Study of Phototransmission Current of CdS Thin Films Prepared Using Sintering Method

Abstract

Sintering method has been used to prepare cadmium sulphide films in which cadmium chloride was used as adhesive and ethylene glycol as binder .The CdS films were annealed between 85-90C for 2 hours on hot plate to make the film homogeneous .Lights from 100 watt bulb were allowed to fall on glass slide containing the film and a detector was mounted to the optical bench. To study the response of light a set up was made to estimate the response of illumination at various intensities on the films. The photovoltage was measured for different intensities and it was found that it increases with increase in intensity.

At every measured intensity the photovoltage increases for film prepared at deposition time of 60 and 120 minutes but comparatively the photovoltage decreases for film prepared at deposition time of 90 minutes. When light is on, phototransmission current starts increasing with time and it becomes constant. When light is off, it falls down abruptly. Above variation is same for films prepared at deposition time 90 minute. The prepared films have been found to be photoconductive and photosensitive in nature and are suitable for sensors and photodetectors.

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Introduction

Thin films occupy a prominent place in basic research and solid state technology. Thin film semiconductors have variety of applications in various electronic and optoelectronic devices. The technological interest in thin film semiconductors is mainly caused by their low production costs. Chalcogenide semiconductor thin films are intensively investigated for low cost photovoltaic and optoelectronic applications. Cadmium sulphide (Cds) is a very useful optoelectronic (Iyechika et al 1988; Bogdanov and Lyssenko, 1988; Obi et al, 2017) , Piezoelectronic (Stefko,1991; Kerk and Kelly,1964) and semiconducting material. Owing to their suitable band gaps and high absorption coefficients, Cd-based compounds such as CdTe and CdS are most promising photovoltaic material available for low cost high efficiency solar cells (Safa et al 2017). The energy dispersive analysis of X-ray showed the CdS film to be stoichiometric (Ankurkumar et al 2018). The phase of CdS films was determined to be hexagonal (W G C Kumarage et al 2017).

There has been a rapid development in the field of 11-V1 semiconductors for their use in solar cells. Belonging to this group Cadmium sulphide is the most widely used material because it has intermediate energy gap, stability and low cost (Lee and Im 1980 ; Nakayama et al 1980).

The sintering method is relatively inexpensive, simple and convenient for the large area of deposition of II-IV compounds. This paper is an effort to prepare the CdS films using sintering method and to study the effect of deposition parameters on the photoconduction process in these films.

All polycrystalline CdS solar cells with different micro structures and properties of the CdS layer were fabricated by coating a number of CdS slurries, which consisted of cadmium and sulphur powders, an appropriate amount of ethylene glycol and various amount of $CdCl_2$, on the sintered CdS films and by sintering the glass-CdS composites at various temperatures. All polycrystalline CdS solar cells with an efficiency of 10.2 % under solar irradiation have been fabricated by a coating and sintering method using cadmium and sulphur powders for the CdS layer.

Synthesis of 3 D complex structures of CdS thin films and studies on their properties are significant and need to be developed, because the structures with complexities exhibit more novel properties, which would be useful for the existing as well as novel application devices (Sarveswaran et al 2016).

Objective

To determine the variation of photovoltage with intensity, variation of photovoltage with deposition time for various intensities and variation of phototransmission current with time for films prepared for different deposition times of CdS thin films (having low production cost and applications in various electronic and optoelectronic devices) .

Experimental Procedure

Commercially available glass substrate were first soaked in acetone for a minute and then dried in air. Thereafter, they were cleaned in isopropyl alcohol, washed with DI water. Then the substrates were dried in air before sintering.

Then samples were prepared by chemical method using Cadmium Sulfide (CdS) powders. There were three CdS powders which were prepared at deposition times of 60 min , 90min and 120 min.

Cadmium Sulfide films were prepared by the sintering technique. For this appropriate amount of Cadmium Sulfide, Cadmium Chloride ($CdCl_2$) was added as an adhesive and ethylene glycol as the binder. The weight of $CdCl_2$ was only 10% of the weight of CdS powder.

The concentration of CdS and $CdCl_2$ with deposition time 60min, 90min and 120min are shown in table below-

CdS weight (mg)	$CdCl_2$ weight (mg)
0.417	0.0417
0.152	0.0152
0.151	0.0151

CdS and $CdCl_2$ were thoroughly mixed and then a few drops of ethylene glycol was added to form the paste. The paste thus prepared was painted by paint brush on the half of glass substrates. Likewise six films were prepared, two of each deposition times. Numbering them, for example 11 and 12 for deposition time 60 min, 21 and 22 for 90min deposition time, 31 and 32 for 120min deposition times.

After sintering films were dried in air at room temperature for one day. The glass substrates were annealed between 85-90^{o}C for 2 hours on the hot plate to make them homogeneous. After annealing the colour of CdS thin film turns slightly to dark yellow. The films are now uniform and well adhered to the glass plates.

Light from 100 watt bulb is allowed to fall on the glass slide containing the film and a detector was mounted to the optical bench. To study the response of light a setup was made to estimate the response of illumination at various intensities on the films. The intensity of light at a given distance from source is given by

I = power/area

Here, area = $4\pi r^2$, where r is the distance of the film from the source. Thus, the voltage at the specified distance is proportional to the intensity. The luminescence of bulb used is 100 watt which is equivalent to 1600 lumens. The following table displays the calculated values of intensities.

Distance(cm)	20	30	40	50	60	70	80
Intensity(watt/cm2)	0.0199	0.0088	0.005	0.0032	0.0022	0.0016	0.0012

Experimental Results and Discussion Variation of Photovoltage with Intensity

The distance between source and detector with film was increased to determine the variation of photovoltage with intensity. It was observed that there is decrease in photovoltage on detector with increase in distance between source and detector with film.

The experimental results of photovoltage and intensities for films are given in following Table 1.

Intensity (watt/ cm^2)	Voltage (volts) for Film-11	Voltage (volts) for Film-21	Voltage (volts) for Film-31
0.0199	0.399	0.322	0.381
0.0088	0.34	0.264	0.282
0.005	0.265	0.206	0.278
0.0032	0.238	0.146	0.239
0.0022	0.189	0.115	0.185
0.0016	0.18	0.08	0.16
0.0012	0.145	0.075	0.14

Plot of intensity and photovoltages for films as shown below-

Figure 1 Variation of Photovoltage with Intensities at Deposition Times

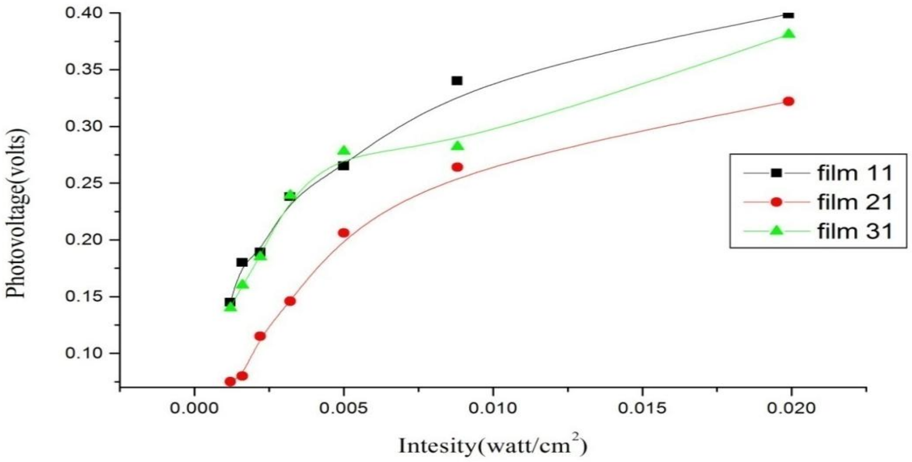


Figure -1 represents the variation of photovoltage with intensities for three different films with deposition times of 60 min., 90 min. and 120 min. It is generally observed that with increase in intensity, there is also increase in photovoltage. This is in good agreement with the behavior reported in the literature. For film-11 which is deposited at 60 min has normal behavior. The photovoltage increases from 0.145V to 0.399V. Firstly photovoltage increases with intensity then it becomes almost constant.

For film-21 which is deposited at 90 min, the photovoltage increases from 0.075V to 0.322V. This increase is smaller than the increase for film-11. This is also in accordance with the fact that as increasing intensity(i.e. decreasing distance) the photovoltage also increases.

In case of film-31 which is deposited at 120 min, the photovoltage is found between film-11 and film-21. The photovolatge increases from 0.140V to 0.381V for this film but the overall response is similar to other films.

The constant values obtained for photovoltage can be assigned to site saturation and depends on the growth of film.

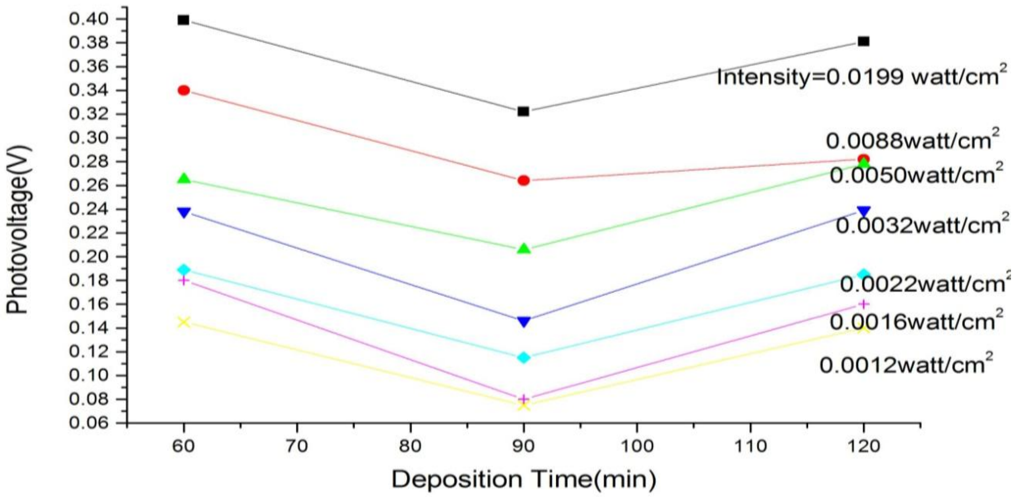
Variation of Photovoltage with Deposition Time for Various Intensities

Tabulated values of photovoltages on various intensities corresponding to different deposition times are as shown in table-2

Deposition Time (min)	**I=0.0199 watt/cm^2 photo voltage(V)**	**I=0.0088 watt/cm^2 photo voltage(V)**	**I=0.005 watt/cm^2 photo voltage(V)**	**I=0.0032 watt/cm^2 photo voltage(V)**	**I=0.0022 watt/cm^2 photo voltage(V)**	**I=.0016 watt/cm^2 photo voltage(V)**	**I=0.0012 watt/cm^2 photo voltage(V)**
60	0.399	0.34	0.265	0.238	0.189	0.18	0.145
90	0.322	0.264	0.206	0.146	0.115	0.08	0.075
120	0.381	0.282	0.278	0.239	0.185	0.16	0.14

A graph is plotted between deposition time of various types of films and photovoltage from detector on various intensities-

Figure -2 Variation of photovoltage with deposition time on various intensities



The response of voltages with different deposition times for various intensities are approximately similar. As shown in graph it is observed that for maximum intensity(0.0199W/cm2), the voltage for film-11(deposition time-60 min) are in sense of increasing but voltage at deposition time-90 min , goes slightly down and for film-31(120 min) voltage again starts increasing (0.381V)

Similarly for other intensities, voltage starts increasing for deposition at 60 min, then it decreases for deposition at 90 min, and for 120 min again starts increasing. This can be due to optimum conditions reached for film growth for 90 min. duration and hence less number of carriers are available for excitation.

Variation of Phototransmission Current With Time for Films Prepared for Different Deposition Times

The films were illuminated for different times and their responses observed through the measurement of photocurrent with time (Table 3-5) using photodetector and nanometer.

Table-3 for Film-11 (Deposition Time 60Minutes)

Time (min.)	Phototransmission Current (mA) (when light is ON)	Phototransmission Current (□ A) (when light is OFF)
1	0.135	1.7
2	0.136	1.4
3	0.147	1.2
4	0.158	0.9
5	0.352	0.7
6	0.362	0.6
7	0.365	0.5
8	0.366	0.3
9	0.377	0.1
10	0.382	0

Table-4 for Film-21(Deposition Time 90 Minutes)-

Time (min)	Phototransmission Current(mA) (when light is ON)	Phototransmission Current(□ A) (when light is OFF)
1	0.574	1.6
2	0.575	1.4
3	0.579	1.2
4	0.584	1
5	0.591	0.8
6	0.596	0.6
7	0.586	0.5
8	0.59	0.3
9	0.585	0.2
10	0.56	0.1

Table-5 for Film-31(Deposition Time 120minutes)-

Time (min)	Phototransmission Current(mA) (when light is ON)	Phototransmission Current(□ A) (when light is OFF)
1	0.258	1.3
2	0.262	1.1
3	0.28	1
4	0.286	0.8
5	0.296	0.6
6	0.304	0.5
7	0.311	0.4
8	0.314	0.3
9	0.315	0.2
10	0.321	0.1

Plots for tabulated values of time and phototransmission current-

Figure-3 Variation of Phototransmission Current with Time for film-11

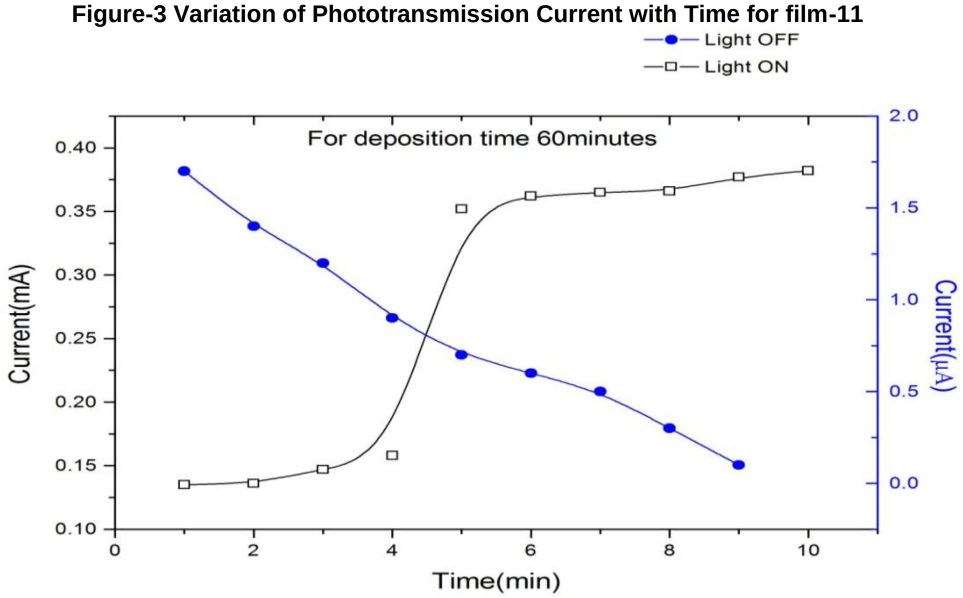


Figure 4 Variation of Phototransmission Current with Time for film-21

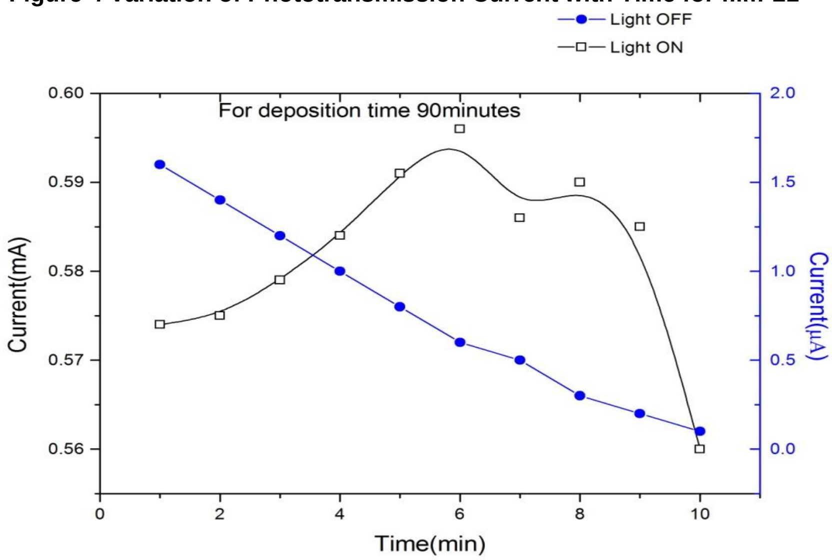
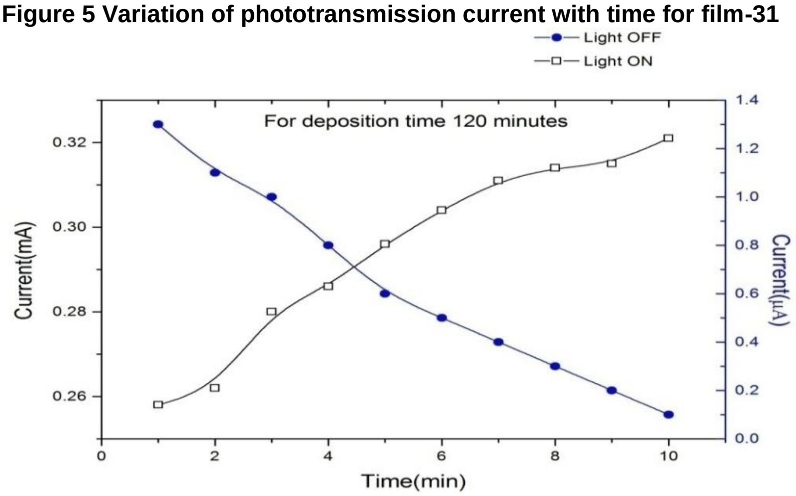


Figure 5 Variation of phototransmission current with time for film-31



The variation of phototransmission current at the specified distance (30cm) is found to increase with time and then saturates to a almost constant value. When light is switched off, the current starts to fall rapidly and reached a certain minimum value which is approximately same for all the films deposited at different times.

The above variation can be understood in the following way. Initially high value of the phototransmission current is due to the absorption of photon by the films, which excites the electrons from the valance band to conduction band. This creates pairs of free holes in valance band and free electrons in conduction band. Most of the electrons are from the surface of the CdS film which moves from valance band to conduction band, it increases the process of pair generation initially, which in turn increases the carrier concentration and hence the number of excited states. Hence, the increase in phototransmission current.

The phototransmission current decreases with time and after some time, the phototransmission current is almost constant. This is due to the fact that carrier concentration decreases with time. Also the process of recombination takes place with respect to time which decrease the value of phototransmission current. A state is obtained where the process of generation of charge carrier and recombination reaches to an equilibrium in constant illumination. This results in a constant phototransmission current with respect to time.

When light is turned off, it decreases steadily with respect to time. Here surface recombination is very high and it leads to a lower carrier concentration at the surface which decreases the value of phototransmission current.

For deposition time 60min the phototransmission current increases from 0.135mA to 0.382mA. This is in accordance with the fact that the phototransmission current increases with time and after sometime it is almost constant. When light is off, the phototransmission current fall down with increase in time. The decrease in phototransmission current is from 1.7□ □ to□ □ □ □ □ □ □ □

For deposition time 90min the phototransmission current increases from 0.574mA to 0.596mA. Then its variation is slightly different, i.e. the phototransmission current starts decreasing as the time is increased. When light is off again the decreases fastly, it is similar as for deposition time

60min and the value of this phototransmission current is from 1.6□ □to□ □ □ □ □ □ □

For deposition time 120min the response of phototransmission current with time is approximately equal to the response for deposition time 60min. Initially the phototransmission current increases as increase in time, after that it is almost constant. It is from 0.258mA to 0.321mA. When light is off, the decrease in phototransmission current is very fast and its value is from 1.3□ □ □to □ □ □ □ □ □

Conclusions

The prepared films are found to be photoconductive in nature and hence the material can be used for fabrication of semiconducting devices such as solar cells, photodetectors etc. Among all kinds of semiconductor materials CdS exhibits high junction quality, high device performance and is environment friendly (Songwei et al 2018)

The CdS films are yellow in colour and increasing of deposition time darkened its color . The photovoltage was measured using light(100 watt) on the different distance i.e. different intensities. It was found that the photovoltage increases with increase in intensity. At each of the measured intensities, with increase in deposition time, the photovoltage increases for film prepared at 60 and 120 min, but comparatively photovoltage decreases for film prepared at 90min.

When light is on the phototransmission current starts increasing with time then it becomes constant. When light is off current falls down abruptly. This indicates that the prepared films are photo sensitive and can be used as sensor for release of light carriers when the intensity falls. Above variation is same for films prepared at deposition time 60 and 120min, but different for film prepared at 90min.

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