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Studies on the light conversion to electricity in a Thin Film CdSe /(aq) Polysulphide photoelectron chemical solar cell

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Abstract:
Thin films of CdSe were grown by vacuum evaporation at a pressure of 5×10^{-5} torr using a powdered alloy of CdSe on a pre-coated In_2O_3. The thickness of the as grown thin film was found to be ≈ 5000 Å. The X-ray diffraction studies showed that the thin film exhibits a Hexagonal structure with $a_o \approx 4.56$ Å and $c_o \approx 6.567$ Å. The optical band gap of the as grown CdSe thin film was found to be $\approx 1.76\,eV$. The thin film CdSe/(aq) Polysulphide junction photoelectrochemical solar cell exhibit a light conversion efficiency of 1.45 %. The reasons for low efficiency are discussed.

1. Introduction

There has been a lot of research in the literature on CdSe having applications in solar cells due to its band gap being close to the visible region [1-2]. People have grown thin films of CdSe by dipping, spray pyrolysis and electrodeposition [3-4]. However very few workers have reported results on thin film photoelectrochemical solar cells using CdSe /(aq) Polysulphide junction where the semiconducting thin film was grown by vacuum evaporation.

2. Experimental

Thin films of CdSe were grown by vacuum evaporation at a pressure of $\approx 5 \times 10^{-5}$ torr on bare glass plates and pre-coated In_2O_3 glass plates. The substrates were cleaned by ethanol and distilled water. The glass plates were dried in an ambient of hot air so that there are no traces of any impurities on the glass plates. A quartz crystal monitor was used to moniter the thickness of the thin film. Structural studies were done using X-ray diffractometer with Cu-Kα as the target material with wavelength, $\lambda \approx 1.5421$ Å. Optical absorption studies were done by a UV-VIS-IR spectrophotometer for measurement of absorption coefficient and then optical band gap was calculated for the semiconducting thin film. An (aq) redox polysulphide electrolyte comprising of 1 M NaOH + 1 M Na_2S + 1 M S was used in the experiment. The photoelectrochemical solar cell was fabricated using thin film semiconducting CdSe as photoanode and graphite as counter electrode. Measurements were done slowly till a stable reading was obtained. The illumination of pho\atoelectrochemical solar cell was done by using white light using Tungsten-Halogen lamp under AM 1.5 conditions. /

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3. Results and Discussion

3.1 X-ray diffraction studies

The thin films of CdSe were subjected to X-ray diffraction. Both bulk and thin film samples showed characteristic peaks. The bulk sample had peaks whose hkl matched with those of the peaks of thin film. This (Fig. 1) shows that the as-grown thin film of CdSe is well formed. The d-values as calculated from the X-ray diffraction data matched fairly well with that of the literature, confirming the formation of CdSe thin film. The d-values as calculated from the X-ray diffraction were nearly found to match with those of the literature [3-4]. Also from literature the corresponding miller indices of the planes were identified. The as-grown thin film exhibited an Hexagonal structure with lattice constant values of $a_o \approx 4.561$ Å and $c_o \approx 7.657$ Å. These values tally much close to that of literature. The grain size in the CdSe thin film was calculated by Williamson-Hall method [6] using the equation:

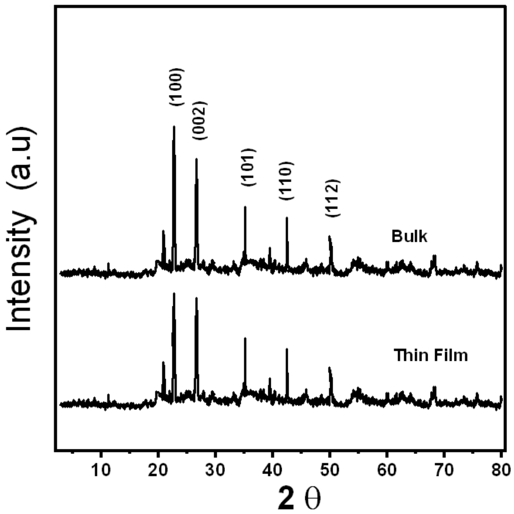

Fig. 1. Typical XRD Plot of as-grown Thin Film and Bulk Powder

$$\beta cos\theta = \frac{k\lambda}{D} + 4\epsilon \sin\theta$$

Where β is the full width at half maxima in radians for a particular peak, θ is the diffraction angle, λ wavelength of Cuk_α radiation, ϵ is the strain induced in the thin film due to crystal imperfections given by the formula:

$$\epsilon = \frac{\beta}{4\tan\theta}$$

A plot of $\beta\cos\theta$ *vs* $4\,sin\theta$ is linear. The slope of the plot gives the value of average strain (assuming that the thin film has an uniform strain), $\epsilon \approx 0.00525 \times 10^{-3}$ in the lattice and the $\beta cos\theta$ axis intercept gives the grain size, D. It is seen that the grain size, D was ≈ 49.50 nm. This indicates that the as-grown thin films have a preference of granular structure. There are grain boundaries separating different grains. The as grown thin film may have dislocations in its structure. This will lead to scattering centres for the minority generated charge carriers on illumination for photovoltaic cell (to be discussed in section 3.3).

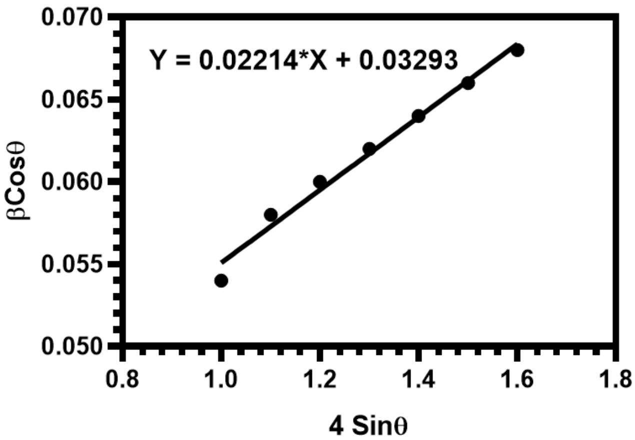

Fig.2. Plot of βCosθ vs 4 Sinθ fpr a CdSe Thin Film

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3.2 Optical Absorption Studies

The optical absorption studies were performed on the thin films of CdSe in the UV-VIS-NIR region to ascertain the band gap. On obtaining the values of optical absorption coefficient, α for each wavelength, λ the corresponding energy, $h\nu$ was calculated. For permitted direct transmissions in the optical region the absorption coefficient, α is given by [7]

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

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

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

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.

The variation of $(\alpha h\nu)^2$ vs $h\nu$ (Fig. 3) gives a straight line plot with intercept on the $h\nu$ axis at $(\alpha h\nu)^2 = 0$ gives the direct optical band gap of the semiconducting CdSe was around $E_g \approx$ 1.76 eV. The films showed a high values of optical absorption confirming that the thin films have a tendency to absorb visible light. This shows that the CdSe thin films can have a profound application in the light to electricity conversion devices like solar cells.

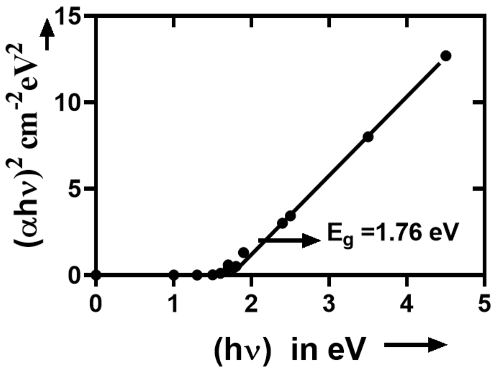

Fig.3. Optical Absorption Plot for CdSe thin film.

3.3 Solar Light to Electricity Conversion.

The thin film CdSe thin film/(aq) Polysulphide photoelectrochemical solar cell was subjected to AM 1.5 white light at an intensity of 100 mW/cm^2, As per Fig. 4, the photoelctrochemical solar cell showed a power conversion efficiency of 1.45%. This fill factor as calculated using the formula given below was $\approx$ 45%. The series resistance was found to be $\approx 350\ \Omega$ and shunt resistance was found to be $\approx 500\ \Omega$. The open circuit voltage was found to be $\approx$ 560 mV and the short circuit current was found to be $\approx 4500\ \mu A$. The

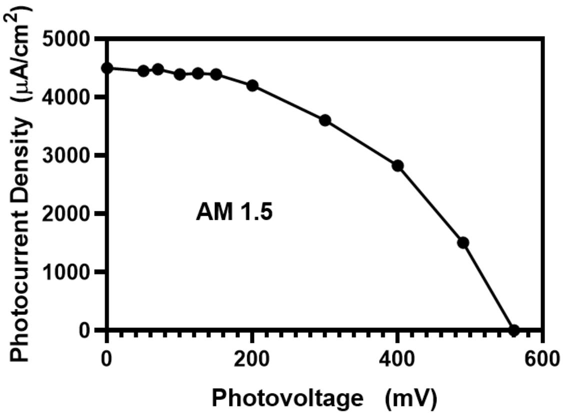

Fig. 4. Power output Characteristics of CdSe/ Polysulphide Photoelectrochemical Solar Cell under AM 1.5 Conditions

reason for the low efficiency is due to the fact that as-grown thin film, especially by thermal evaporation, has lot of defects as the thin film gets deposited sequentially. At a micro level the thin film will have lot of grain boundaries which can act as scattering centres for minority carriers [8]. These minority carries suffer leakages along the surface of the thin film leading to low shunt resistance and high series resistance. For an ideal solar cell [9], the shunt resistance should be $\approx \infty$ and series resistance should be ≈ 0.

Conclusion

The thin films of CdSe grown by thermal vacuum evaporation .showed a Hexagonal structure with lattice constants matching with those of the literature. Also the optical band gap of the thin film was a direct band gap. The value of the optical band gap was found to match with the literature. The solar light to electricity conversion was found to be $\eta \approx 1.45\,\%$. The low efficiency being attributed to the high resistance of the thin film, large grain boundary centres for scattering of minority generated charge carriers.

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