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Speech Steganography in Wavelet Domain Using Continuous Genetic Numerical Simulation of CdTe thin film solar Cell with AMPS-1D

[1,*]AshrafAlsadat Mirkamali, [2]Kh.Kh. Muminov, [2]K. Kabodov

[1]*Department of Science and Engineering, Behshahr Branch, Islamic Azad University, Behshahr, Iran.*

ash.mirkamali@gmail.com

[2]*Physical-Technical Institute named after S.U.umarov, academy of Sciences of the Republic of Tajikistan, Dushanbe, Tajikistan.*

muminov@phti.tj , khikmat@inbox.ru

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Abstract:

We conducted the analysis of parameters and the efficiency of photovoltaic effect in CdTe thin film Solar Cell depending on its thickness variations by use of AMPS-1D software. The simulation of the main parameter has been carried out in order to optimize the performance of thin solar cell. The results are in a good agreement with the result obtained from the literature. In this paper it has been shown, a conversion efficiency of 14.6% has been achieved for 1 µm thick CdTe cell, which indicates that with only 25% CdTe absorber material of the baseline cell the compromise for efficiency is only 0.8% (15.4% to 14.6%).

KeyWords: AMPS-1D, efficiency, Thickness, thin film, simulation.

1. Introduction

For significant energy production, large-area solar-cell installations are necessary. In comparison to wafer based Si technology, thin-film solar cells can be cheaply deposited on large areas of (soda-lime) glass [1], stainless steel [2], or even on polyimide substrates, which would make these solar cells truly lightweight [3, 4]. Now day is a strong need for the development of photovoltaic cells with low cost, high efficiency, and good stability. In thin film technologies, there exists a common problem with conversion efficiency due to poor materials quality; the photogenerated electrons and holes cannot travel very far before recombination (short free-carrier diffusion lengths) and are hence lost for power conversion. If the solar cell can be made using nanoscale heterojunctions, then every photogenerated carrier will have less distance to travel, and the problem of recombination can be greatly reduced [5]. Thin-film solar cells

* Corresponding author

have the potential to be significantly cheaper in large-scale production. Recent studies have shown that the application of today's technologies in "super-large scale" manufacturing of thin-film solar cells would lead to solar electricity prices that are competitive with conventional energy sources [6].

Thin-film polycrystalline CdTe based solar cells are one of the most promising candidates for photovoltaic energy conversion because of their potential to realize low cost, high efficiency, reliable and stable thin film solar cell. The thickness required for an absorption layer makes the cost of material for CdTe solar cells relatively low. Clearly one of the main goals of today's solar cell research is using less semiconductor material by making the cells thinner.
Thinning will not only save material, but will also reduce the recombination loss as well as lower production time, and the energy needed to produce the solar cells. All of these factors will decrease the production cost. Moreover, from optoelectronic and chemical properties, CdS is the best suited n-type hetero junction partner to CdTe for high-efficiency and low-cost cells. The maximum theoretical efficiency for CdTe band gap (1.45 eV) and a standard solar spectrum is about 29%. In 1982, Tyan et al. published an interesting paper on CdTe/CdS thin film solar cells reporting an efficiency of 10% [7]. Afterwards, an efficiency of 15.8% has been reached by Ferekides et al. [8]. Finally a group of NREL researchers reported a record efficiency of 16.5% [9]. This champion 16.5% efficient CdS/CdTe cell used modified cell structure of CTO/ZTO/CdS/CdTe with 0.1 µm CdS and 10 µm of CdTe layer fabricated using three different technology CSS for CdTe film, CBD for CdS film and magnetron sputtering for all other layers. This champion cell efficiency (16.5%) is a little over half of the 29% theoretical limit, but it was estimated that practical CdTe devices with 18–19% efficiencies should be feasible in the near future [10].

1.1. The main parameters of cells

The main parameters that are used to characterize the performance of solar cells are the peak power, $P_{\max}$, the short-circuit current density, J_{sc}, the open-circuit voltage, V_{oc}, and the fill factor, FF.
The total photo-induced current can be calculated by summing (i.e., integrating) the contributions to the current from excitation at each wavelength. Hence, the short-circuit photocurrent density (J_{sc}) is:

$$J_{sc} = q\int I_s(E)(QY)(E)dE \qquad (1)$$

Where I_s = solar photon flux, E = photon energy (inversely proportional to the wavelength of the photon), and QY = quantum yield (electrons collected per incident photon). The net current density (J) is:

$$J(V) = J_{sc} - J_{dark}(V) = J_{sc} - J_0(e^{qv/KT} - 1) \qquad (2a)$$

However, ideal diode behavior is seldom seen. This is accounted for by introducing a non-ideality factor, m, into Equation (2a):

$$J(V) = J_{sc} - J_{dark}(V) = J_{sc} - J_0(e^{qv/mKT} - 1) \quad (2b)$$

Because no current flows at open circuit, the open-circuit voltage (V_{oc}) for the ideal device is obtained by setting $J(V) = 0$,

$$V_{oc} = [KT / q]\ln[(J_{sc} / J_0) + 1] \quad (3)$$

A plot of the net photocurrent density (J) vs. voltage is provided in the figure, which shows the current-voltage characteristic of a PV cell. The conversion efficiency (η) of the PV cell is determined by the maximum rectangle in the figure that can fit within the net photocurrent-voltage characteristic. The maximum power point of the cell, or so-called operating point, is the values of J and V (J_m and V_m) at which the maximum rectangle in the figure meets the $J - V$ curve. This defines a term called the "fill factor" (FF)

$$FF = J_m V_m / J_{sc} V_{oc} \quad (4)$$

That characterizes the "squareness" of the $J - V$ characteristic. The maximum FF value is 1.0; it occurs when $J_m = J_{sc}$ and $V_m = V_{sc}$, but in reality, the diode equation limits the maximum FF to 0.83. The cell conversion efficiency is the electrical power density $(J_m V_m)$ $(watts / cm^2)$ divided by the incident solar power density (P_{sun}), multiplied by 100 to obtain a percent value [11]

$$\eta = J_m V_m / P_{sun} = 100 * J_{sc} V_{oc} FF / P_{sun} \quad (5)$$

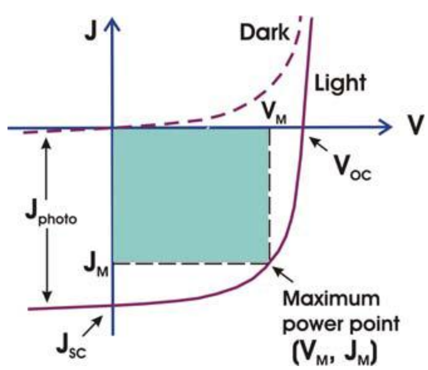

Fig.1. Current-voltage curve of a solar cell in dark (dashed) and in light (solid).

1.2. AMPS-1D Program:

Numerical modeling is increasingly used to obtain insight into the details of the physical operation of thin-film solar cells. Over the years, several modeling tools specific to thin-film PV devices have been developed. A number of sophisticated semiconductor device simulation is the AMPS-1D (Analysis of microelectronic and photonic structure-one dimension) has been used to analyze transport in a wide variety of device structures that can contain combinations of crystalline, polycrystalline, or amorphous layers. The one-dimensional device simulation program (AMPS-1D) developed by S. Fonash and colleagues at Pennsylvania State University. [12]

The one-dimensional device simulation program AMPS solves Poisson equation and the electron and hole continuity equations by using the method of finite differences and the Newton-Raphson technique. Poisson's equation links free carrier populations, trapped charge populations, and ionized dopant populations to the electrostatic field present in a material system. In one-dimensional space, Poisson's equation is given by:

$$\frac{d}{dx}\left(-\varepsilon(x)\frac{d\psi'}{dx}\right) = q \bullet \left[p(x) - n(x) + N_D^+(x) - N_A^-(x) + p_t(x) - n_t(x)\right] \tag{6}$$

Where the electrostatic potential ψ' and the free electron n, free hole p, trapped electron n_t, and trapped hole p_t, as well as the ionized donor-like doping N_D^+ and ionized acceptor – like doping N_A^- concentrations are all functions of the position coordinate x. Here, ε is the permittivity and q is the magnitude of the charge of an electron [12].

In this work the program was used to study the optimum performance of CdS|CdT with change the thickness of cell.

2. Experimental detail

2.1. Materials

The CdTe thin film solar cells have shown long-term stable performance [13] and high efficiency [14, 15, 16] under AM1.5 illumination for terrestrial usage.

The band gap of CdS is low enough (2.4 eV) for the high-energy violet region of the AM1.5 solar spectrum to be absorbed by the window material, so that fewer photons are available for the absorber layer for generating electron-hole pairs. For similar reasons, ITO has also been replaced with FTO as the transparent conductive oxide (TCO) material that is interfacing the front surface of the oxide layer.

In this research, the skeletal structure of the most typical devices based on CdTe has been modeled. These devices utilize 10 nm to 200 nm In2O3-SnO2 (ITO) as the TCO, CdS window layer thickness from 20 nm to 200 nm serves as the window material that forms the Schottky barrier with the CdTe layer thickness from 6 µm to 10 nm has been varied by keeping all other parameters at the fixed values as shown in Table 1. Aiming to achieve the efficient and thinner CdS/CdTe solar cell. Copper has been used as the metal forming the ohmic contact at the rear end, and its thickness is not a consideration that affects PV behavior.

Table 1: Material parameters those have been used in this CdS/CdTe solar cell simulation.

Material	Band Gap (eV)	Conductivity Type	Conduction Band	Valence Band	Electron Affinity (eV)	Electron Mobility (cm2 /v/s)	Hole Mobility (cm2 /v/s)	Free Carrier Concentration (cm-3)	Relative Permittivity
ITO	3.60	N	$2.0*10^{20}$	$1.8*10^{19}$	4.10	50.0	70.0	$1.0*10^{20}$	2.0
CdS	2.40	n	$2.2*10^{18}$	$1.8*10^{19}$	4.0	25.0	100.0	$1.1*10^{18}$	10.0
CdTe	1.50	p	$8.0*10^{17}$	$1.8*10^{19}$	3.90	40.0	320.0	$2.0*10^{14}$	9.4

2.2 Results of simulation and discussion

The CdTe thickness has been varied from 0.01 µm to 6 µm to explore thinner absorber layer and the results obtained from the simulation are shown in Fig.1.

It is clear from the Fig.1 that all the solar cell output parameters are almost constant above the CdTe thickness of 2 µm. The short circuit current density (Jsc) slowly decreased but the Voc and FF remained unaffected by the reduction of CdTe thickness until 1 µm, but below 1 µm of CdTe thickness all the cell output parameters decreased drastically, which has shown good agreement with similar works [17]. As a result, the efficiency showed very slow decreasing trend with the reduction of CdTe thickness until 1 µm and below 1 µm of CdTe thickness decreases rapidly which indicates that 1 µm thick CdTe cell has possibilities with very small decrease or loss in efficiency. A conversion efficiency of 14.6% (Voc = 0.92 V, Jsc = 24.6 mA/cm2, FF = 0.706) has been achieved for 1 µm thick CdTe cell, which indicates that with only 25% CdTe absorber material of the baseline cell the compromise for efficiency is only 0.8% (15.4% to 14.6%). These results are in good agreement with related published results by others on CdTe cells [18].

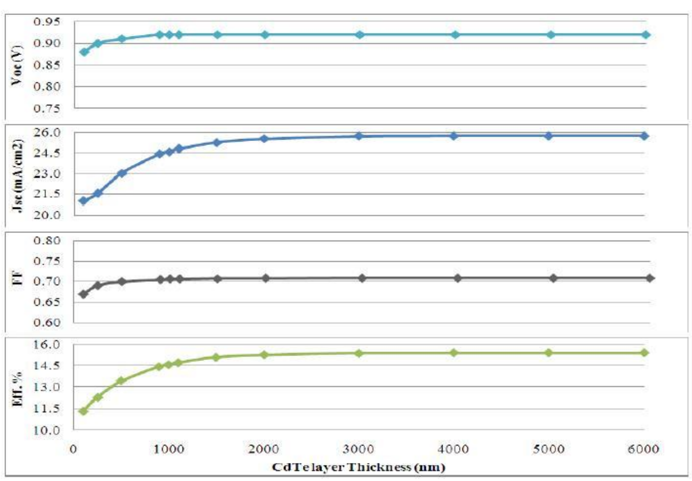

Figure 1: Effect of the CdTe film thicknesses on cell performance.

3. Conclusion

Theoretically the minimum thickness required for CdTe films to absorb 99% of the incident photons with energy greater than Eg is approximately 1-2 µm [19, 20]. However, to date almost all the high efficiency CdTe solar cells have been fabricated with more than 5 µm thick CdTe layer. However, further numerical analysis has been done aiming to conserve the material required and cost in CdS/CdTe solar cells by reducing the thickness of CdTe and CdS layers. The CdTe thickness has been varied from 0.01 µm to 6 µm to explore thinner absorber layer and the results obtained from the simulation are shown A conversion efficiency of 14.6% (Voc = 0.92 V, Jsc = 24.6 mA/cm2, FF = 0.706) has been achieved for 1 µm thick CdTe cell, which indicates that with only 25% CdTe absorber material of the baseline cell the compromise for efficiency is only 0.8% (15.4% to 14.6%).

References

[1] W. N. Shafarman and L. Stolt, Handbook of Photovoltaic Science and Engineering (Wiley Chichester, 2003), chap. Cu (In,Ga)Se2 Solar Cells, pp. 567–616.
[2] L. J. Simpson, J. S. Britt, S. Wiedeman, M. E. Beck, B. S. Joshi, T. L. Vincent, J. P. Delplanque, R. J. Kee, N. B. Gomez, K. M. Williams, et al., in Proc. NCPV and Solar Program Review Meeting (2003), p. 604.
[3] G. Jensen, J. Schaefer, G. M. Hanket, E. Eser, and S. Wiedeman, in Proc. NCPV and Solar Program Review Meeting (2003), p. 877.
[4] R. Birkmire, E. Eser, S. Fields, and W. Shafarman, Prog. Photovoltaics 13, 141 (2005).
[5] Bent, et al; "Inorganic Nanocomposite Solar Cells by ALD"; GCEP Technical Report (2006).
[6]M.S. Keshner and R. Arya, Tech. Rep., National Renewable Energy Laboratory, http://www.nrel.gov/docs/fy05osti/36846.pdf (2004).
[7] YJ.S. Tyan, E.A. Perez-Albuerne, Efficient thin film CdS/CdTe solar cells, Proceedings of 16th IEEE Photovoltaic Specialists Conference, IEEE Publishing, New York, 1982, p. 794.
[8] C. Ferekides, J. Britt, Y. Ma, L. Killian,"High efficiency CdTe solar cells by close spaced sublimation", Proceedings of Twenty- Third-Photovoltaic-Specialists-Conference IEEE, New York, USA, 1993, p. 389
[9] Xuanzhi Wu, "High-efficiency polycrystalline CdTe thin-film solar cells", Solar Energy, 2004, 77, pp. 803–814.
[10] S. Demtsu and J. Sites, Proc of 30th IEEE Photovoltaic Specialist Conference, pages 744– 747, 2005.
[11] Nathan S. Lewis, George Crabtree (2005);" Basic research needs for solar energy utilization"; pp.67-69.
[12] AMPS-1D (1997); Pennsylvania State University; http://www.empl.psu.edu/amps.
[13] D. L. Batzner, A. Romeo, H. Zogg, R. Wendt, A. N. Tiwari, Thin Solid Films 387, 151 (2001).
[14] X. Wu, J.C. Keane, R.G. Dhere, C. DeHart, D.S. Albin, A. Duda, T.A. Gessert, S. Asher, D.H. Levi, P. Sheldon, Proc. of 17th European Photovolt. Sol. Energy Conf., 2001, Munich, Germany.
[15] Nowshad Amin, Akira Yamada and Makoto Konagai, Japanese Journal of Applied Physics 41(5A), Part 1 (2002).
[16] M.A. Matin, M. Mannir Aliyu, Abrar H. Quadery and Nowshad Amin, SOLMAT, 94, 1496 (2010).
[17] Nowshad Amin, Kamaruzzaman Sopian, M. Yahya and A. Zaharim, Proceedings of the 8th WSEAS International Conference on POWER SYSTEMS (PS 2008), Santander, Cantabria, Spain, September 23-25, 2008, pp.299.
[18] N. Amin, T. Isaka, T. Okamoto, A. Yamada, M. Konagai, Jpanese Journal of Applied Physics 38 (1999) 4666.

[19] Xuanzhi Wu, “High-efficiency polycrystalline CdTe thin-film solar cells”, Solar Energy, 2004, 77, pp. 803–814.
[20] N. Amin, K. Sopian, M. Konagai, Solar Energy Materials and Solar Cells 91 (2007) 1202.