresh ammonia (specific gravity 0.91) was added when a clear solution was obtained. Thiourea solution was mixed with 150 ml of ammonia and added to the clear cadmium ammonia complex and refluxed on a heating mantle, provided with a facility for magnetically stirring the contents, for two hours. 30 ml of ammonia was added at intervals of 30 minutes. The solution turned canary yellow in colour at the beginning, a little later, shining tiny crystals of cadmium sulphide are noticed in the solution as well as on the walls of the flask and finally the bulk precipitate of cadmium sulphide turned to a bright orange hue. The heating is stopped and the precipitate was allowed to age for 12 – 16 hours. It was filtered through a Buchner funnel with Whatmann 42 filter paper using rotary vacuum suction provided with requisite traps to avoid pump oil vapour contaminating the powder. The precipitate was washed with hot (70 C) acetic acid solution to remove traces of hydroxide/oxide of cadmium that may still be present. Further washings were carried out in triple distilled water till the filtrate showed neutral pH and finally washed with pure ethanol. The precipitate was dried in vacuum oven and stored in a vacuum desiccator.

3.Results and discussion

The cadmium sulphide powder, thus prepared are analysed by atomic absorption spectroscopy (Perkin Elmer Model 380). The results are given in Table 1. For the sake of comparison, AAS results on imported Koch-light cadmium sulphide powder are also given in the same table. It is clear from the AAS analysis that the cadmium sulphide powder prepared in the laboratory is of comparable purity with the Koch-light powder.

Table 1. AAS Analysis of CdS powder.

Sample	Impurity content in ppm						
	Cu	Fe	Ca	K	Na	Zn	Pb
CdS(prepared)	4	15	10	2	2	-	-
CdS(Koch light)	-	22	95	7	6	2	5

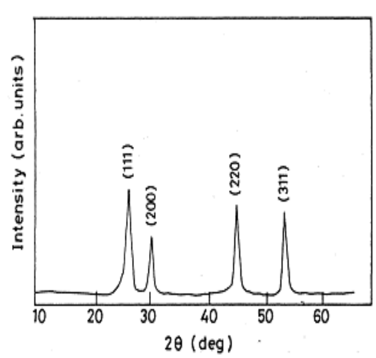

Fig.1. XRD pattern of CdS powder synthesized in the laboratory.

X-ray diffractogram (XRD) of the cadmium sulphide powder is shown in Fig.1. The as prepared powder indicates all the peaks corresponding to cubic CdS with a lattice constant of a = 5.818 Å. Peaks corresponding to free cadmium or sulphur are not observed. AAS studies indicated the material to be of phase purity similar to that of imported Koch Light CdS powder. This powder was used as the source material for the deposition of CdS films on clean glass and titanium substrates kept at different temperatures in the range of 30 - 300°C. Thickness of the films estimated by using Mutitoyo surface profiler varied in the range of 1.5 – 2.0μm with increase of substrate temperature. The films exhibited hexagonal structure with the intensity of the peaks increasing with substrate temperature(Fig.2).

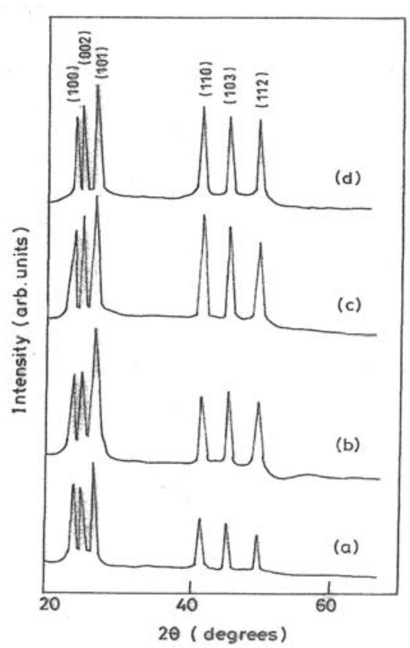

Fig.2. XRD patterns of CdS films deposited at different temperatures (a) 30°C (b)100°C (c) 200°C (d) 300°C.

Optical band gap of the films were estimated by recording the absorbance spectra in the wavelength range 300 – 800 nm by placing an uncoated glass substrate in the reference beam. Direct band gap value of 2.39 eV was obtained by extrapolating the linear region of the $(\alpha h\nu)^2$ vs $h\nu$ plot(Fig.3). This result is in agreement with the earlier report [11,12]. The films deposited at different temperature on titanium substrates were used as photo-electrodes in photo-electrochemical cells, and the load characteristics was studied at different intensities. The as deposited films exhibited low

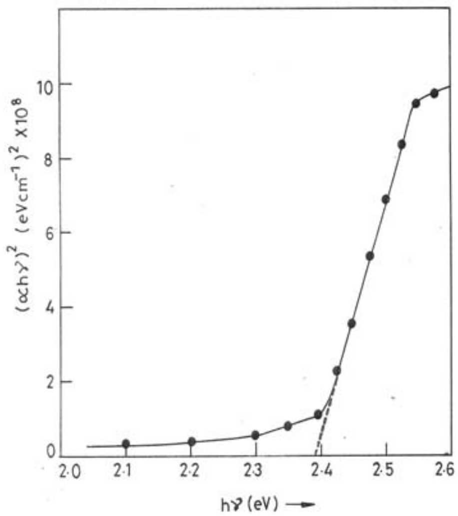

Fig.3 - $(\alpha h\nu)^2$ vs hν plot of CdS films deposited at a substrate temperature of 300ºC.

photoactivity, hence they were heat treated in argon atmosphere for 10 min at different temperatures in the range of 450 -550°C. The heat treated films exhibited good photoactivity. Films deposited at 250°C and post heat treated at 500°C indicated maximum photoactivity(Fig.4). The power output characteristics of the electrodes deposited on titanium substrates and heat treated at 500ºC were studied at different intensities of illumination in the range 20 –100 $mWcm^{-2}$. It was observed that both V_{oc} and J_{sc} increased with increase of intensity. V_{oc} increased from 0.36 V to 0.50 V as the intensity increased from 20 – 100 $mWcm^{-2}$. Beyond 80 mWcm-2 illumination, V_{oc} was found to saturate as is commonly observed in the case of photovoltaic cells and PEC cells. J_{sc} is found to increase linearly with the intensity of illumination. It is observed that J_{sc} increases from

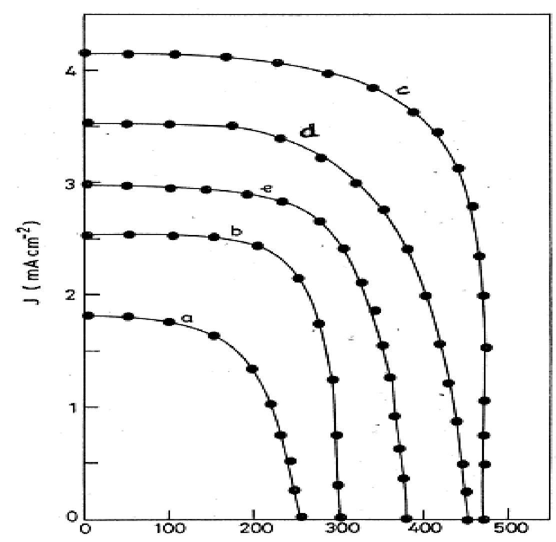

Fig. 4. Power Output Characteristics of CdS electrodes annealed in argon atmosphere at different temperatures (a) 450°C (b) 475°C (c) 500°C (d) 525ºC (e) 550ºC.

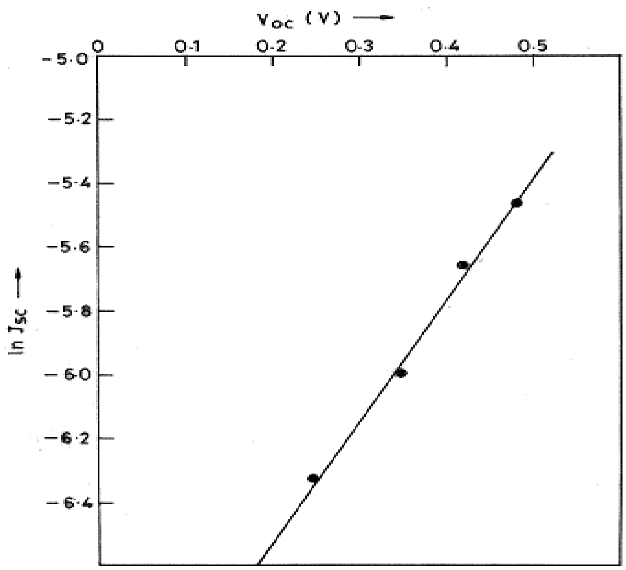

Fig.5. Plot of lnJ_{sc} vs V_{oc} of CdS electrodes annealed in argon atmosphere at 500°C.

3.6 $mAcm^{-2}$ to 5.2 $mAcm^{-2}$ as the intensity increased from 20 – 100 $mWcm^{-2}$. A plot of lnJ_{sc} vs V_{oc} (Fig.5) yielded a straight line and the reverse saturation current density J_0 was of 1.5 x 10^{-7} Acm^{-2}. The ideality factor (n) was calculated from the slope of the straight line was 2.65. The photo output of the CdS electrodes prepared by the flash evaporation technique are higher than the values obtained with CdS photo-electrodes prepared by the doctor blade technique[13].

4.Conclusion

The results of this work, clearly demonstrate that CdS films with good photo-activity can easily be prepared by the flash evaporation technique. Further work aims at the deposition of 100 cm^2 area CdS electrodes and to study the stability of these electrodes under sunlight illumination.

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