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Research Article

EFFICIENCY ENHANCEMENT AND ARCHITECTURE OF TANDEM SOLAR CELL USING SCAPS-1D SIMULATION

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Abstract

Tandem solar cell is a mixture of silicon and Perovskite absorbers, and in terms of performance, it can be used to beat silicon single junction solar cells. In photovoltaic (PV) techniques organic-inorganic Pb free Perovskite generally plays an important role because it's effective, lightweight and economical, in particular methyl ammonium Perovskite iodide. The Perovskite here functions as an absorber layer and its band gap is ~1.35 eV, which is tunable and thus companionable to be combined among a silicon (Si) solar cell with a band gap of 1.124eV, thereby creating a tandem solar cell. This approach is a good solution for increasing tandem solar cell efficiency. This article focuses primarily on the creation of a lead free silicon/Perovskite tandem solar cell system model utilizing SCAPS1D simulation. In this work, the PCE (power conversion efficiency) of the configured system was found to be 23.95% with V_{oc}=0.6941 V, J_{sc}=40.93 mA/cm^2, FF=84.28%.

Keywords: Perovskite solar cell, Si-Solar Cell, Tandem solar cell, Tunable band gap, SCAPS-1D Simulation.

INTRODUCTION

The planet today is asking for a secure supply of electricity. Nowadays, oil or energy use has gradually risen with the growth of societies and in order to keep pace with the development of industrial culture in the immediate future, energy or energy use would rise dramatically, which may contribute to a crisis scenario. Therefore, renewable panels and solar cell technologies may be the only solution to reduce this energy or power problem. However, its use has been reduced due to lower performance and high cost photovoltaic solar cells. Consequently, rising performance and lowering the cost of solar cells are now a gigantic confront for researchers. The performance of the single solar cell junction has already hit 18.1 percent (Single Silicon Solar Cell junction) and with this single junction, a target efficiency of 20 percent will be attained. So, to resolve this restriction, a multi-junction solar cell has been added. During the initial phase, these kind of solar cells were used in satellites. These types of solar multi-joint cells have basically been designed using high quality contents like GaAs, which have too high a cost for land usage. That is why, by assembling tandem solar with c-Si and Perovskite base solar cells, I concentrate on low-cost high-performance solar cells. The power conversion efficiency (PCE) of crystalline silicon solar cells have not enhanced in the last 15-20 years and is still 25%. Because the crystalline silicon is safe, non-toxic and plentiful, the most excellent approach to enhance its design efficiency is by means of designing it inside a tandem solar cell using a material with a band-gap of more than 1.124eV of the silicon energy band-gap as the top cell (Ramlia *et al.,* 2017; Vasoya *et al.,* 2020). As a consequence, photons with higher energy can produce a voltage of about two times the volume of silicone. The next aspect is the advancement of the bio-in-organic, Perovskite-based, yet very fast solar cells in the past 5 years, with a performance of over 25 per cent for applications in small-scale applications (Snaith *et al.,* 2013; Hodes and Cahen, 2014; Burschika *et al.,* 2013; Noh *et al.,* 2013; Mailoa *et al.,* 2015).

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The Perovskite cell confirmed greater built-in stress and higher V_{OC} than a single c-Si crossroads beneath the visible range of sunlight relative to a 1.35 eV band-band difference (400-800nm). Moreover, the tandem design can be strengthened by flipping the bandage by adding Br atoms into the ultimate crystal structure of Perovskite (Noh *et al.,* 2013). The extremely energized photons would be absorbed into the top Perovskite for Silicon-Perovskite (Pb -free) applications, despite the fact that the low-energy photons are taken in the Si bottom cell (Mailoa *et al.,* 2015). The Perovskite with ~1.35 eV bandwidth has recently become a compatible nominee for tandem configuration as content for the top cell (Mailoa *et al.,* 2015 Todorov *et al.,* 2014). It has clear chemical and physical characteristics. Among other items, this tin dependent type of Perovskite solar cell promises to be generated at near to the ground temperatures with a effortless deposition system such as solution- dispensation and steam-handling owing to its sky-scraping efficiency, trivial, economic ability. Special attractive candidates for the purposes of solar cell absorber as well as low production costs and high-density production at low temperatures on flexible substrates are the opto-electronic properties of Pb free Perovskite. The $CH_3NH_3SnI_3$ optical bandwidth is 1.35 eV and can be tuned by removing the halide or cation (Zhou *et al.,* 2016; Benzetta *et al.*) as well. In all visible spectrum, the absorption factor of Pb -free Perovskite is strong and the absorption coefficient is sharp and poor. A 100 nm broad Perovskite coating is thus able to withstand a substantial quantity of incident light. as of the investigator point of view, it could be reported that the long diffusion length of the carrier, the highly loaded bipolar load transport, and the substantially condensed recombination of the substratum and surface, produce free-free carrier directly by photo-excitement, are induced by negligible exciting binding energy in room temperature [300K]. These free-charge carriers obtained for selective contacts, which enable a high filling factor (FF) and an open-circuit voltage (Voc) internal quantum efficiency of nearly 100 per cent, resulting in record levels of efficiency. The Perovskite sub cell absorbs high energy photons, and high voltage is obtained in multi junction solar cells without significant thermal ionization losses. Photons with wavelength in the infrasound surface are typically

transmitted via the Perovskite and emit photons with a large spectral spectrum up to 1.12eV in the crystal silicon sub cell, as defined by the silicon band duration. This duo has an all-embracing equilibrium limit of 40% more than that of single-joint silicone (Ramlia *et al.,* 2017) by Shockley Queisser.

METHODOLOGY

The Pb-free tandem solar cell is a very durable material that can improve performance by up to 30%. The simulation is conceded out with the SCAPS-1D programme to analyze the structure of the Si-Perovskite (Pb Free) tandem solar cell to minimize the electrical properties of the input parameters, primarily thickness and dopant concentration of $CH_3NH_3SnI_3$ as the top cell and the Si-wafer substrate as the bottom cell. In most instances of multi junction solar cells, the absorber layer used is Methyl ammonium Pb iodide-based Perovskite layer, but lead is a hazardous substance and is not a suitable absorber layer material. Research is carried out using SCAPS-1D tech, which is essentially used for solar cell simulation.

Figure 1. Simulation of SCAPAS 1-D effective course of action

DEVICE MODELING AND ANALYSIS

In this part, we describe the modeling and analysis method for obtaining solar cell characteristics Pb Free Perovskite/Si Tandem. With regard to a two-band gap device, it's recognized that for optimum operation, the top-cell content gap must exist higher than the foundation cell. As illustrated in the preceding part, Perovskite has the characteristics that are close to the highest cell band gap of the ideal two-band gap phase between 1.3 and 1.7 eV (greater than Si). In addition to selecting the energy gap (Eg) of an absorber coating on the upper cell, records above the single silicone junction must be increased. To obtain the existing voltage features of the two terminal multi junction solar cells in which the cells are sequentially configured. Initially, the top Perovskite cell was optimized. We then used a silicone cell for the bottom/substratum in order to match or maximize the output of the current density. In order to see the belongings on the performance of the tandem cells and gain insight in maximizing the tandem cell, various physical parameters have been varied in both cells. For the top solar cell, the strongest band gap is 1.35 eV.

We also created a cell consisting of a single layer of absorber. As one cell absorber, we selected $CH_3NH_3SnI_3$. The material varies specifically from the band. $CH_3NH_3SnI_3$ has a band gap of $MASnI_3$ with high voltage transfer and high power exchange efficiency and high current (SC) density. For the single $CH_3NH_3SnI_3$ layer absorber structure. We have high conversion efficiency and high SC. Here we configured is front/Zn0(n)/$CH_3NH_3SnI_3$/Si(n)/Si(p)/Si(p+)/ back touch for configured solar cells. The p-layer is bigger than n-layer, since the electron's mobility is higher than the hole's mobility, such that the same amount of chargers (electrons and holes) are almost identical in time for the opposite electrons, but are not recombined, so this is rather important for maximum strength.

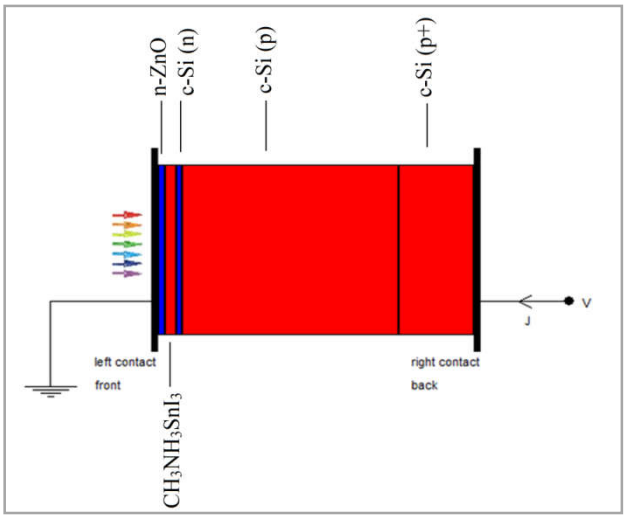

Figure 2.Simulated Model Architecture of $CH_3NH_3SnI_3$ Solar Cell

In this work we have modeled the cell structure of the Pb Free (SPF) tandem solar cells using the SCAPS-1D (Solar Cell Control Simulator). SCAPS is an Electronics and Information Technology (ELIS) one-dimensional (1D) solar cell panel simulator at the University of Ghetto. The key emphasis of these researches is on the results of the Jsc vocation, the Fill Factor (FF) and the efficiency of 300K. Individual material settings for the C-Si, $CH_3NH_3SnI_3$ as sum up in Table 1.

RESULTS AND DISCUSSION

The following graphs outlined the findings on the proposed solar cell layout, counting open circuit voltage (Voc), fill-factor (FF%), short-circuit current density (Jsc) and output. Efficiency outcomes of the optimized solar cell have been calculated according to optimal material parameters.

Table 1. Entered constraints for Pb Free Perovskite /Si multi junction Solar Cell, and they are available for the following materials: distance band (Eg), electron affinity (χ)., dielectric permittivity (ε), conducting band density (N) electron mobility

Parameters	n-ZnO	$CH_3NH_3SnI_3$	Si		
			n-type	p-type	p+-type
Thickness(μm)	0.080	0.110	0.060	1.9	0.800
Band gap (eV)	3.370	1.35	1.12	1.12	1.12
Electron similarity (eV)	4.350	4.170	3.9	4.05	3.9
Dielectric permittivity (ε)	10	6.50	11.9	11.9	11.9
Conduction Band effectual Density of states (cm^{-3})	$2.22x10^{18}$	$1.00x10^{18}$	$2.8x10^{19}$	$2.6x10^{19}$	$2.84x10^{19}$
Valance Band effectual Density of states (cm^{-3})	$1.78x10^{19}$	$1.00x10^{19}$	$2.6x10^{19}$	$2.6x10^{19}$	$2.68x10^{19}$
Electron mobility (cm^2/v-s)	100	1.6	1215	1041	1215
Hole mobility (cm^2/v-s)	25	1.6	443	421	443
Donor attentiveness(cm^{-3})	$1.00x10^{20}$	0	$1.00x10^{18}$	0	0
Acceptor Concentration (cm^{-3})	0	$3.20x10^{15}$	0	$1.5x10^{15}$	$9.00x10^{19}$

#values are taken from references

During work, we have a varying thickness and doping concentration of all the layers before we have an optimal result. From my observation, the range of Perovskite layer thickness is 100-300 nm, which suggests a better outcome. All the simulated results for the configured solar cell shown below.

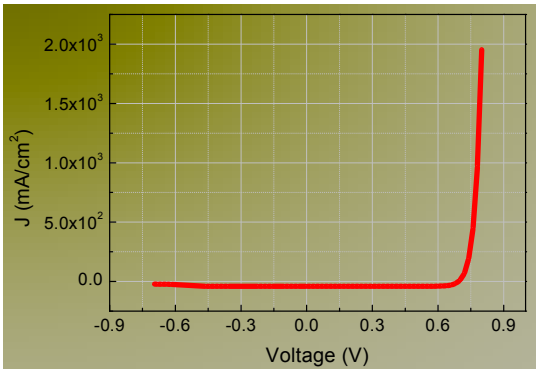

Figure 3. J-V Plot for the scalable of $CH_3NH_3SnI_3$ Solar Cell.

J-V characteristics of $CH_3NH_3SnI_3$ Perovskite base solar cell have been simulated as depicted in figure 3. This graph shows good device produced for $CH_3NH_3SnI_3$/Si material. Recombination current will increase with voltage and it depicts in figure 4. Figure 5. Shows QE (Quantum Efficiency) of $CH_3NH_3SnI_3$ Perovskite base solar cell which leads to efficiency to 23.95% as a function of wavelength for the given structure showing development of compilation of efficiency is become aware of in the short-wavelength (390-500nm) for $CH_3NH_3SnI_3$ Perovskite base solar cell originate by enhanced response of the n-ZnO coating and the abridged failure of photon absorption in this coating (Zhou *et al.,* 2016; Benzetta *et al.*), therefore, leading solar cell to enhance efficiency.

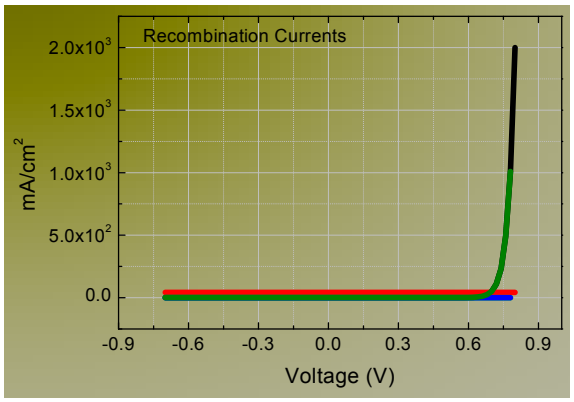

Figure 4. Recombination current reports of $CH_3NH_3SnI_3$ Solar Cell

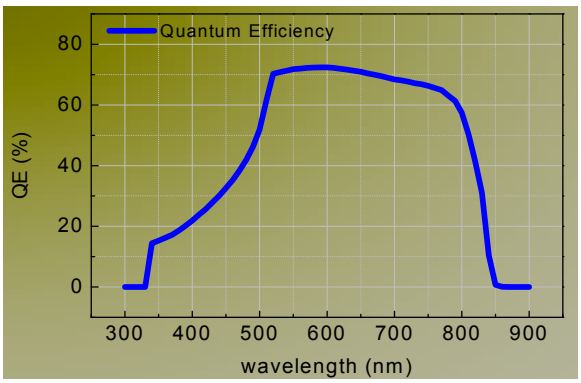

Figure 5. Quantum efficiency (%) vs. wavelength (nm) graph $CH_3NH_3SnI_3$ Solar Cell

CONCLUSION

The built form of Silicon-Perovskite (Pb Free) multi junction Solar Cell with ZnO as ETM (Electron Transport Material) showed better performance compared to Si Solar Cell and the model demonstrates that its efficiency can be increased by integrating Si and Perovskite (tandem). The Si-Perovskite (Tin based) multi junction solar cell achieved an efficiency output of 23.95% with V_{oc} = 0.6941 V J_{sc}=40.93 m/cm2, FF=84.28%. The optimum thickness of $CH_3NH_3SnI_3$ was calculated to be 100-300 nm for this tandem solar cell since good electrical properties could be confirmed at that stage. In addition, the donor doping concentration of $CH_3NH_3SnI_3$ is the most influential element for the Si-Perovskite (Pb-free) tandem solar cell, and the ZnO pulse as ETM showed some prospective to boost multi junction solar cell efficiency. In this work, however, the proposed solar cell structure is free of HTM (Hole Transport Material) so the advantages would be much lower and the production method will be easier, however the key drawbacks are low open-circuit voltage and can also impact the output matrix of the engineered solar cell. Our future work would therefore be to find the necessary HTM (Hole Transport Material) for this multi junction solar cell and to enhance the open circuit voltage (voc). Ability (%eta) utilizing various layers of HTM.

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