Studies on thin film $CdSe_{0.7}Te_{0.3}$/(aq) Ferro-Ferricyanide photo electrochemical solar cells

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Abstract: Photoelectrochemical (PEC) Solar Cells were made using thin film vaccum evaporated $CdSe_{0.7}Te_{0.3}$ (thickness ≈ 4000 Å) at 30 ± 1Å/sec on indium oxide coated glass plates at high vacuum dipped in aqueous Ferro-Ferricyanide solution with graphite electrode as counter electrode. The PEC solar cell efficiency was measured using AM1.5 solar radiation for efficiency calculation. Mott-Schottky plots were performed in dark to evaluate parameters of semiconducting thin film. The thin films were characterized by X-ray diffraction and the band gap of the thin film was calculated by optical studies.

(Key words: Semiconductors, Thin films, X-ray diffraction, Power Conversion Efficiency)

1.0 Introduction:

Polycrystalline chalcogenides find a vast application especially the alloys of Cd-Se-Te [1] which show their band gap in the visible region of the solar spectrum. This is very useful in applications for fabrication of solar cells. On varying the composition of Cd, Se and Te in the alloy the band gap of the resultant alloy can be tailored to suit the light to energy conversion devices. In this paper we have characterized the $CdSe_{0.7}Te_{0.3}$/(aq) Ferro-Ferricyanide photoelectrochemical junction photoelectrochemical cells for efficiency studies.

1.1 Experimental Details:

The highly pure solid material of Cadmium (Cd), Selenium (Se) and Telerium (Te) were used to form an alloy in a quartz tube which was evacuated to 5×10^{-5} torr and heated to 575 ^{o}C for 12 hours so that a homogeneous mixture was formed. This homogenous mixture was powdered in a mortar and crucible. The thin films of the powdered $CdSe_{0.7}Te_{0.3}$ were deposited by vacuum evaporation at the rate of 30± 1Å/sec. The thin films were subjected to X-rays diffraction analysis using a Philips X-ray diffractormeter using a Cu-Kα (λ = 1.542 Å).

1.2 Fabrication of Photoelectrochemical Cells:

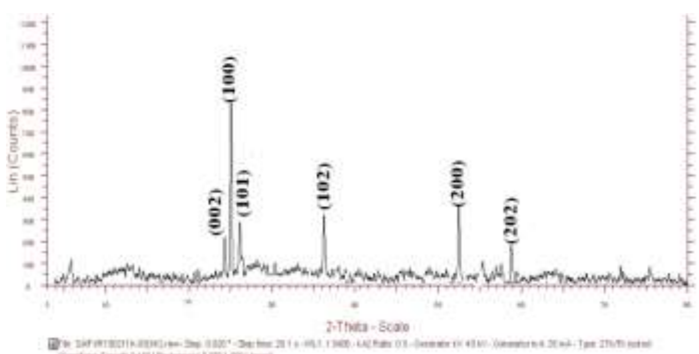
The photoelectrochemical solar cells were devised using a SUNLUX 500 W/250 V tungsten filament-halogenlamp, for white light illumination at 100 mW cm^2(AM l.5). The redox electrolyte used for photoelectrochemical studies was (aq) 0.1 M $K_4Fe(CN)_6$ +0.3 M $K_3Fe(CN)_6$, + (aq) 0.3 M KOH using analyticalreagent (AR) grade chemicals. A three electrode configuration was used for all the photoelectrochemical measurements. The counter electrode was graphite, thereference electrode was a saturated calomel electrode(SCE) attached very near to $CdSe_{0.7}Te_{0.3}$ photoanode. The photoanode – counterelectrode (graphite) distance was 6 mm. The desired surface area for our experiment was exposed to light and the rest area was coated with epoxy resin. The contacts to base Indium Oxide thin film and external wires were ohmic by coating Indium at the contacts. All theelectrical measurements were made using Keithley digital multimeters (Model 175). The capacitance was measured using a RADART (Model 1203) capacitance bridgewith an inbuilt oscillator of frequency 1 KHz and themodulated sinusoidal signal was kept constant at about$\pm$10 mV peak to peak.

2.0 Results and Discussion

2.1 X-ray Diffraction Studies: The X-ray diffraction pattern of the as-grown thin films is shown in the Fig. 1., The film shows hexagonal structure with lattice parameters of a_o= 4.41Å and c_o= 7.25Å agreeing well with literature [2-4].

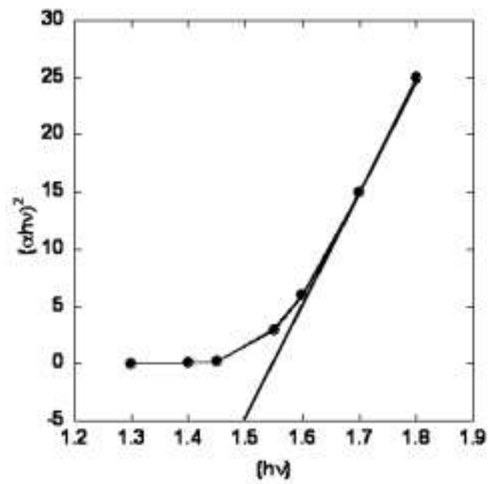
Sr. No.	d (Observed)	d (Literature)	(hkl)
1	1.5461	1.5824	(202)
2.	1.7163	1.7315	(200)
3	2.4690	2.4782	(102)
4	3.1119	3.1121	(101)
5	3.4610	3.4551	(100)
6	3.5475	3.5496	(002)

Table: 1: Comparison of d-values of $CdSe_{0.7}Te_{0.3}$ thin films with literature $CdSe_{0.7}Te_{0.3}$ thin film



Fig,1. Typical X-ray Diffractogram of a typical

2.2 Optical Absorption Studies



The optical absorption studies were carried on $CdSe_{0.7}Te_{0.3}$ thin films coated on glass at room temperature in the wavelength region of 300-900 nm to ascertain the band gap of the as grown thin films. From Fig. 2., a plot of $(\alpha\hbar\nu)^2 vs \hbar\nu$ was a straight line with intercept on the hν (energy) axis to be ≈ 1.52 eV. This shows that the semiconducting thin films exhibit direct band gap nature. As per theory the absorption coefficient α near the absorption edge is given by: [5]

$$\alpha \approx \frac{A^*}{h\nu}(h\nu - E_g)^{\frac{1}{2}}$$

Fig.2 Optical Absorption studies of the as grown $CdSe_{0.7}Te_{0.3}$ thin films

Where ν is the frequency of incident light, h is the Planck's constant, E_g is the band gap of the semiconductor and the coefficient, A^* given by:

$$A^* \approx q^2\left(\frac{2m_e^* m_h^*}{m_e^* + m_h^*}\right)(nch^2 m_e^*)^{-1}$$

Where m_e^* and m_h^* are the effective electron and hole masses respectively, c is the speed of light, h is the Planck's constant and n is the refractive index.

2.3Mott- Schottky Plot:

Figure 3 shows the Mott-Schottky plot of a $CdSe_{0.7}Te_{0.3}$/(aq) Ferro-Ferricyanide system for a PEC cell in dark. The value of flat band potential V_{FB} was obtained from the graph at $1/C_{SC}=0$ on the potential axis according to the Mott-Schottky relation [6,7]::

$$\frac{1}{C_{SC}^2} = \left[\frac{2}{\epsilon_o \epsilon_s q N_D}\right]\left[V - V_{FB} - \left(\frac{k_B T}{q}\right)\right]$$

Where C_{SC} is the space charge capacitance, V_{FB} is the Flat Band potential, ϵ_o is the permittivity of the free space, ϵ_s is the static permittivity of the semiconductor. N_D is the Donor concentration of the semiconductor. As seen from the plot we see upto certain voltages with respect to saturated calomel electrode the plot is linear but beyond certain voltages, it deviates from linearity. This is due to the fact that the at the semiconductor-electrolyte junction there are large density of states due to non uniform nature of the as-grown semiconductor thin film. Secondly the grain size of the as-grown thin films is small, thus there is a prevalence of large amount of grain boundaries thus the linear behavior is not consistent after certain voltage. The value of Flat Band Potential $V_{FB}$is by the relation $\frac{1}{C_{SC}^2} = 0$. Which in our case comes out to be ≈-1.2 V_{SCE}. For a semiconductor electrolyte junction, the majority of charge carriers in the semiconductor side are electrons and thus respond to the built in sinusoidal signal of the capacitance bridge and the ions in the electrolyte respond faster to the signal. The effective mass of the electrons in the semiconductor is very low compared to the ionic charge in the redox electrolyte. So only space charge capacitance is being considered in this case and the capacitance due to depletion width on the electrolyte side is neglected. So from theory, the Mott-Schottky plots have contribution from space charge capacitance. The linearity of the Mott-Schottky plot shows that the surface has low surface charge density and lesser defects.

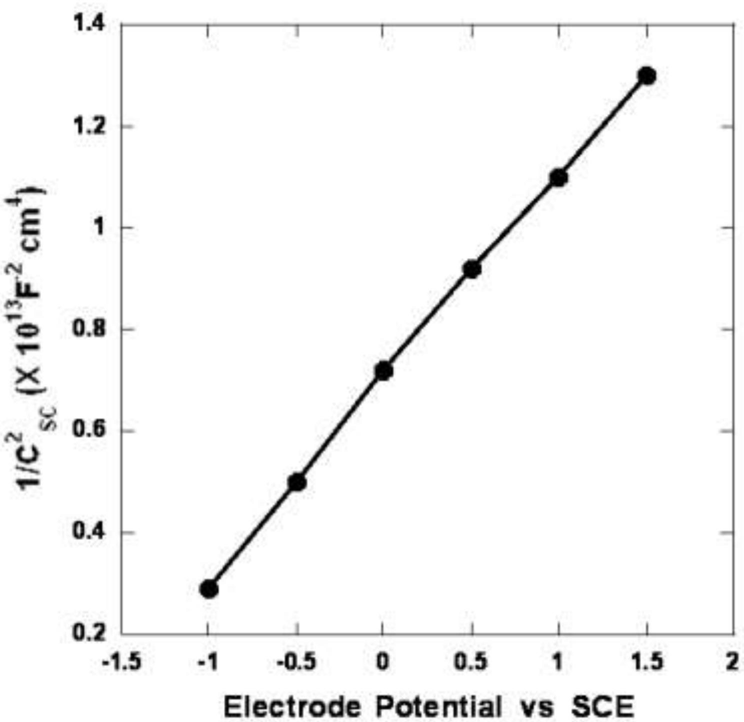


Fig. 3 Mott-Schottky plots of $CdSe_{0.7}Te_{0.3}$/(aq) Ferro Ferricyanide junction.

2.4 Power Output Characteristics

The PEC cell was subjected to power out characteristics with graphite as anode and n-$CdSe_{0.7}Te_{0.3}$ as cathode. The power conversion efficiency of the $CdSe_{0.7}Te_{0.3}$/(aq) Ferro-Ferricyanide junction PEC cell was close to 0.98 %. The fig. 4.0 shows the plot for power output characteristics.

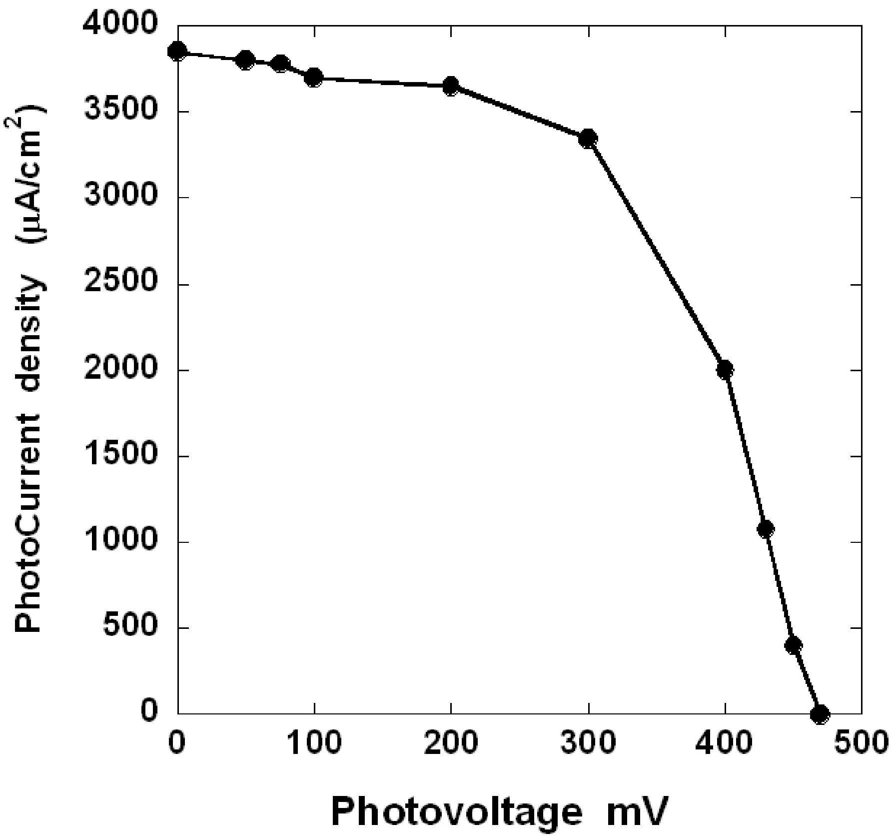


Fig. 3. A typical plot of power output characteristics of $CdSe_{0.7}Te_{0.3}$/(aq) Ferro-Ferricyanide junction PEC cell under AM 1.5 white light illumination.

The solar power conversion efficiency was calculated using the following relation:

$$\eta = \frac{V_m J_m}{Input\ Solar\ Power\ at\ AM\ 1.5} = \frac{V_m\ J_m}{100\frac{mW}{cm^2}}$$

Where V_m = Maximum Voltage and J_m = Maximum Current Density.

3.0 Conclusion

The $CdSe_{0.7}Te_{0.3}$/(aq) Ferro-Ferricyanidejunction formed was also used to study Mott-Shottky plots to find the flat band potential and investigate the behavior of $\frac{1}{C_{SC}^2}$ Vs Potential and the plot showed that it is found to be as straight line. The optical band gap of semiconducting$CdSe_{0.7}Te_{0.3}$was calculated using optical absorption studies and it was found to ≈ 1.52 eV which is close to literature [8]. The efficiency of the $CdSe_{0.7}Te_{0.3}$/(aq) Ferro-Ferricyanide junction PEC cell was close to 0.78 % under white light illumination (AM 1.5).

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