

Progressive Performance Of Dual Layer PEC Solar Cell

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Abstract

CdSe and ZnSe has the low cost and higher efficient material of bandgap 1.7eV and 2.54 eV respectively for the fabrication of PEC solar cells. In order to compare the cell parameters of single and dual layered photo-electrodes in PEC cells. Solar energy is one of the most important renewable sources of energy your planet. Conventional solar panel mainly use Si based photovoltaic cells, which is expensive because of complex manufacturing processes and high purity materials. The problem with present solar cells are high manufacturing cost due to high purity silicon material, complex fabrication process, installation and maintenance can also increase the overall cost. Therefore researchers are working on developing low cost solar cells that can produces electricity at a low price while maintaining good efficiency. Dual and single layer of CdSe and ZnSe have prepared onto titanium(pure 99.9%) substrate by electro-co-deposition technique in an aqueous acidic electrolyte employing different current density and deposition time duration. The cell configuration CdSe(0.1Mole)/ ZnSe(0.1Mole)/ SeO₂(0.3Mole)/ H₂SO₄(0.5Mole)/ NaOH/Na₂S/ Counter electrode graphite is used for studying the photovoltaic characteristic under illumination of 1950 lux light intensity to evaluate various cell parameters. The single layer of CdSe were deposited for time duration varied from 20/20 minutes to 60/60 minutes with a current density varying from 2mA/cm² to 10 mA/cm². Similarly other film of ZnSe deposited over it for same time duration with same current density and photo-electrode was annealed from 100°C to 200°C for 1 hours. Photo-electrode cleaned by double distilled water. Finally, Observed that ZnSe gives very poor performance with $\eta = 5\%$ due to its large band gap only small portion of the light spectrum is utilized to generate electron and holes. CdSe shows better results with $\eta = 20\%$ but a dual layer of CdSe/ZnSe photo-electrode of an efficiency of $\eta = 40\%$.

Key Words: Dual layer of CdSe, ZnSe, Current density, Deposition time, Current density, Annealing.

I. Introduction

In recent year bulk material CdSe/ZnSe has attracted much attention because of their properties differ significantly from other materials. The dual layer solar cells technology as the new building blocks to prepare high energy harvesting solar cells have opened up new way to utilize natural radiant energy sources. Dual layer structure materials is the advanced branch of material research and is attractive in various areas such as a nano-solar cells, electrochemical solar cells, opto-electronics solar cells, nano-composites etc. Recently, lot of work on has been reported on the promising material CdSe and ZnSe materials and further expanded the possibility of developing new strategies for energy conversion¹. Bouroushia² et al have deposited polycrystalline textured single layer CdSe and double layer of CdSe/ZnSe thin films by electro-deposition method. Solanki³ et al has grown nanowires composed of ZnSe/CdSe super lattices by atomic layer deposition. Growth of the nanowires was

initiated using gold nano particles and the vapor-liquid-solid mechanism. Kehar Singh⁴ et al have investigated photo responsiveness and photo-electrochemical characteristic of electro-synthesized (Zn-Cd)Se film of variable composition. E. Kurtz⁵ et al have prepared ZnCdSe alloy quantum dots grown by atomic layer epitaxy (ALE). They found enhanced surface diffusion, formation of coherently strained islands already well below the critical thickness (3 monolayers) of CdSe on ZnSe. The preparation of the material in the thin film form is relatively simple and less expensive as compared to the other crystals. Electro-chemical deposition method for metal chalcogenide thin film preparation is currently attracting considerable attention, simple and convenient for large areas deposition. it is a low (at room temperature) temperature process, which avoids oxidation and corrosion of metallic substrate⁶. In present investigation CdSe and ZnSe, single layer as well as dual layers have been deposited on titanium (99.9% pure) substrates and these were used as photo- electrodes in PEC solar cells by electro-co-deposition technique and recorded to various cell parameters. Our aim is to prepare dual layer photo-electrodes for PEC solar cells and study their photovoltaic effect. Dual layer solar cell utilizes more part of solar spectrum. Dual layer solar cell technology gives better performance compare to traditional solar cell made of single SC materials. This technology is not only scientifically interesting, but also hold great potential for many applications. We have chosen the double junction CdSe and ZnSe semiconductor material. The single and double layers of CdSe and ZnSe films have been deposited on titanium substrate by electro-co-deposition technique. These are used as photo-electrodes in PEC cell with polysulfide electrolyte and graphite as counter electrode. We have tested the performance of the PEC solar cell on the basis of short circuit current I_{sc} , output voltage V_{oc} , power output P_o , fill factor ff , efficiency and compared the all PEC solar cell parameter for single and double layers of CdSe, ZnSe and CdSe/ZnSe films. The preparative condition of photo-electrodes such as current density and deposition time duration are also optimized for best performance and effect of annealing the PE has also studied. This investigation may be useful in obtaining efficient, stable and low cost PEC solar cells, which may compete with the existing technology.

II. Literature Review

Many experts used different technique to prepare CdSe/ZnSe thin films. Bouroushian et al have deposited polycrystalline (111) textured single layer CdSe and double layer of CdSe/ZnSe thin films by electro-deposition method and used as active electrodes in regenerative, liquid junction solar cells with aqueous sulphide-polysulphide or ferro-ferricyanide redox electrolytes⁷. Deshmukh et al have prepared thin films of $Cd_{1-x}Fe_xS$ by on variable composition⁸. E. Kurtz et al have prepared ZnCdSe alloy quantum dots (SQDs) grown by atomic layer epitaxy (ALE). They found enhanced surface diffusion, formation of coherently strained islands already well below the critical thickness (3 monolayers) of CdSe on ZnSe⁹. Mahapatra et al have prepared of CdSe/ZnSe film grown by conventional molecular beam epitaxy (MBE) and two other variants of the same (low temperature MBE and in-situ annealing)¹⁰. Dwivedi have successfully fabricated CdTe/ZnTe heterojunction thin films using electron beam deposition technique on smooth photographic Pyrex glass substrate at different substrate temperatures. Films have been annealed in vacuum (5×10^{-4})

torr for one hour at as-deposited to 400K, 500K and 600K respectively¹¹. Mahapatra et al have suggested that the two steps electro-deposition method is the most convenient way for thin film deposition of CdS, CdSe and mixed CdS-CdSe on to nickel substrate. The improved performance of CdS-CdSe semiconductor electrode is due to decrease in band gap energy, higher flat band potential and smaller electron affinity of the mixed electrode materials Addition of a small amount of suitable dye to the redox electrolyte could enhance the efficiency of the cells appreciably due to increase in the population of majority carriers ¹²⁻¹⁴.

III. Experimental

The single and dual layer film of CdSe and ZnSe films have deposited on titanium substrate by electro-co-deposition technique are shown in figure. These are titanium substrate used as photo-electrodes and graphite as counter electrode. The cell configuration, CdSe(0.1Mole)/ZnSe(0.1Mole)/SeO₂(0.3Mole)/H₂SO₄(0.5Mole)/NaOH/Na₂S/Conter electrode graphite is used for studying the photovoltaic characteristic. Photo-electrode is dipped in 45ml solution of electrolyte and illumination by 200Watt tungsten lamp with an intensity of 1950 lux. Photoelectrode and graphite counter electrode are separate by a distance 1cm. The setup was placed on optical bench at fixed distance from the light source. The light source used for illumination was 200 Watt tungsten filament lamp. Two electrodes were connected to a potentiometer with variable load resistance 20K to 100K. CdSe, ZnSe and CdSe/ZnSe photo-electrode were used as a negative and graphite as positive electrode. The load resistance was varied and the output voltage and current were measured.

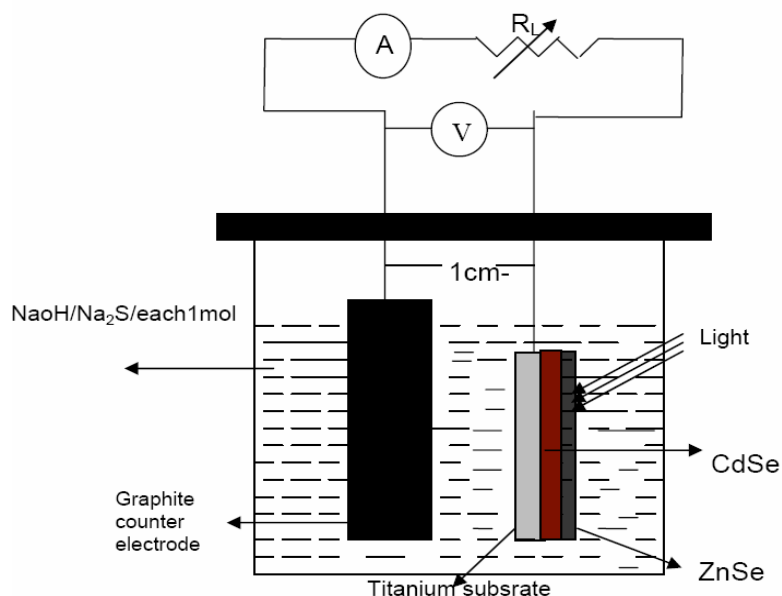


Fig. 1: Experimental Setup

The cell parameters are recorded for single and dual layer films at current density $J_D=10\text{mA/cm}^2$ and deposition time 60/60 (120) minutes. The solar cell parameters are shown in following table.

Table-1: Recorded Solar Cells Parameters

Sample	V_o (mV)	I_{sc} (mA)	Power Output $\times 10^{-6}$ mA/cm^2	Fill-factor (%)	Efficiency (%)
CdSe	250	0.640	67560	42	15.8
ZnSe	210	0.280	21450	38	5.0
CdSe/ZnSe	360	1.031	171737	55	40.0

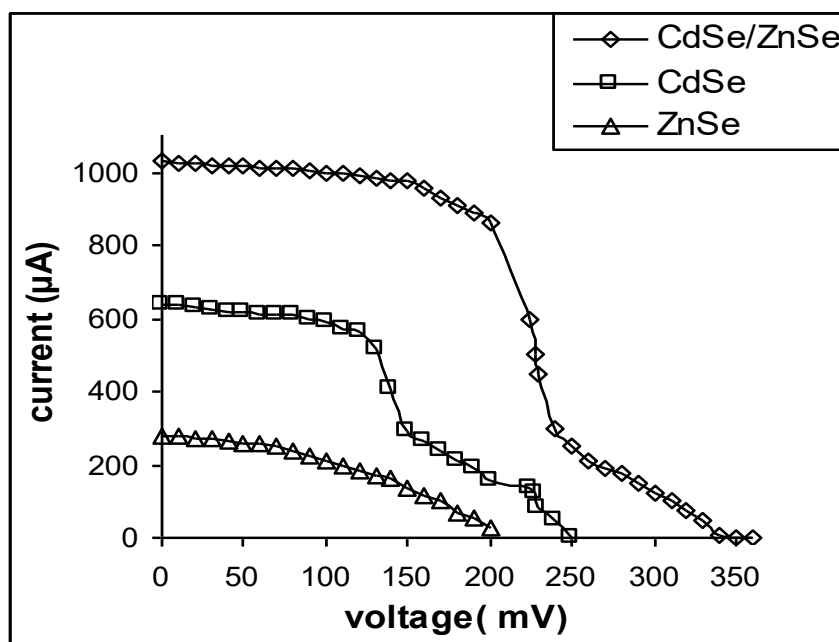


Fig. 2: Comparison Single and Dual Layer Films

1. Effect of Current Density

Current density play a critical role in the chemical and structural properties of electrodeposited of CdSe and ZnSe film. Controlling the stoichiometry, grain size,

deposition rate of the film. At the optimum current density film is well adhere. However, at too high current density, hydrogen evolution becomes dominant, leading to decreases in the efficiency of the deposited films and reduction in thickness of the films. Observed that as the current density (J_D) is increase, the solar cell performance is enhanced at $J_D = 10\text{mA/cm}^2$. At higher current the films do not adhere will to the substrate i.e. at optimum current density film were seen gray/black adhered well to the substrate. At the higher current density film coverage on the photoelectrode is poor and appearance red/brown. The film deposited at current density $J_D=10\text{mA/cm}^2$ with constant deposition time period at 60/60(120) minute gave the best performance of PEC solar calls.

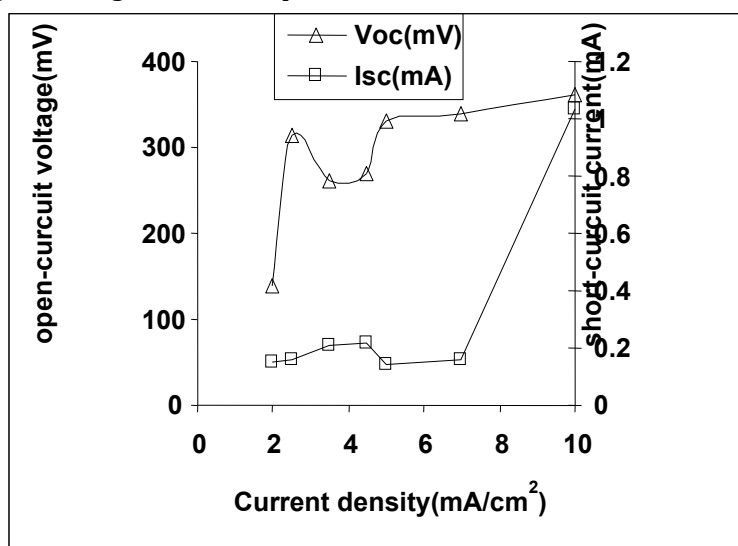


Fig. 3 :Variation of Voc and Isc with Current Density used for CdSe/ZnSe PE Deposition.

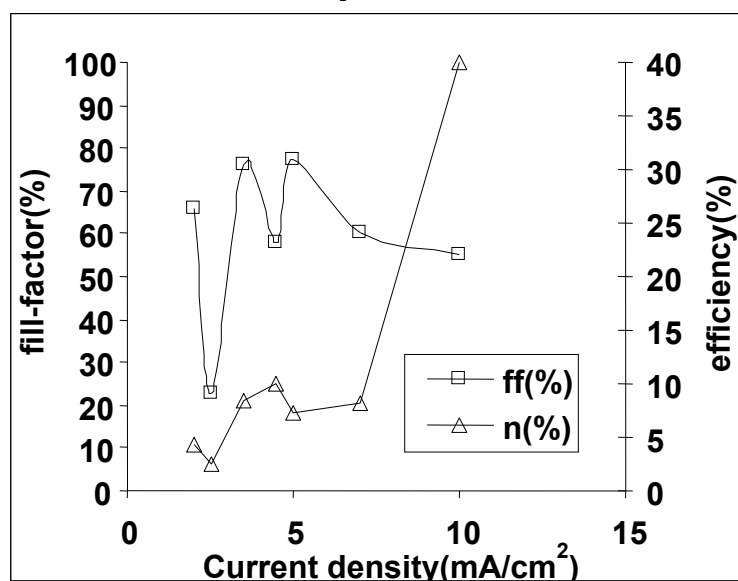


Fig. 4: Variation of Fill-Factor and Efficiency with Current Density Used of CdSe/ZnSe PE

It can see that the cell parameters increase gradually with increasing current density of the single CdSe or ZnSe layer as well as for double layer of CdSe/ZnSe films. At higher current densities above $10\text{mA}/\text{cm}^2$ the films are not found to adhere properly to the substrate and get dissolved in the electrolyte. The film deposited at optimum current densities were gray/black in appearance and adhered well to the substrate. However, films deposited at more positive current densities were distinctly red/brown in appearance that means poor coverage on substrate.

2. Effect of Deposition Time

Deposition time is critical parameters in the electro-deposition method of CdSe, ZnSe films, directly controlling thickness of film, crystallinity, surface morphology and optical properties. Increases the deposition time generally improve the film thickness, but excessive time can increase defects. The single and dual film deposited for various deposition time periods from 20/20 (40min.), 25/25 (50min.), 30/30 (60min.), 40/40 (80min.), 45/45 (90min.), 50/50 (100min.), 60/60 (120min) and 120/120 (240min.) at constant current density $J_D = 10\text{mA}/\text{cm}^2$. It has been observed that the cells parameter of film gave the best performance for deposition time periods at 60/60(120) minutes and photo- electrode attain maximum thickness. Thereafter, decreases thickness with further increasing deposition time periods at 120/120(240) minute.

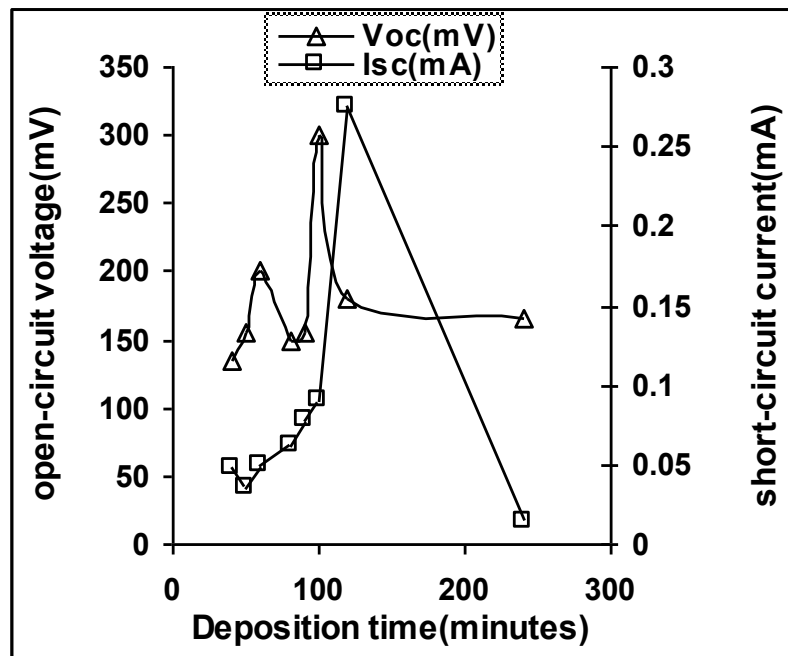


Fig. 5: Variation of V_{oc} and I_{sc} with Deposition Time Duration of PE.

It has been reported that as the deposition time duration is increased the films attain maximum thickness (at 60/60 minute) and thereafter thickness decrease with further increases in deposition time duration. This is attributed to the increase in rate of dissolution than the rate of deposition after attaining the maximum thickness. The best performance is obtained for the double layered CdSe/ZnSe films deposited by 60/60 minutes.

3. Effect of Annealing

Annealing of photo-electrodes enhanced performance of PEC solar cell parameters. The enhancement of I-V characteristic is due to increase in grain size and film structure by annealing. Annealing eliminate disorder in crystalline and give higher carriers mobility within the thin films, and improve decreasing resistivity and reducing surface states. We found that the PEC cell parameters are improved by annealing the PE at temperature 200°C for one hour. Annealing above 200°C cells parameter become poor. Annealing of the electro-co-deposited films has been reported to improve their performance in PEC cells.

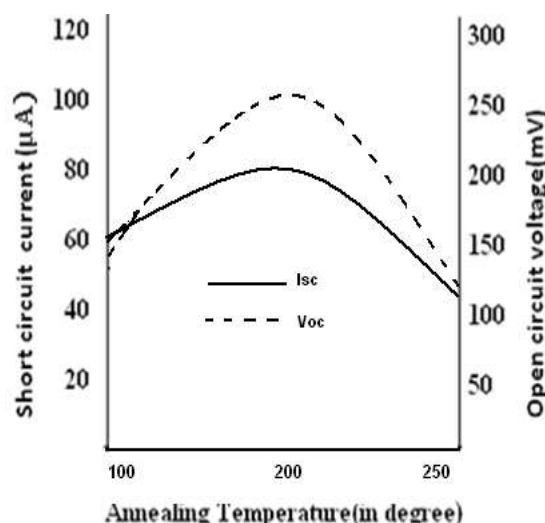


Fig. 6: Annealing Temperature(in Degree)

IV. Discussion and Conclusion

From present investigation following conclusion has been drawn:-

1. Electrochemical deposition technique is an effective technique for the preparation of single and dual layer of CdSe,ZnSe for PEC solar cells.
2. Use of double layer of CdSe/ZnSe on titanium as photo-electrode give much better performance as compared to any of the single layer.
3. PEC performance is improved by increasing the thickness of materials on substrate.
4. At higher current density films are not formed properly.

5. The cells parameter of film gave the best performance for deposition time periods at 60/60(120) minute and photo electrode attain maximum thickness. At still larger duration of deposition redissolution occurs and film formation is poor.
6. The surface treatment technique such as annealing lead to enhancement of efficiency of PEC cells. The PEC solar cells parameter is enhanced by annealing the CdSe/ZnSe photo-electrode at 200°C for one hour.
7. Dual layer technique is very significant to achieve desirable results. This research opens up several interesting avenues such as in advanced research field and low cost cells for commercial uses etc.

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