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Electrochemical Deposition of Low Cost Cadmium Telluride Thin Films

[*1]Shivali Chauhan

[*1]Associate Professor, Department of Physics, M.S.J. Govt. PG College, Bharatpur, Rajasthan, India.

Abstract

Solar cell constitutes a critical technology for overcoming global environmental and energy problems. Cadmium Telluride is a compound semiconductor with an ideal 1.45 eV bandgap for direct light to electricity conversion. The availability of higher quality CdTe based compounds and an impending energy crisis suggest examining this material further for terrestrial Solar cells. We have grown thin films of Cadmium Telluride on Tin Oxide coated glass substrates. Conducting Tin Oxide films were deposited on glass slides with the help of chemical vapour deposition technique. Films of Cadmium Telluride were deposited by electrodeposition. The electrochemical bath was made up of aqueous solutions of Cadmium Chloride and Mercuric Chloride. Acetonitrile was added to the bath for complexation. A platinum electrode was used as the counter electrode, a standardized saturated calomel electrode as the reference electrode and Tin Oxide coated glass acted as the working electrode. Films were deposited under stirred conditions of the bath. Bandgap of the films was also calculated with the help of Transmission Spectra.

Keywords: Electrodeposition, CdTe, thin films, cyclic voltammograms, CH_3CN

Introduction

Solar cell technology has played a crucial role in addressing global environmental and energy challenges, tracing its roots back to the discovery of the p-n junction in 1949 and Pearson's development of the crystalline Si solar cell in 1954[1]. Since then, significant advancements have been made, with various materials like polysilicon, CdTe, $CuInSe_2$, $CuInS_2$, and GaAs being utilized for solar cell production, marking notable progress over the past several decades[2]. Despite the efficiency and stability demonstrated by traditional single crystal photovoltaic devices such as Si and GaAs, their high production costs have posed a barrier[3]. In response, there has been a notable shift towards thin film technologies in recent years due to their potential for cost reduction. Thin film photovoltaic systems, including options like amorphous silicon and composite configurations like $CdZnS/Cu_2S$, CdS/InP, CdS/CdTe, $CdZnS/CuInSe_2$, and $CdS/CuInS_2$, have emerged as promising alternatives with their efficient material usage and simplified preparation methods. However, challenges persist, including the need to enhance efficiency, ensure stability, and scale up production. Addressing these challenges requires continued research and development efforts in materials science, device engineering, and manufacturing processes. By driving down costs and improving performance, these endeavors can accelerate the adoption of photovoltaic systems, contributing to global efforts to combat environmental and energy crises.

CdTe is a compound semiconductor with an ideal 1.45 eV bandgap for direct light-to-electricity conversion and a high absorption coefficient, making it a promising material for solar cells [4, 5]. Various techniques can be employed to prepare CdTe thin films, such as close space sublimation (CSS) [6], metal-organic chemical vapor deposition (MOCVD) [7], chemical bath deposition [8], screen printing [9], spray pyrolysis [10], sputtering [11, 12] and electrodeposition[13-16]. However, most techniques, except for electrodeposition, are expensive, require complex systems, or involve poisonous gases. Electrodeposition offers several key advantages: it enables the growth of uniform films over large areas and irregularly shaped surfaces, is a simple technique with high material utilization, and is more environmentally friendly than other methods. It is inexpensive, minimizes material waste, and may not require very pure starting materials due to the purification that occurs during the electrodeposition process. Additionally, it is a straightforward, low-cost method that has recently been used to grow various binary and ternary alloys and semiconductors.

In this paper we have demonstrated very low-cost electrodeposition technique suitable for deposition of thin films of CdTe, thus reducing the cost of solar cells.

Experimental Details

Thin Films of CdTe were grown on SnO_2-coated glass substrates, where the SnO_2 films were deposited using the chemical vapour deposition technique. Films of CdTe were deposited through electrodeposition, utilizing an EG&G PARC (VERSASTAT-II) computer-controlled potentiostat. The electrochemical bath was prepared with aqueous

***Corresponding Author:** Shivali Chauhan

solutions of Cadmium Chloride ($CdCl_2$) and Tellurium (Te), which had been reacted with Nitric Acid (HNO_3), and CH_3CN (acetonitrile) was used as a complexing agent. For the ionic solutions, $CdCl_2$ supplied by Qualigens (molecular weight 183.31) provided the 'Cd' ions, and Tellurium metal supplied by C.D.H provided the 'Te' ions. Tellurium was converted into Tellurium oxide by adding concentrated HNO_3. Each ion in solution (Cd and Te) was maintained at a concentration of 0.05 M and mixed in double-distilled water. The solution's pH was adjusted to between 1 and 1.5 by adding HCl. A platinum electrode was used as the counter electrode, a standardized saturated calomel electrode as the reference electrode, and the SnO_2-coated glass served as the working electrode. Film deposition occurred under stirring conditions. Cyclic voltammograms were studied to identify the optimal potential for growing uniform, single-phase CdTe films.

Result and Discussion

Cyclic voltammetry (CV) curves for aqueous solutions of having different concentrations of $CdCl_2$ and Te ions were obtained from the bath. It was observed that in the voltammograms, in general for both the elements deposition potentials were separated from each other. For Cd, it lays roundabout -600mV and for Te, it is roundabout -450mV. It is clear from the Krogers theory that since the potentials are separated from each other so we cannot get single phase thin films of CdTe from the bath containing solution of CdCl2 and Te pre reacted with HNO3. But when we added Acetonitrile in the above bath and in stirring condition we obtained cyclic voltammogram, which is shown in Fig. 1. Here we see that both the potential merges together and a plateau region between -0.4 volts and -0.6 is seen. Selecting different deposition potentials with in this plateau region number of films were grown and characterized.

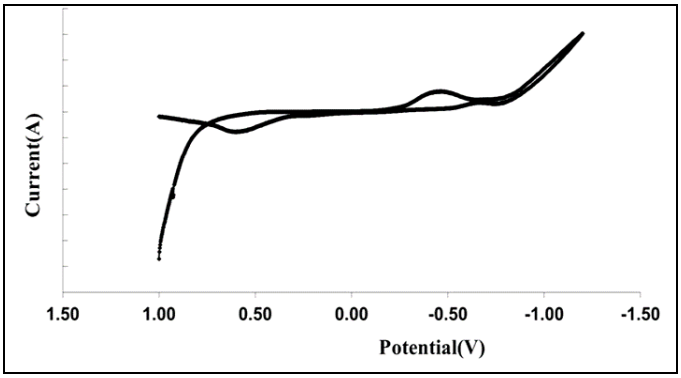

Fig 1: Cyclic voltammogram from the bath containing Cd and Te ions with Acetonitrile

To determine the bandgap of CdTe films grown on SnO_2 coated glass substrates using optical transmission spectra, the following steps were taken. First, the transmission spectra of the CdTe films were measured using a Shimadzu UV-Vis two-beam spectrophotometer with a wavelength range of 200-1100 nm. A SnO_2 coated glass slide was used as a reference to account for the substrate's transmission. The transmission (T) versus wavelength (λ) data was recorded and converted to absorbance (A) using the formula A = -log (T). The absorption coefficient (α) at each wavelength was then calculated using α=2.303A/d, where d is the thickness of the CdTe film. The wavelength (λ) data was converted to photon energy (hν) using the equation hν = hc/λ. Next, (αhν) was calculated for each wavelength and squared to obtain $(\alpha h\nu)^2$. A plot of $(\alpha h\nu)^2$ as a function of photon energy (hν) was created, and the linear portion near the band edge was identified. By extrapolating this linear region to the hν axis, the intercept, where $(\alpha h\nu)^2 = 0$, provided the bandgap energy (Eg) of the CdTe films. Fig 2 shows plot between Photon energy hν and $(\alpha h\nu)^2$ of thin film of CdTe. With the help of figure we can see that bandgap is 1.4 eV.

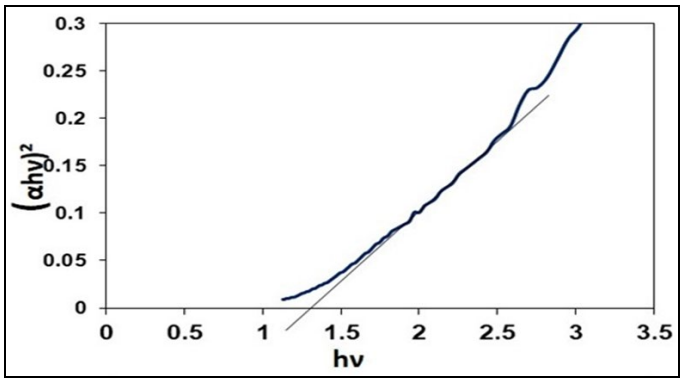

Fig 2: Plot between Photon energy hν and $(\alpha h\nu)^2$

Conclusion

In conclusion, the conditions necessary for the electrochemical growth of single-phase CdTe thin films have been determined, with the effectiveness of Acetonitrile as a complexing agent in this process being clearly demonstrated.

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