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The Impact of P-Type Layer on Performance and Stability of Thin Film Silicon Solar Cells in Relation to Third Generation: A review Analysis

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ABSTRACT

Thin-film Silicon (Si) Solar Cells (SCs) have emerged as a promising candidate for next-generation photovoltaic devices due to their potential for cost-effectiveness and versatility. However, achieving high efficiency and long-term stability remains a significant challenge in their development. The primary challenges with thin-film Si SCs have been the poor infrared light absorption of Hydrogenated Microcrystalline Silicon (c-Si: H) and the light-induced metastability of Hydrogenated Amorphous Silicon (a-Si: H). This study reviewed the influence of the p-type layer, a key component in thin-film Si SCs, on both performance and stability. Third generation SCs are optimized for high Power Conversion Efficiency (PCE) at low manufacturing costs. According to the review of the comparison analysis, Patel K. et al., (2021) obtained the highest PCE of 30.17% with the a-Si/$MoTe_2$ material (Photocurrent Density Jsc = 32.41mA/cm^2, An Open-Circuit Voltage Voc = 1.093V, and Fill Factor (FF) = 85.12%) of the state-of-the-art previous works. The findings presented here contribute valuable insights toward the development of efficient and durable SC technology, crucial for advancing the adoption of renewable energy sources in our ever-growing energy demand.

Keywords: Thin Film Solar Cells, Third Generation, Stability, P-type Layer, Photovoltaic (PV) Cells

1. Introduction

Energy consumption has increased because of both rapid population expansion and increased industrialization. Renewable energy sources are the most effective response to these rising energy demands. As a result of their contribution to ozone depletion, greenhouse gas emissions, and climate change, fossil fuels are, unfortunately, the primary source of energy for 80.2% of the world's population [1]. The significant global climate change in 2015 prompted almost every nation on Earth to create the Paris Agreement, with the goal of keeping the global temperature under the 1.5^{o}C obstacle [2]. Sustainable economic growth that aims to reach the 2050 net zero emission objective is facilitated by the shift from non-renewable to renewable energy [3]. Figure 1 displays the percentage of total US energy demand met by renewables in 2021[4]. There is growing support across all economic sectors for the objective of transitioning to 100% renewable energy in the United States by the year 2050 [5].

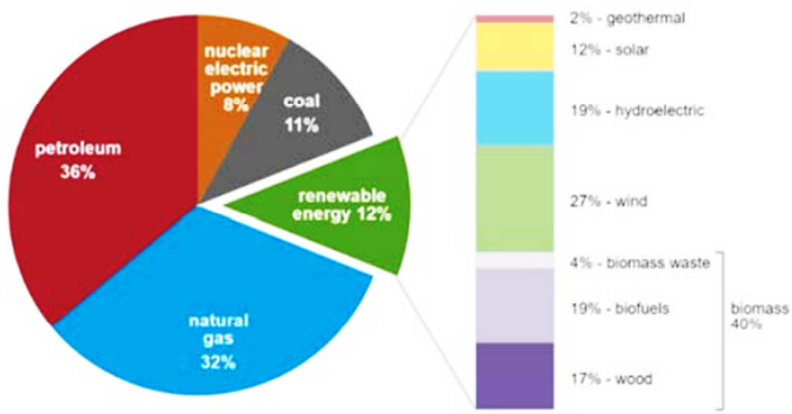

Figure 1: U.S. primary energy consumption

The increasing need for energy and the attendant environmental and societal problems with the extensive use of fossil fuels have led experts to conclude that solar energy is an increasingly considerable and reliable renewable energy source. Solar energy also has the highest availability, reliability, and lowest cost of any renewable energy source [6]. SCs could be broken down into three categories, depending on the technology or production method employed: organic solar cells, PV cells, and hybrid SCs. The PV cell has been the most widely used solar energy technology for some time now. PV cells are gadgets that convert sunlight into electricity. It is estimated that first-generation SCs account for over 89% of the worldwide SC market [7,8].

The p-n junction is the simplest semiconductor junction and is employed to distinguish between photogenerated charge carriers in SCs by providing an interface between the p-type and n-type regions of a single semiconductor. A material must be able to exhibit the basic semiconductor attribute, namely, the capacity to modify its conductivity by doping before it can be considered for use in SCs. For a-Si: H, this was the situation. In 1965, it was stated that the first a-Si: H layers were films of "Si from silane" produced in a radio frequency glow discharge. Although a-Si: H has long been known to have semiconducting characteristics, it wasn't generally acknowledged until scientists Spear and Lacombe from Dundee University demonstrated that it could be doped type and p-type by adding phosphine or diborane to the light discharge gas combination. This discovery is especially important given the previously held idea that amorphous Si could not be doped. Hydrogen's significance in the newly created a-Si: H-doped films was not readily understood at the time. a-Si: H, a silicon-hydrogen alloy, is very suitable for doping in electrical applications. The electrical grade of a-Si is known as a-Si: H [9].

The p-type layer plays a pivotal role in enhancing the electrical performance of these SCs. Thin-film Si SCs often utilize materials like amorphous or microcrystalline silicon, which can be prone to charge carrier trapping and recombination due to defects or impurities. The p-type layer acts as a critical intermediary, facilitating the efficient extraction of photogenerated electrons from the absorbing layer. By minimizing recombination losses and improving charge carrier transport, the p-type layer contributes to higher overall efficiency and improved energy conversion rates. The presence of the p-type layer greatly influences the stability of thin-film Si SCs. Third-generation SC technologies aim to address issues related to long-term reliability and durability. One prominent concern in thin-film Si devices is the Staebler-Wronski effect, characterized by light-induced degradation.

1.1 Third-generation solar cells

Third-generation PVs reduced prices significantly from the second-generation, reaching as low as \$.50/W. This financial gain was accompanied by the ecological and productivity benefits of thin-film deposition methods [10]. Smaller solar panels are needed to get the same output; hence, the increased efficiency of >30% significantly contributed to reduced prices. The many types of third-generation photovoltaics have been separated into three distinct categories [11].

- **Dye-Sensitized Solar Cells (DSSCs)**

DSSCs are a specific form of semiconductor SC that uses dye to convert light into electricity [12]. Fabrication of DSSC is straightforward and inexpensive; the cells could be coated on a flexible substrate, and they have the potential to attain a high conversion efficiency in the future [13,14]. Conducting glass substrates constructed from Transparent Conducting Oxide (TCO) are used in the conventional design of DSSC. Fluorine Doped Tin Oxide (FTO) And Indium Doped Tin Oxide (ITO) were the two most common materials employed by TCO. Semiconductor materials (such as TiO_2, SnO_2, or ZnO) are used to create the working electrodes. Most often, carbon (C) or platinum (Pt) are used as counter electrodes. Both manufactured and natural dyes could be utilized to create a sensitizer and an electrolyte formed from a solution of the iodide/triiodide (I- /I-3) redox pair is possible [15]. The great efficiency and cheap cost of DSSCs are the result of several researchers' efforts to modify DSSC components. Because of its impact on the DSSC's method of operation, the photosensitizer is one of the primary components that has seen extensive development by scientists. The sensitizer is responsible for taking in light, transferring that energy to the semiconductor, and releasing the energy as heat [16-18]. Figure 2 is a simplified schematic depicting the different parts of a DSSC.

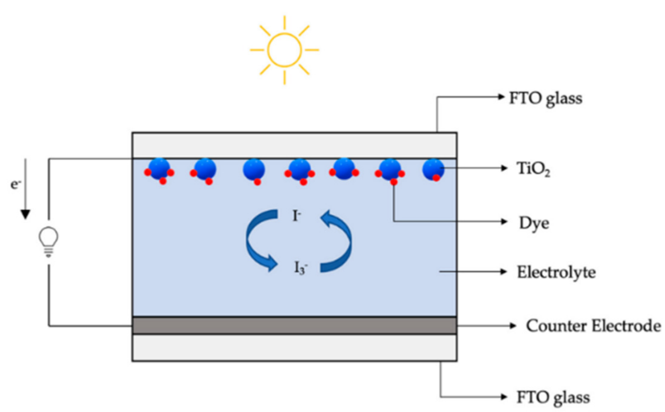

Figure 2: Architecture of the DSSC [19]

- **Organic Solar Cells (OSCs)**

A SC is an electrochemical device that harnesses the sun's rays to generate electricity through the photovoltaic effect. Organic materials or Si-based materials could be used in the fabrication of SCs. OSCs have low manufacturing costs because they can be made using inexpensive organic ingredients and organic polymers that can be solution processed at high throughput. The widespread use of OSCs could be attributed to their ease of production, adaptability, minimal thermal processing requirements, and roll-to-roll processing [20,21]. Figure 3 depicts the fundamental design of an OSC.

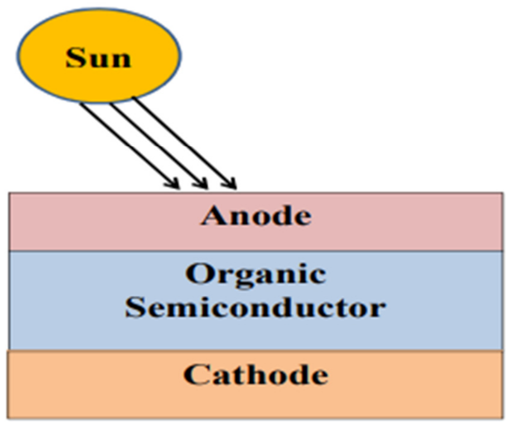

Figure 3: Structure of Organic Solar Cell

It consists of an anode and a cathode electrode, with an active layer of organic semiconductor in between. One electrode is made see-through so that it may collect solar power. Sunlight, which is made up of individual particles called photons, is partially reflected, and partially absorbed by the cell surface. The photon is absorbed by an electron in the Highest Occupied Molecular-Orbit (HOMO), which causes the electron to acquire energy and travel to the Lowest Occupied Molecular-Orbit (LUMO), the orbit with the fewest occupied electrons. The difference in energy between the HOMO and LUMO could be anything from 1eV to 4eV [22,23].

- **Perovskite Solar Cells (PSCs)**

PSCs are a kind of PV cell that was developed in the third generation; its device architecture is derived from that of second-generation DSSCs) [24,25]. DSSCs are inefficient cells because the poor absorption coefficient of organic sensitizers limits their light-harvesting capacity. In [26] examining the PV effect in a Photoelectrochemical (PEC) DSSC by exchanging the organic molecules of the dye with those of the organic-inorganic halide perovskite molecules $CH_3NH_3PbBr_3$ ($MAPbBr_3$) and $CH_3NH_3PbI_3$ ($MAPbI_3$), and recorded PCEs of 3.1% and 3.8%, respectively. Although perovskites have positive PV features such as optical, excitonic, and electrical conductivity, the material's solubility in the liquid electrolyte has been implicated in unfavorable low efficiencies [27]. The structure of a PSC is shown in Figure 4.

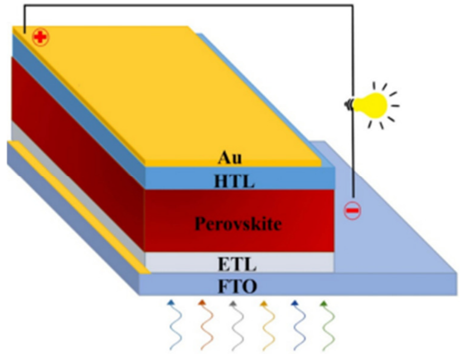

Figure 4: Perovskite Solar Cell [28].

2. Review of Literature

This section defines the previous studies of several authors built on the impact of the p-type layer on the performance and stability of thin film Si SCs in relation to a third generation.

Rani A. et al., (2022) [29] illustrated the GPVDM software's ability to simulate the electrical behavior of hybrid PV systems with varying active thickness layers. SiGe and PTAA thicknesses range from 100 nm to 500 nm and 1000 rpm to 5000 rpm, respectively. The findings demonstrate that the thickness of both semiconductors influences their electrical characteristics. The Jsc current density rises with increasing SiGe thickness. The open-circuit voltage, Voc, changed due to the presence of PTAA as an active layer. When comparing SiGe combinations, the one with the lowest rpm had the highest Voc value. This paper also presents the solar panel's FF and efficiency rate. The consequence of varying the thickness of each semiconductor layer on the device's electrical properties is the primary emphasis of this study.

Liang J. et al., (2022) [30] found different kinds of OSCs and inverted PSCs used chlorine-doped CuSCN (Cl2-CuSCN) as a Hole Transport Layer (HTL). It has been discovered that doping CuSCN thin films with chlorine may boost the device performance of various OSCs to levels competitive with PEDOT: PSS-based OSCs. Notably, the functionality of the inverted PSCs based on Cl2-CuSCN was superior to that of the inverted PSCs based on either pure CuSCN or PEDOT: PSS. OSCs and PSCs based on Cl2-CuSCN are also substantially more stable than those based on pure CuSCN or PEDOT: PSS. The findings of the study demonstrate that Cl2-CuSCN thin films could be used as a generally related HTL for developing SC technologies, enhancing the functionality and reliability of the devices.

Patel K. et al., (2021) [31] suggested research also shows that a-Si is preferable to MoTe2 for CIGS SCs, which is useful for HTL applications. This study presents an optimization of the cell characteristics, including the thickness, defect density, and acceptor concentration of the CIGS absorber layer. PCE for a CIGS SC with a Si HTL was optimized to a maximum value of 30.17% (Voc =1.093V, Jsc=32.41 mA/cm^2, and FF=85.12%) using several methods of improvement. Extensive simulation analysis was performed at a range of operating temperatures and series resistances to get insight into the solar device. Combined, the models we developed show promise for realizing a thin, efficient energy harvesting application in the ultra-nanoscale range.

Barrientos A. et al., (2021) [32] initiated studies on the properties of PECVD-deposited a-Si:H thin films by analyzing their composition, synthesizing new ones, and characterizing the old ones. Atomic Force

Microscopy (AFM) was utilized to evaluate the surface morphology of the films, Scanning Electron Microscopy (SEM) was used to analyze the films, and UV-visible ellipsometry was utilized to determine the optical band gap and film thickness. The present study found that the minimum required for materials made of a-Si:H Si for high-quality SCs was met when the flow of dopant gases (phosphine or diborane) was increased, indicating that the best conditions can be acquired when the flow of dopant gases is maximized.

Belfar A. et al., (2021) [33] evaluated the impact on n-i-p a-Si:H built SC performance by employing two distinct double p-type layers, one based on Hydrogenated Nanocrystalline Silicon (nc-Si:H) and the other based on Hydrogenated Nanocrystalline Silicon Oxide (nc-SiOx:H). The i/p-window interface recombination is suppressed, and the VOC is enhanced by the presence of a p-nc-SiOx:H buffer layer. SCs with double p-nc-SiOx:H type window layers achieved the best performances (Jsc = 13.80 mA/cm^2, Voc = 934 mV, FF = 79.1%, and Eff = 10.21%).

Peksu E. et al., (2021) [34] examined the use of one-step thermal evaporation to create phase pure CZTS thin films on glass substrates from a single crystalline ingot formed using the Bridgman method. TiO_2 NRs were developed using the hydrothermal method, which provides a straightforward and inexpensive strategy for the commercially viable manufacture of uniformly sized nanorods. The SC achieved the best efficiency to date for a 1-D TiO_2 nanostructures-based superstrate CZTS SC, with a Voc of 0.35 V, Vsc of 7.28 mA/cm^2, an FF of 23.9%, and a PCE of 0.61%.

Khatun M. et al., (2021) [35] determined how efficient thin-film heterojunction SCs based on WS2 were in converting light into electricity. This work uses simulations to evaluate the efficiency of an SC with the suggested configuration of Al/FTO/CdS/WS_2/CuI/Ni vs. the reference WS2-based SC structure without HTL, which consists of Al/FTO/CdS/WS_2/Ni. For reference, WS_2 SC without HTL, the conversion efficiency was determined to be 22.09%. However, when the device structure is adjusted, the efficiency of the suggested SC containing CuI HTL is found to be 29.87%. This study could provide a new perspective on how to make a heterojunction thin-film SC that is commercially practical, low-cost, and highly efficient.

Duan C. et al., (2018) [36] examined and optimized the work function of the TCO layers, the Back Surface Field (BSF), the thickness of the CdS thin film, and the Si substrate in a CdS/p-Si heterojunction SC. Simulation findings suggested that the work function of TCO should be less than 4.4 eV, and that of BSF should be more than 4.8 eV. The electrical performance of a CdS/p-Si SC is significantly impacted by the thickness of the CdS thin films; specifically, the Voc and Jsc decrease with increasing CdS thin film thickness.

Mehmood H. et al., (2017) [37] suggested a SC based on p-nc-Si:H/i-a. Through analyzing the thickness of the window and intrinsic absorber layers and the amount of doping, SILVACO TCAD has simulated the Si:H (buffer)/i-a-Si:H/n-a-Si:H configuration. The recombination rate has been lowered by designing the p/i interface and carefully evaluating the characteristics of the absorber flaws. Simulation findings for a single-junction device optimization showed a promising Vsc of 0.865 V, Jsc of 21.7 mA/cm^2, FF of 0.69, and PCE of 12.93% in comparison to the previously reported SC.

Table 1 below summarizes the summary of the Review of Literature and the authors' process used in their studies.

Table 1. Summary of Review of Literature

Authors	Technique Used	Outcomes
Rani A. et al., (2022) [29]	High power computational	The modeling of ITO/SiGe-PTAA/Al solar indicated that a combination of SiGe/PTAA thickness of 1:1 is optimal.
Liang J. et al., (2022) [30]	Pristine CuSCN	In the experiments, they discovered that exposing PBDB-T-2F:Y6 OSCs using pristine CuSCN or PEDOT: PSS as HTLs to chlorine increased their overall performance.
Patel K. et al., (2021) [31]	SEM	Finally, by adjusting the CIGS layer's thickness, doping concentration, and defect density, they were able to achieve an overall PCE of 30.17% (Voc=1.0935V, Jsc=32.41 mA/cm^2, and FF =85.12%).
Barrientos A. et al., (2021) [32]	SEM	Based on the transmittance curve, they determined that Processes A3 and B3 produced the most optically optimal a-Si:H thin films for the deposition technique and circumstances.
Belfar A. et al., (2021) [33]	High power computational	The Jsc rises from 13.52 mA/cm^2 to 13.80 mA/cm^2, the Voc rises from 898 mV to 934 mV, the FF rises from 73.8 % to 79.1%, and the PCE rises from 8.5 % to 10.21%.
Peksu E. et al., (2021) [34]	Bridgeman Technique	The SC achieved the best efficiency ever measured for a 1-D TiO_2 nanostructures-based superstrate CZTS SC with a Voc of 0.35 V, aVsc of 7.28 mA/cm2, a FF of 23.9 percent, and a PCE of 0.61%.
Khatun M. et al., (2021) [35]	SEM	Voc = 0.98 V, Jsc = 35.19 mA/cm2, and FF = 87.08% are all measurements of the efficiency of the suggested WS2-based SC using the CuI HTL.
Duan C. et al., (2018) [36]	TCO	According to the simulation findings, the work function of TCO should be less than 4.4 eV, and the work function of BSF should be more than 4.8 eV.
Mehmood H. et al., (2017) [37]	Wide-Band Gap	Although the suggested unoptimized device had a low FF value (9.55%), its PCE was rather high. Numerical optimization of the device led to an increase in PCE to 12.93 percent, a decrease in Voc to 0.86 volts, an increase in Jsc to 21.7 mA/cm^2, and a rise in FF to 0.69.

3. Comparison Analysis

In this study, the authors have reviewed some a-Si:H and come out with the findings of these materials. The authors used different factors which is Jsc is a measure of the maximum current output in a SC when exposed to light, indicating the cell's ability to generate electrical current under illumination. Voc is the highest voltage a SC can produce when no current is flowing through it, representing its potential for generating voltage under optimal conditions, and FF assesses how efficiently a SC converts sunlight into electricity by comparing its actual performance to the theoretical maximum, accounting for losses due to resistance and non-ideal behavior. Table 2 compares the output properties of many different a-Si cells that were produced using different materials. Based on the data presented in the table and conducted a comparison of various factors revealed that the a-Si/$MoTe_2$ material proposed by Patel K. et al., (2021) [31] combination achieved the highest PCE at 30.17%, with corresponding values of Jsc = 32.41, Voc = 1.093, and FF = 85.12%. Figure 5 to 8 shows the graph of the performance of the numerous a-Si:H depending on SCs.

Table 2. PV performance evaluation of several a-Si:H based SCs.

Ref	Material	Jsc mA/cm^2	Voc (V)	FF	E_{ff}
Rani A. et al., (2022)	SiGe/PTAA	4.63	0.58	77.16%	1.49%
Patel K. et al., (2021)	a-Si/$MoTe_2$	32.41	1.093	85.12%	30.17%
Belfar A. et al., (2021)	p-nc-SiOx:H	13.80	0.34	79.1%	10.21%
Peksu E. et al., (2021)	Cu_2ZnSnS_4	7.28	0.35	23.9%	0.61%
Mehmood H. et al., (2017)	p-nc-Si:H/i-aSi:H/i-a-Si:H/n-a-Si:H	21.7	0.865	69%	12.93%

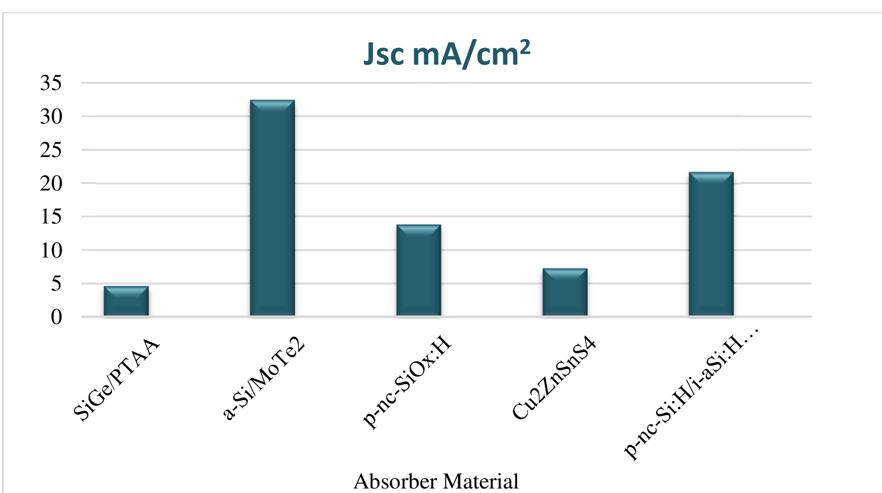

Figure 5: Comparison of PV performance based on Jsc

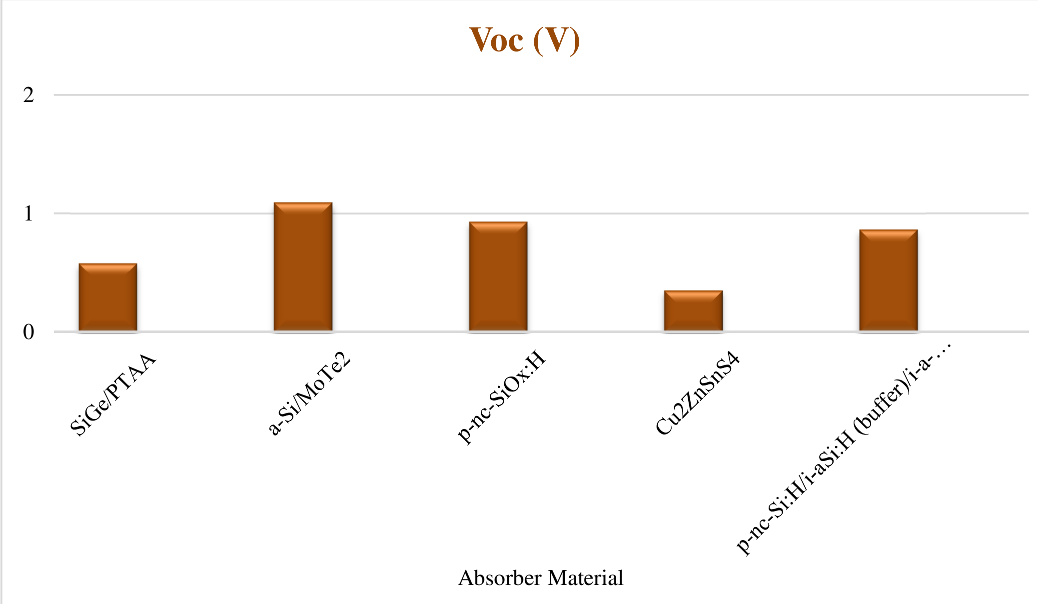

Figure 6: Comparison of PV performance based on Voc

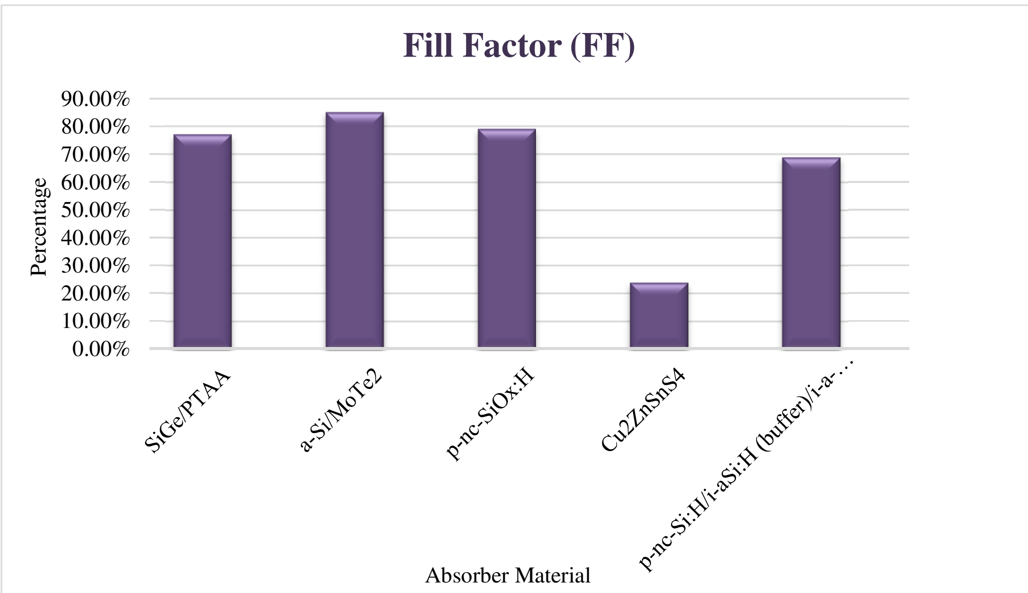

Figure 7: Comparison of PV performance based on FF

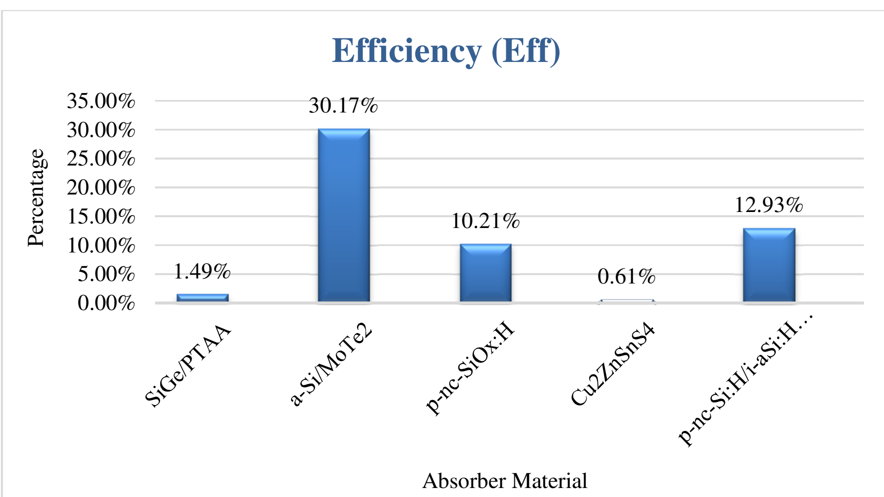

Figure 8: Comparison of PV performance based on efficiency.

4. Conclusion and Future Scope

Thin-film SC modules to the market are giving these potentially more cost-effective methods a chance to prove themselves. Several novel thin-film technologies, including those based on a-Si: H, polycrystalline Si, mixed-phase Si, and chalcogenides, are either now commercially accessible or are in the last stages of development. This paper reviewed the impact of the p-type layer on the performance and stability of thin-film Si SCs in relation to third-generation solar technologies is significant. By incorporating advanced p-type materials and engineering techniques, researchers and industry professionals have made substantial progress in enhancing the efficiency, durability, and overall viability of thin-film Si SCs. These developments are crucial in the context of third-generation SCs, where improved performance and stability are essential for widespread adoption and integration into various applications. Based on the review, Patel K. et al., (2021) have achieved the highest PCE of 30.17% using the a-Si/$MoTe_2$ material, accompanied by a Jsc of 32.41mA/cm2, a Voc of 1.093V, and an FF of 85.12%, surpassing previous state-of-the-art efforts in this field. The future scope for thin-film Si SCs lies in further enhancing their efficiency and scalability to meet growing global energy demands while also exploring advanced materials and manufacturing processes for improved sustainability and cost-effectiveness.

References:

[1]. IEA, "Global Energy Review," 2020. (Online). Available: https://www.iea.org/reports/global-energy-review-2020.

[2]. IPCC, "Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response," Cambridge University Press, Cambridge, UK, 2018.

[3]. Y. Adediji, "A Review of Analysis of Structural Deformation of Solar Photovoltaic System under Wind-Wave Load," Engineering Archive, 2022.

[4]. EIA, "How much of US energy consumption and electricity generation comes from renewable energy sources?," 2022. (Online). Available: https://www.eia.gov/tools/faqs/faq.php?id=92&t=3.

[5]. https://www.researchgate.net/profile/Yaqub-Adediji/publication/368925684_a-review-of-current-trends-in-thin-film-solar-cell-technologies/links/6400dc9d0d98a97717d0b8cd/a-review-of-current-trends-in-thin-film-solar-cell-technologies.pdf

[6]. Kannan N, Vakeesan D (2016) Solar energy for future world review. Renew Sustain Energy Rev 62:1092–1105.

[7]. ElKhamisy KM, El-Rabaie S, Elagooz SS, Abd Elhamid H (2019) The effect of different surface grating shapes on thin film solar cell efficiency. 2019 International Conference on Innovative Trends in Computer Engineering (ITCE), pp 297–300.

[8]. ElKhamisy, Khalil, Hamdy Abdelhamid, El-Sayed M. El-Rabaie, and Nariman Abdel-Salam. "A Comprehensive Survey of Silicon Thin-film Solar Cell: Challenges and Novel Trends." *Plasmonics* (2023): 1-20.

[9]. http://www.ijaresm.com/uploaded_files/document_file/Satish_KumarIgxw.pdf

[10]. Green MA. Third generation photovoltaics: ultra-high conversion efficiency at low cost. Progress in Photovoltaics: Research and Applications, 2001, 9:123–135.

[11]. Mirabi, Elahe, Fatemeh Akrami Abarghuie, and Rezvan Arazi. "Integration of buildings with third-generation photovoltaic solar cells: a review." *Clean Energy* 5, no. 3 (2021): 505-526.

[12]. Maurya I C, Srivastava P, and Bahadur L 2016 Optical. Materials. 52 150-156.

[13]. Bhogaita M, Shukla A D, and Nalini R P 2016 Solar. Energy. 137 212-224

[14]. Chen J-Z, Yan Y-C, and Lin K-J 2010 J. Chin. Chem. Soc. 57 5B 1180-1184.

[15]. Torchani A, Saadaoui S, Gharbi R, and Fathallah M 2015 Curren. Applied. Phy. 15 307-312.

[16]. Calogero G, Citro I, Crupi C, and Marco G D 2014 Spectrochimica. Acta. Part A: Molecular. and Biomolecular. Spectroscopy. 132 477-484.

[17]. Jeon B C, Kim M S, Cho M J, Choi D H, Ahn K-S, and Kim J H 2014 J. Synthetic. Metals. 188 130-135.

[18]. Pratiwi, D. D., F. Nurosyid, A. Supriyanto, and R. Suryana. "Performance improvement of dye-sensitized solar cells (DSSC) by using dyes mixture from chlorophyll and anthocyanin." In *Journal of Physics: Conference Series*, vol. 909, no. 1, p. 012025. IOP Publishing, 2017.

[19]. Syed, Tajamul Hussain, and Wei Wei. "Technoeconomic Analysis of Dye Sensitized Solar Cells (DSSCs) with WS2/Carbon Composite as Counter Electrode Material." *Inorganics* 10, no. 11 (2022): 191.

[20]. B. Kumar, B. K. Kaushik, Y. S. Negi, "Perspectives and challenges for organic thin film transistors: materials, devices, processes and application", Journal of Material Science: Materials in Electronics, Vol. 25, pp. 1-30, Jan. 2014.

[21]. B. Kumar, B. K. Kaushik, and Y. S. Negi, "Organic thin film transistors: Structures, models, materials, fabrication and applications- A- review", Polymer Reviews, Vol. 54(1), pp. 33-111, Feb.2014.

[22]. Wallace C.H. Choy, editor, "Organic solar cells materials and device physics" Springer-Verlag London, pp. 4471-4823, 2013.

[23]. Najam, Suboori, and Brijesh Kumar. "Organic Solar Cell: Operating Principle, Performance Parameters, Structures and Its Advantages." In *2018 5th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON)*, pp. 1-6. IEEE, 2018.

[24]. Meng, L.; You, J.; Guo, T.-F.; Yang, Y. Recent Advances in the Inverted Planar Structure of Perovskite Solar Cells. *Acc. Chem. Res.* **2015**, *49*, 155–165.

[25]. Abdi-Jalebi, M.; Dar, M.I.; Sadhanala, A.; Senanayak, S.P.; Grätzel, M.; Friend, R.H. Monovalent Cation Doping of $CH_3NH_3PbI_3$ for Efficient Perovskite Solar Cells. *J. Vis. Exp.* **2017**, *121*, e55307.

[26]. Kojima, A.; Teshima, K.; Shirai, Y.; Miyasaka, T. Organometal Halide Perovskites as Visible-Light Sensitizers for Photovoltaic Cells. *J. Am. Chem. Soc.* **2009**, *131*, 6050–6051.

[27]. Lekesi, Lehlohonolo P., Lehlohonolo F. Koao, Setumo V. Motloung, Tshwafo E. Motaung, and Thembinkosi Malevu. "Developments on perovskite solar cells (PSCs): A critical review." *Applied Sciences* 12, no. 2 (2022): 672.

[28]. Kartikay, Purnendu, Krishnaiah Mokurala, Bosky Sharma, Ravi Kali, Nagaraju Mukurala, Dhananjay Mishra, Ajit Kumar, Sudhanshu Mallick, Junyoung Song, and Sung Hun Jin. "Recent advances and challenges in solar photovoltaic and energy storage materials: future directions in Indian perspective." *Journal of Physics: Energy* 3, no. 3 (2021): 034018.

[29]. https://www.researchgate.net/publication/362454813_The_Effect_of_SiGePTAA_Thin_Film_Thickness_as_An_Active_Layer_for_Solar_Cell_Application.

[30]. Liang, Jian-Wei, Yuliar Firdaus, Randi Azmi, Hendrik Faber, Dimitrios Kaltsas, Chun Hong Kang, Mohamad Insan Nugraha et al. "Cl2-Doped CuSCN Hole Transport Layer for Organic and Perovskite Solar Cells with Improved Stability." *ACS Energy Letters* 7, no. 9 (2022): 3139-3148.

[31]. Patel, Alok Kumar, Praveen Kumar Rao, Rajan Mishra, and Sanjay Kumar Soni. "Numerical study of a high-performance thin film CIGS solar cell with a-Si and MoTe2 hole transport layer." *Optik* 243 (2021): 167498.

[32]. Garcia-Barrientos, Abel, Jose Luis Bernal-Ponce, Jairo Plaza-Castillo, Alberto Cuevas-Salgado, Ariosto Medina-Flores, María Silvia Garcia-Monterrosas, and Alfonso Torres-Jacome. "Analysis, Synthesis and Characterization of Thin Films of a-Si: H (n-type and p-type) Deposited by PECVD for Solar Cell Applications." *Materials* 14, no. 21 (2021): 6349.

[33]. Belfar, Abbas, and Wafa Hadj Kouider. "Improvement in a-Si: H silicon solar cells with using double p-type window layers based on nanocrystalline silicon oxide." *Optik* 244 (2021): 167610.

[34]. Peksu, Elif, and Hakan Karaagac. "Characterization of Cu2ZnSnS4 thin films deposited by one-step thermal evaporation for a third generation solar cell." *Journal of Alloys and Compounds* 862 (2021): 158503.

[35]. Khatun, Most Marzia, Adil Sunny, and Sheikh Rashel Al Ahmed. "Numerical investigation on performance improvement of WS2 thin-film solar cell with copper iodide as hole transport layer." *Solar Energy* 224 (2021): 956-965.

[36]. Duan, Chunyan, Yingwen Zhao, Shenghao Li, Qun Ban, Yizhan Chen, and Hui Shen. "Numerical simulation and optimization of CdS/p-Si Heterojunction solar cells." In *2018 7th International Conference on Energy and Environmental Protection (ICEEP 2018)*, pp. 1463-1469. Atlantis Press, 2018.

[37]. Mehmood, Haris, and Tauseef Tauqeer. "Modelling and performance analysis of amorphous silicon solar cell using wide band gap nc-Si: H window layer." *IET Circuits, Devices & Systems* 11, no. 6 (2017): 666-675.

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