

Effects of Metal Back Contacts on the Efficiencies of CdS/CdTe Thin Film Solar Cells

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Abstract

Device simulation is used to investigate the effects of metal back contacts on the performance of CdS/CdTe thin film solar cells at different working temperatures. The simulations were done for chemical and physical based deposition techniques. The working temperatures studied ranges from 300 to 600K for Copper, Cobalt and Platinum back contacts using standard SCAPS 3.3.03 version software. Thin film solar cells with Platinum back contact of work function of 5.6eV exhibited better efficiency 17.24% at working temperature 350K with chemical method and 18.54% at 300K for physical method. Cobalt with metal work function of 5.0eV had 5.66% efficiency at working temperature 400K with chemical method and 6.58% at working temperature 300K for physical method. Copper with work function of 4.7eV showed the least efficiencies of 0.81 and 0.73% for chemical and physical method respectively at the same working temperature of 300K. The right metal work function should be selected as back contact electrode and using back contact buffer is encouraged to enhance the efficiency.

1.0 Introduction

Electrical and optical numerical simulations of thin film solar cells are becoming a common practice [1, 2, 3]. In recent years, the study on CdTe solar cells has made noticeable progress and has been put into large scale production. The benefit of using CdTe is for being a direct bandgap material with high absorption (in relationship with silicon) and the ease of device processing. It can be deposited on glass in thin film typically a few micrometers and at low temperature [4, 5, 6]. The theoretical efficiency of CdTe solar cells is predicted to be up to 28%, while the best experimental efficiency on laboratory scale has so far reached is less than 20% which is far from theoretical prediction [7, 8, 9]. One of the major impact factors for this difference is CdTe back contacts.

It has been shown that a CdTe back contact barrier may be responsible for the frequently observed rollover of the current-voltage characteristics [10] and reported to strongly influence the cell behavior [11]. An important issue related to the limiting performance of CdTe cells is the back contact [4]. It is very difficult to achieve good ohmic contacts between the CdTe layer and metal back electrodes due to differences in work function and electron affinity between the metals and semiconductors. The working temperature of the PV is also an issue. The electrical performance is primarily influenced by the type of PV used. A typical PV module converts 6-20% of the incident solar radiation into electricity, depending upon the type of solar cells and climatic conditions. The rest of the incident solar radiation is converted into heat, which significantly increases the temperature of the PV module and reduces the PV efficiency of the module [11]. The efficiency η (%) of the thin film solar cells [12] is given as

$$\eta(\%) = \frac{I_{max} V_{max}}{P_{in}} \quad (1)$$

Where I_{max} and V_{max} are the current and voltage obtained at the maximum power point on the photovoltaic power output curve and P_{in} is the power density of the incident radiation respectively.

In this paper, efforts are made to investigate the performances of CdS/CdTe thin film solar cells at different working temperature conditions for Platinum, Cobalt and Copper back contact electrodes.

2.0 The Simulation Program SCAPS

SCAPS is a windows application program, developed at the University of Gent with LabWindows/CVI of National

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Instruments. It has been made available to university researchers in the photovoltaic community after the second PV World Conference in Wien, 1998. The program opens with an 'action panel', where the user can set an operating point (temperature, voltage, frequency, illumination) and action list of calculations to carry out (I-V, C-V, C-f, $Q(\lambda)$). SCAPS version 3.3.03, which is available now, has some enhancements over version 2.0 to 3.0 [2].

3.0 Design Method

In this design, the schematic of a CdTe thin film solar cell used in the simulation with ITO/ZnO/CdS(n-type)/CdTe(p-type)/metal structure is shown below. The simulations were done by considering the thickness of CdS and CdTe to be 100nm and 7 μ m as window and active layer respectively. The electron affinity used for CdS and CdTe were 4.5 and 4.3eV with energy bandgap of 2.45 and 1.45eV respectively among other parameters. The working temperatures were varied from 300 to 600K while studying the efficiencies of CdS/CdTe thin film solar cells with different back contact electrodes under investigation for chemical and physical methods of deposition. Figure 1 shows the CdS/CdTe thin film structure in superstrate configuration.

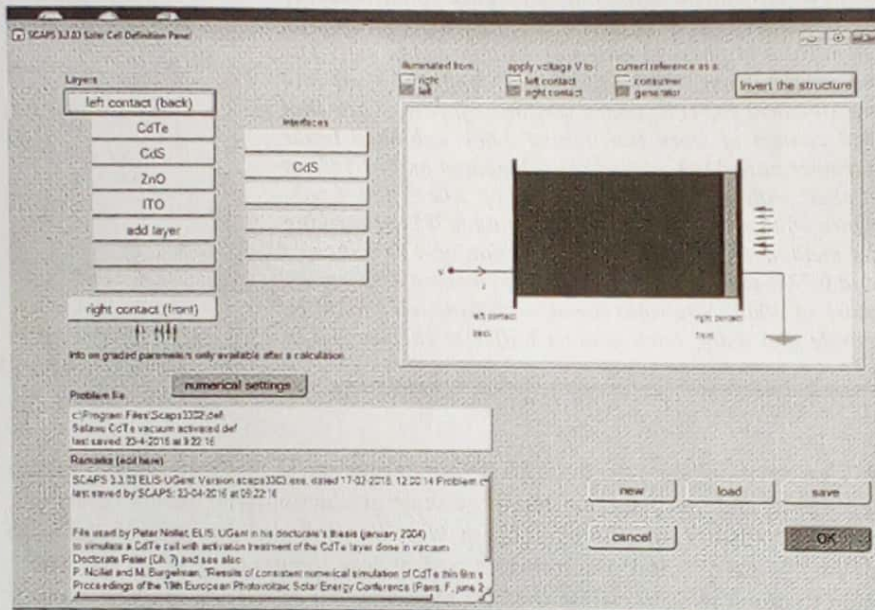


Figure 1: CdS/CdTe Thin Film Structure in Superstrate Configuration Under Investigation.

4.0 Results and Discussion

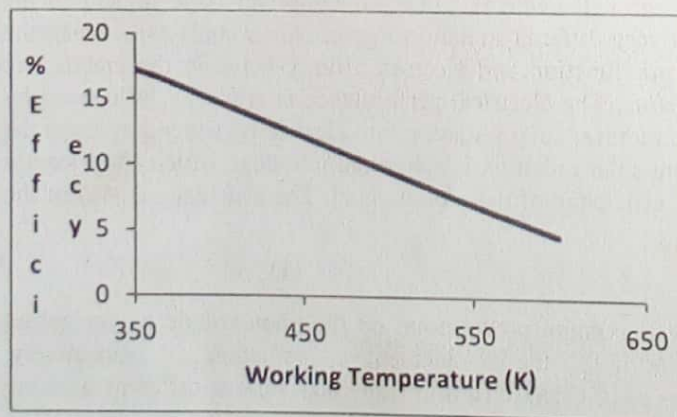


Fig 2: % Efficiency against Working Temperatures for chemical method with Platinum back contact

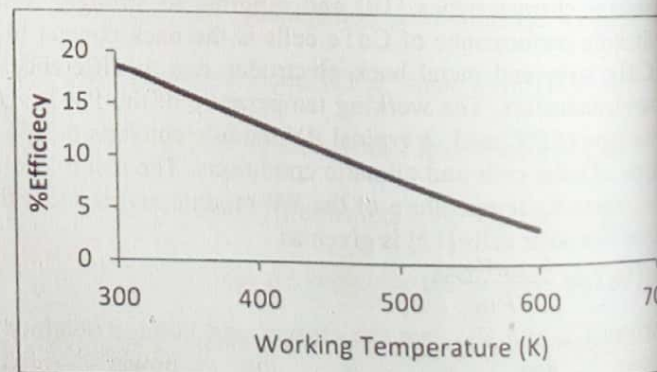


Fig 3: % Efficiency against working Temperature for physical method with Platinum back contact

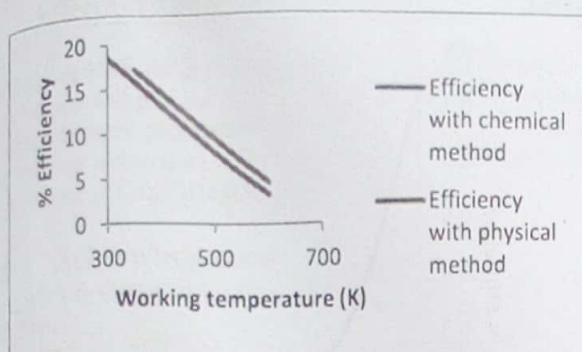


Fig 4: Comparison between efficiency of chemical and physical methods with Platinum back contact

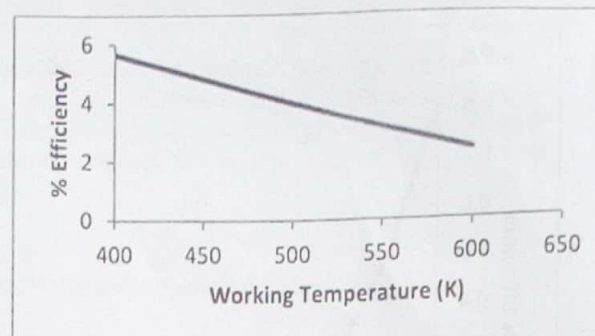


Fig 5: % Efficiency against working Temperature for chemical method with Cobalt back contact

The efficiencies of Platinum back contact CdS/CdTe thin film solar cells degraded from the threshold working temperature for both chemical and physical methods of deposition. For chemical method, the best efficiency achieved was 17.24% at threshold working temperature 350K (Figure 2) while for physical method; efficiency of 18.54% was achieved at threshold working temperature 300K (Figure 3). The efficiencies of both techniques degraded as the temperature increases from their respective threshold working temperatures. The increases in temperature supposed to aid the conversion efficiency but converted to heat and have effect on the device efficiency.

The work function of Platinum (5.6eV) is close to that of Cadmium Telluride, so electrons can easily be moved to the back contact electrode. At 350K and above, efficiency of chemical method were slightly higher than that of physical technique of deposition at the working temperatures under investigation (Figure 4).

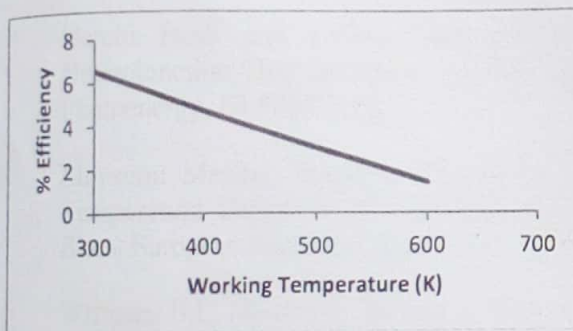


Fig 6: % Efficiency against working Temperature for physical method with Cobalt back contact

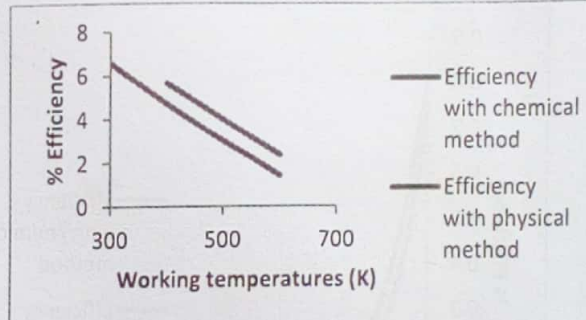


Fig 7: Comparison between Efficiency obtained with chemical and physical methods with Cobalt back contact

Using Cobalt with metal work function of 5.0eV as back contact electrode, efficiencies obtained for both chemical and physical methods diminishes in relative with that obtained with platinum back contact (Figure 7). At 300K, efficiency of 6.58% was obtained with physical method (Figure 6) whereas no efficiency obtained with chemical method at the same working temperature (Figure 5). Efficiency of 5.66% was obtained with chemical method at 400K working temperature. When the working temperature of the PV increases from the threshold value, efficiency of the PV decreases for both methods due to the heating effect.

The type of metal back contact electrode used has contributed to the downfall of the efficiencies for the two methods owing to the disparity between the work function of Cobalt and the cadmium telluride.

Effects of Metal Back Contacts...

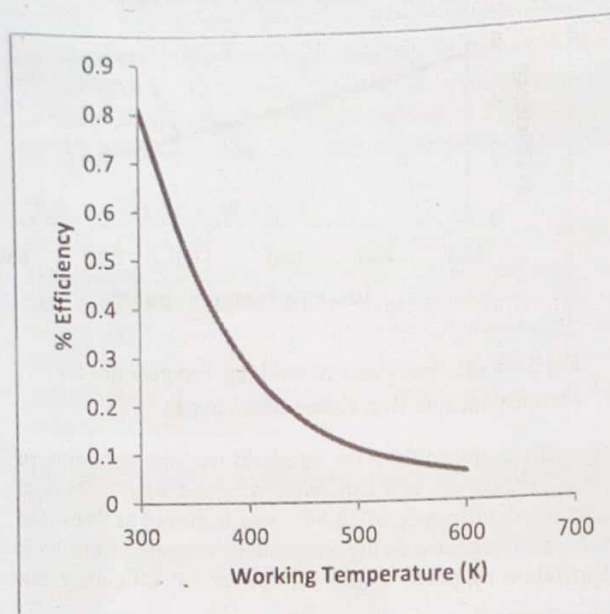


Fig 8: % Efficiency against working Temperatures for chemical method with Copper back contact

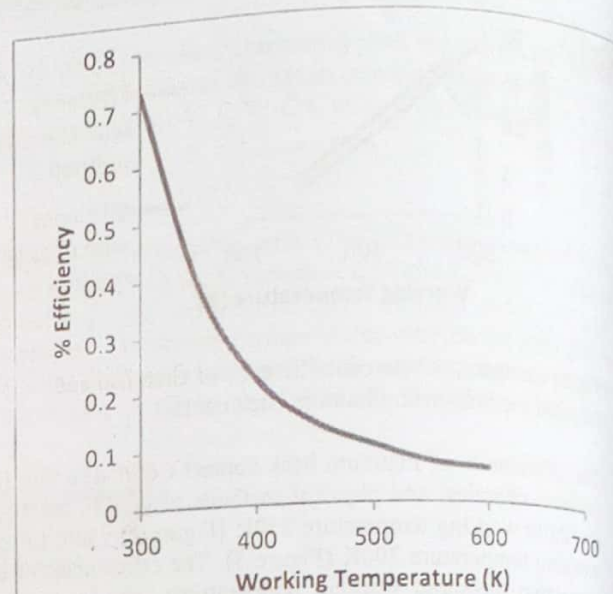


Fig 9: % Efficiency against working Temperatures for physical method with Copper back contact

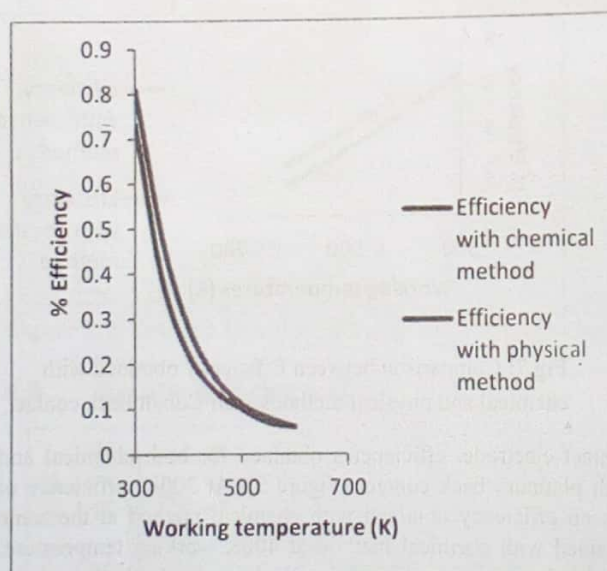


Fig 10: Comparison between efficiency obtained with chemical and physical methods with Copper back contact electrode.

For Copper back contact electrode, efficiency at different working temperatures was very poor less than 1% for both chemical and physical methods of deposition. The copper electrode on Cadmium Telluride presents a non ohmic contact owing to the large disparity in minimum thermodynamic work required to remove electrons from the surface of the active layer to the back contact electrode. Different work functions and Fermi energy level that exists between them plays a major role in the reduction of CdS/CdTe thin film conversion efficiencies.

5.0 Conclusion

In this work, CdS/CdTe thin film solar cells with Platinum back contact of work function of 5.6eV exhibited better efficiency 17.24% at working temperature 350K with chemical method and 18.54% at 300K for physical method. Cobalt with metal work function of 5.0eV had 5.66% efficiency at working temperature 400K with chemical method and 6.58% at working

temperature 300K for physical method. Copper with work function of 4.7eV showed the least efficiencies of 0.81 and 0.73% for chemical and physical method respectively at the same working temperature of 300K. The working temperature plays a crucial role in the photovoltaic conversion process. The electrical efficiency and the power output of a PV cells depends on the working temperature. The right metal work function as back contact electrode is also very important to enhance the performance of CdS/CdTe thin film solar cells.

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