

Studies of Fabrication Techniques of Hetero-junction 'CdS-CdTe' Thin Film Solar Cell

M. S. Sonawane, M. S. Shinde, A. N. Kulkarni and R. S. Patil*

*Dept. of Physics, P. S. G. V. P. M'S Arts, Science & Commerce College, Shahada,
Dist- Nandurbar - 425 409.*

Abstract

The chemical bath deposition (CBD) method is used to grow CdS thin layer with thickness $\sim 1 \mu\text{m}$ on SnO_2 coated glass substrate. The optimized preparative parameters including temperature, deposition time, pH of solution have been optimised for CdS film growth. CdTe thin layer with thickness $\sim 10 \mu\text{m}$ deposited by physical vapour deposition (PVD) method using rotary-diffusion thin film coating unit on earlier deposited CdS thin layer. As deposited CdS and CdTe thin films have been characterized for the electrical properties using four point probe method.

Keywords - Thin film, Chemical bath deposition, Physical vapour deposition, Electrical properties, Thickness.

*corresponding author: rspatil_shahada@yahoo.co.in

INTRODUCTION

The objective of this paper is to discuss fabricate of 'CdS-CdTe' heterojunction solar cell. One of the striking features of these cells is that we can obtain fairly good efficiency at low cost.

METHODOLOGY

In the 'CdS-CdTe' heterojunction solar cell, the different deposition methods and different heat treatment required for each layer and on the materials selected as front/back contacts. Our procedure consists of sequentially depositing several layers onto a borosilicate glass substrate, configured as glass/TCO/CdS/CdTe/Cu [1]. Borosilicate glass was used due to the high temperatures involved in CdTe processing. transparent conducting oxides (TCO)'s were used as front contacts and silver used as the back contact. Chemical bath deposition (CBD) method is very simple, cost effective and also capable in growing nanocrystals, microcrystal and epitaxial structure under various growth condition. The rate of deposition of CBD thin film can be controlled by optimizing preparative parameters like, concentration of sulphide, temperature, pH and appropriate stirring [2].

In Physical vapour deposition (PVD) the material is transported in vapour form to the substrate where it is deposited. The precursor for the PVD is a solid. At high vacuum conditions the solid is first converted to liquid and then to vapour. Because of the high vacuum conditions the vapour is deposited directly on the substrate [3].

The transparent conducting oxide (TCO) layer was deposited onto a borosilicate glass substrate. Transparent conducting oxides like SnO_2 in general are n-type semiconductors with good electrical conductivity and high transparency in the visible spectrum. SnO_2 has a large band gap of 3.7 eV and high optical transmission. SnO_2 is used as the front contact of a solar cell [4].

The polycrystalline n-CdS layer is an essential component of the cell as it contributes one half of the p-n junction. CdS should be conductive, thin to allow high transmission. Its band gap is 2.4 eV. Being a wide band gap material it is transparent to wavelengths of around 515 nm and above, and

therefore it is referred to as the window layer. CdS was deposited by the CBD method [5,6].

The CdS thin films were chemically deposited on SnO_2 coated glass substrates. All analytical grade (A.R) reagents were used for the deposition of CdS thin films. Aqueous solution of 0.1M Cadmium sulphate, 0.1M thiourea and complexing agent liquor ammonia was used. Initially 36 ml of CdSO_4 solution and 9 ml ammonia was placed in 100 ml beaker, after stirring for several minutes solution becomes homogeneous under continuous stirring, 24ml. thiourea solution was introduced then cleaned SnO_2 coated glass substrate were vertically immersed into the prepared bath at 85°C temperature. Preparative parameters are optimized for best quality CdS film. We obtained uniform-yellowish films with thickness of 100 nm, after 120 min having good adherent property.

CdTe has long been recognized as a leading thin film photovoltaic material due to its near optimum band gap of 1.45 eV and high absorption coefficient. CdTe absorbs over 90% of available photons ($h\nu > 1.45 \text{ eV}$) in less than $2 \mu\text{m}$ thickness. It is called the absorber layer. CdTe is polycrystalline and is p-type doped [6].

CdTe layer having thickness of $2\text{-}8 \mu\text{m}$ was deposited on earlier CdS layer by physical vapour deposition using rotary-diffusion vacuum system in the presence of 8×10^{-5} mbar pressure in chamber. Rate of deposition was $\sim 2 \text{ \AA/sec}$ at initial temperature 34°C and heater voltage slowly increased upto 22 volt. The 'CdS-CdTe' film followed by anneal at $\sim 300^\circ\text{C}$ in air for 5 minutes. The devices were then masked and contacted with HgTe:Cu doped graphite paste. Silver electrical contacts, on the surface of each CdTe film from set of samples.

Formation of low resistance back contacts to p-CdTe is needed for the fabrication of high efficiency solar cells. CdTe has a high electron affinity ($\chi = 4.5 \text{ eV}$) and no metal exists with a high work function (ψ_m).

There are no low-cost metals available with appropriate higher work function ($> 4.5 \text{ eV}$) to form ohmic contact on CdTe and Au has been used in most cases. Ni-based contacts

have also shown promising results. Here, a highly doped semiconductor is first deposited on a CdTe surface followed by the application of a metal film contact. Semiconductors such as HgTe, ZnTe:Cu, Cu_xTe, and Te can be deposited between CdTe and contact metal to achieve a good ohmic contact. Cu-doped graphite paste and antimony telluride have also been tried. The use of elemental Cu leads to p⁺ Cu₂Te formation [9].

CdS-CdTe thin film solar cell used in Whether monitoring and Railway signalling equipment, cathodic protection of oil pipe lines, Radio and television sets, etc.

RESULTS AND DISCUSSION

A. Mass difference method

Film thickness was determined by weighing method using the formula,

$$t = w / A \cdot \rho$$

| Mass of the slide in 'gm' | | Mass of the materials (m) in 'gm' | Dimensions of the films | | Thickness of the film (w) in 'μm' |
|---------------------------|------------------|-----------------------------------|-------------------------|--------------------|-----------------------------------|
| Before deposition | After deposition | | Length (l) in 'cm' | Breath (b) in 'cm' | |
| 9.6480 | 9.6680 | 0.020 | 5.4 | 1.1 | 5.755 |
| 9.7430 | 9.7640 | 0.021 | 5.5 | 1.1 | 5.933 |
| 9.6373 | 9.6573 | 0.020 | 5.4 | 1.1 | 5.755 |
| 9.7761 | 9.7960 | 0.020 | 5.3 | 1.1 | 5.864 |

Where, 't' is the thickness of the film, 'w' is the weight gain, A is the area of the coated film and ρ is the density.

Table 1 Thickness measurement of CdS thin films by mass difference

| Mass of the slide in 'gm' | | Mass of the materials (m) in 'gm' | Dimensions of the films | | Thickness of the film (w) in 'μm' |
|---------------------------|------------------|-----------------------------------|-------------------------|--------------------|-----------------------------------|
| Before deposition | After deposition | | Length (l) in 'cm' | Breath (b) in 'cm' | |
| 9.6470 | 9.6480 | 0.0010 | 5.2 | 2.1 | 0.094 |
| 9.7418 | 9.7430 | 0.0012 | 5.4 | 2.2 | 0.1 |
| 9.6363 | 9.6373 | 0.0010 | 5.1 | 2.1 | 0.096 |
| 9.7751 | 9.7761 | 0.0010 | 5.2 | 2.1 | 0.094 |

method

Density of CdS material is 4.82 gm/cm³ and deposited CdS thin film having thickness of ~100 nm. [10].

Table 2 Thickness measurement of CdTe thin films by mass difference method

Density of CdTe material is 5.85 gm/cm³ and deposited CdTe thin films having thickness of ~ 5.9 μm [10].

B. Electrical resistivity

The resistivity of thin films with non-conducting bottom surface is determined by using four probe method.

The useful equation to determine resistivity of thin film is,

$$\rho = \rho_0 \times (1 / G_7)$$

$$\text{Where, } \rho_0 = (V/I) [2\pi S]$$

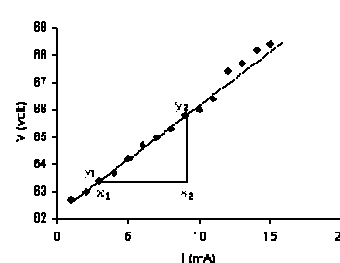
$$G_7 = (2S/w) (\log_e 2)$$

Where, w is thickness of the film

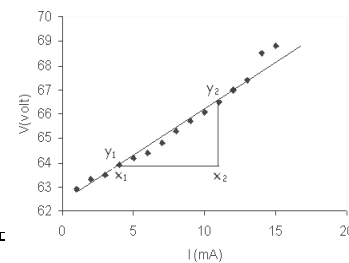
The CdS layer was deposited to a thickness of 0.094μm by the chemical bath deposition method. Using four probe

method, we find resistivity of CdS thin film, by passing current 'I' through the outer probes and measuring floating potential across the inner probes. The results for CdS thin film are presented by graph-I of floating potential Vs current. From graph-I, slope (V/I) is 0.38×10³ (volt/A).

The resistivity of CdS thin film at room temperature was found to be 3.73×10⁴ Ω-cm [11,12].



Graph-I for CdS thin film



Graph-II for CdTe thin film

The CdTe layer was deposited to a thickness of 5.755μm by the physical vapour deposition method. The results for CdTe thin film are presented by Graph-II of floating potential Vs current. From this Graph-II, slope (V/I) is 0.372×10³ (volt/A). The resistivity of CdTe thin film at room temperature was found to be 2.23× 10² Ω-cm [13].

CONCLUSIONS

Chemical bath deposition, Physical vapour deposition (PVD) methods have been used to deposit uniform and well adherent CdS & CdTe thin films respectively. The electrical resistivity of CdS & CdTe thin film is found to be of order 10⁴ & 10² Ω-cm respectively. It is observed that the resistivity decreases with increase in temperature, indicating semiconducting nature of the films.

REFERENCES

- [1] K. L. Chopra, P. D. Paulson and V. Dutta, Prog. Photovolt: Res. Appl., Wiley & Sons, Ltd., **69-92** (2004).
- [2] J. Herrero, M.T. Gutierrez, C. Guillen, J.M. Dona, M.A. Martinez, A.M. Chaparro and R. Bayon., **28-33**(2000).
- [3] Alessandro Romeo., **11-15**(2002).
- [4] Mursheda Hussain, **8-11**(2004).
- [5] Poulomi Roy and Suneel Kumar Srivastava, Materials Chemistry and Physics, **235-241**(2006).
- [6] L. R. Cruz, V.D. Falcao, C.L. Ferreira, W.A. Pinheiro, I.G. Mattoso, and R. M. P. Alves., Vol. 25, **1, 15-19** (2006).
- [7] P Raji, C Sanjeeviraja and K Ramachandran., Bull. Mater. Sci., Vol. 28, No. 3, **233-238**(2005).
- [8] A. V. Feitosa, M. A. R. Miranda, J. M. Sasaki, and M. A. Araujo-Silva., Brazilian Journal of Physics, Vol. 34, No. 2B, **656-658**(2004).
- [9] X. Wu and P. Sheldon, **285-286**(2000).
- [10] H. S. Ullal, K. Zweibel, and B. von Roedern, 29th IEEE Conference, **1-7** (2002).
- [11] G. G. Rusu, M. Rusu, E. K. Polychroniadis, C. Lioutas, Journal of Optoelectronics and Advanced Materials, Vol. 7, No. 4, **1957-1964**(2005).
- [12] C.Santiago Tepantlan, A. M. Perez Gonzalez and I. Valeriano Arreola, Rev. Mex.Fis., Vol.54, No.2, **112-117**(2008).

- [13] A. U. Ubale, R. J. Dhokne, P. S. Chikhlikar, V. S. Sangawar and D. K. Kulkarni, Bull. Mater. Sci., Vol. 29, No. 2, **165–168**(2006).