Optik 139 (2017) 397–406

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Original research article

Design prospects of cadmium telluride/silicon (CdTe/Si) tandem solar cells from numerical simulation

F.M.T. Enam [a], K.S. Rahman [a], M.I. Kamaruzzaman [a], K. Sobayel [a], P. Chelvanathan [a], B. Bais [a], M. Akhtaruzzaman [b], A.R.M. Alamoud [c], N. Amin [a,b,c,*]

[a] Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering and Built Environment, The National University of Malaysia, 43600 Bangi, Selangor, Malaysia
[b] Solar Energy Research Institute, The National University of Malaysia, 43600 Bangi, Selangor, Malaysia
[c] Department of Electrical Engineering, College of Engineering, King Saud University, Riyadh 11421, Saudi Arabia

ARTICLE INFO

Article history:
Received 22 October 2016
Received in revised form 23 March 2017
Accepted 24 March 2017

Keywords:
Solar cells
Thin film tandem structure
CdTe
Si
Conversion efficiency

ABSTRACT

Tandem or multi-junction structures have been utilized to enhance the performance of existing solar cell to achieve higher efficiency in thin film solar cells with the least material usage. In this paper, silicon (Si) has been used as the multi junction partner with the standard CdTe solar cell (n-SnO_2/n-CdS/p-CdTe/Al) structure to investigate the efficiency and stability. Photovoltaic properties of CdTe/Si tandem solar cell with the configuration of n-SnO_2/n-CdS/p-CdTe/p+-CdTe/n+-Si/n-Si/p-Si/p+-Si/Al have been studied by Analysis of Microelectronic and Photonic Structure (AMPS-1D) simulation software. This modified structure has been investigated by adding tunnel junction, which consists of highly doped p-CdTe and n-Si with the variation of simulation parameters such as layer thickness, carrier concentration and operating temperature. Enhanced photovoltaic effects have been observed by optimizing the layer thickness of p-CdTe, n-Si, p-Si and carrier concentration of p-CdTe. From the simulation result, the best efficiency of 28.457% has been achieved for CdTe/Si tandem structure with V_{oc} = 1.15 V, J_{sc} = 27.612 mA/cm^2, FF = 0.894 as compared with the baseline CdTe solar cell efficiency of 19.701%.

1. Introduction

Solar energy is the most consistent source of renewable energy that comes either directly or indirectly from the sun. The utmost challenge in realizing the sustainable energy is to expand technology for incorporation and control of renewable energy resources as a major alternative option. Photovoltaic (PV) solar cells are used to generate electricity direct from the sun through the photovoltaic effect. Nowadays, thin film solar cells are demandable among the researchers and commercials for their high efficiency, low cost and better stability [1,2]. Cadmium Telluride (CdTe) absorber layer has higher absorption coefficient (>5 × 10^5/cm) and direct band gap 1.45 eV that significantly corresponds with the sunlight spectra [3,28]. For thin film heterojunction as well as solar cells, CdTe is one of the best candidates because of its long-term performance stability [4,5]. Single junction solar cell can't absorb low energy photons and consequently it has relatively low efficiency [6,7]. To

* Corresponding author at: Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering and Built Environment, The National University of Malaysia, 43600 Bangi, Selangor, Malaysia.
E-mail address: nowshad@ukm.edu.my (N. Amin).

http://dx.doi.org/10.1016/j.ijleo.2017.03.106

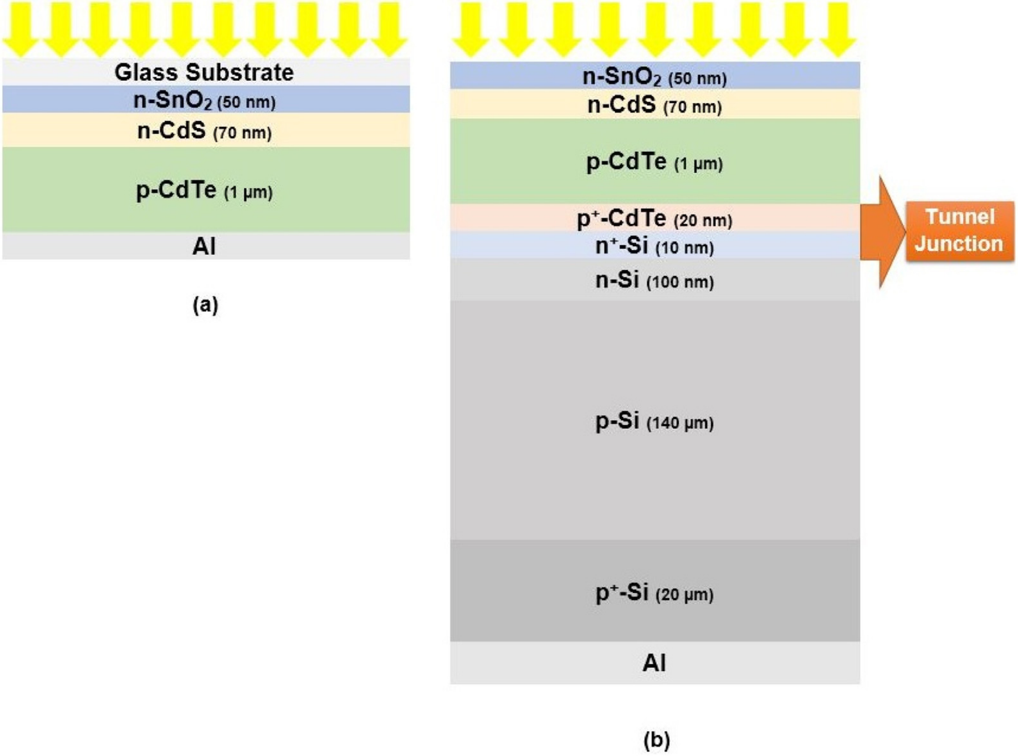

Fig. 1. Structural view of (a) baseline CdTe and (b) proposed CdTe/Si tandem solar cell.

overcome this limitation, multi junction (double/triple) solar cells can be considered, where two or more sub cells can be incorporated and make a unique form of complete solar cell. Hence, tandem or multi junction solar cells are useful for better photon absorption and improved efficiency with the modification of semiconductor material properties and the designs or structure of the cells [8,9]. The National Renewable Energy Laboratory (NREL) of USA worked on high quality single crystal CdZnTe/Si tandem structure and mentioned the possibilities of CdTe/Si tandem solar cells for full cell growth fabrication [10]. However, numerical modelling of CdTe/Si tandem solar cell has not been explored by any literature using AMPS-1D or other simulation. The aim of the numerical modelling is to check whether the cells are working properly or not with varying the parameters of the materials. Apart from that a tunnel junction has been used as a thin insulating layer, whereby electrons can pass through the barrier by the quantum tunnelling process [11,12]. Mainly tunnel junctions are used to provide a low electrical resistance and optically low-loss connection between two sub cells [13]. Without it, the p-doped region of the top cell would be directly connected with the n-doped region of the middle cell. Hence, a *p-n* junction with opposite direction to the others would appear between the top cell and the subsequent cell. If there would be no parasitic diode, the photo-voltage would be lower. It is simply a wide band gap, highly doped diode. In this study, highly doped CdTe and Si thin layers in range

Table 1
Material parameters for CdTe/Si tandem solar cell.

Parameters	n-SnO_2	n-CdS	p-CdTe	p+-CdTe	n+-Si	n-Si	p-Si	p+-Si
Thickness, W (μm)	0.05 μm	0.07 μm	1 μm–5 μm	0.02 μm	0.01 μm	0.02 μm–0.1 μm	140 μm–180 μm	20 μm
Dielectric Ratio ($\varepsilon/\varepsilon 0$)	9	10	9.4	9.4	11.9	11.9	11.9	11.9
Electron mobility, μN (cm^2/Vs)	100	100	320	320	1350	1350	1350	1350
Hole mobility, μP (cm^2/Vs)	25	25	40	40	450	450	450	450
Acceptor concentration, (cm^{-3})	–	–	1.0×10^{14}	1.0×10^{20}	–	–	1.0×10^{16}	1.0×10^{19}
Donor concentration, (cm^{-3})	1.0×10^{17}	1.0×10^{17}	–	–	1.0×10^{19}	1.0×10^{16}	–	–
Band gap, E_g (eV)	3.40	2.42	1.50	1.50	1.12	1.12	1.12	1.12
Density of states, NC (cm^{-3})	2.20×10^{18}	2.20×10^{18}	7.5×10^{17}	7.5×10^{17}	2.8×10^{19}	2.80×10^{19}	2.80×10^{19}	2.80×10^{19}
Density of states, NV (cm^{-3})	1.8×10^{19}	1.8×10^{19}	1.8×10^{19}	1.8×10^{19}	1.04×10^{19}	1.04×10^{19}	1.04×10^{19}	1.04×10^{19}
Electron affinity, χ(eV)	4.20	4.50	4.28	4.28	4.05	4.05	4.05	4.05