

STABILITY ENHANCEMENT IN INVERTED PEROVSKITE SOLAR CELL USING SANDWICHED COMPOSITE MATERIALS IN INTERFACE LAYERS

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Abstract

Perovskite solar cells (PSCs) have fast improvements in power conversion efficiency, as well as stability and upscaling. However, due to the increase in power conversion efficiency from 3.8% to 25.5%, the real-world applications of PSCs are still severely constrained due to their poor device stability. Furthermore, out-diffusion of cationic components and the presence of moisturization content in the interface layers of PSCs results in leakage of materials and low efficiency in solar cells. Hence, in this research, leakage of materials and instability in solar cell is reduced by using a novel **Multilayered sandwiched additive composite material perovskite solar cell** in which the electron transport layer with CNT dip-doped on Au is used to increase the mobility of photon transfer and thereby, generate the more energy. Moreover, a single PCBM layer is inserted as an additive composite to eliminate out-diffusion of cationic components and PTAA is used in the hole transport layer which generate more carrier energy with the mitigation of moisturization content in layer boundaries. Finally, the addition of glass into the device is to produce more energy and the leakage of materials is eliminated by the inverted multilayered structure of Perovskite solar cells. As a result, the proposed device increases the power conversion efficiency (PCE) without sacrificing stability and reduces leakage of materials.

Keywords: carbon nanotube (CNT), stability, dip-doping, hole transport layer, power conversion efficiency, perovskite solar cell.

Nomenclature:

V_{OC} – Open circuit voltage
 FF – Fill factor
 P_{in} – Total incidence irradiance
 J_{SC} – Short circuit current density
 g/cm^3 - Density

Introduction

Photovoltaic technology transforms solar energy directly into electricity that got a lot of attention in recent years as the need for clean and renewable energy has grown [1]. Perovskite solar cells have a high specific power (i.e., power to weight ratio) that are compatible with flexible substrates, and have great radiation resistance, making them a viable choice for next-generation space photovoltaic technology. PSCs varied optoelectronic features, metal halide perovskites have piqued attention in the field of photovoltaics [2]. PSC research has exploded due to low-cost solution processing and appealing optoelectronic features such as tunable bandgap, high absorption coefficient, low recombination rate, and high charge carrier mobility [3]. Solar cells are made up of three main components: stability, efficiency, and cost of manufacture. Third-generation Perovskite solar cells can solve the problem of high production costs without sacrificing efficiency in this situation [4]. Aside from efficiency, the golden triangle is show in figure 1 (lifetime, stability, and cost) are used to assess the technical viability of PV technologies for commercialization, however, there is a real-time issue arise related to their stability [5].

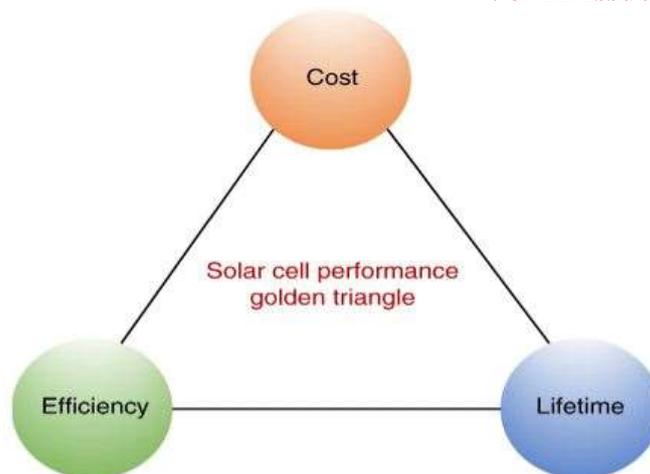


Figure 1: Golden triangle of solar cell performance.

Organic photovoltaics (OPVs) are a developing PV technology that belongs to the third generation of PV cells, which typically divided into three generations. Organic photovoltaics have been presented as not only intriguing alternatives but also tempting complements to traditional inorganic photovoltaics due to their inherent characteristics (IPVs) [6]. To satisfy the needs of the high-throughput R2R manufacturing process, OPVs with active layers thicker than 200 nm chosen, and projected to improve the short circuit current density (JSC) due to increased light absorption and excitation formation in thick active layers [7-11]. In reality, as the active layer thickness increases, the fill factor (FF) and power conversion efficiency (PCE) of OPVs would drop, due to significant charge recombination in thick active layers [12-14].

Hybrid organic-inorganic perovskite solar cells have recently emerged as a promising photovoltaic (PV) candidate [15]. Engineering the perovskite precursor with an additive is a critical and successful technique for influencing perovskite crystallization, passivating defects at the GBs and at the surface, promoting interface charge diffusion, and improving hybrid PSC operational stability [16]. PSCs, on the other hand, do not have the same stability as their Si-based predecessors, which limit their commercialization [17]. Non-radiative recombination via defects at the interfaces between the perovskite and charge-transport layers is the major cause of voltage losses for PSCs, according to several studies [18]. The main contributions of this paper are as follows:

- To develop a multilayered sandwiched additive composite material perovskite solar cell for improve the stability of perovskite solar cell and,
- Reduce the ion migration and voltage loss without sacrificing performance of the perovskite solar cell.

The structure of the paper has been developed as follows out of which section 1 is the introduction; Section 2 presents the recent works of literature; section 3 depicts the detailed description of the materials and processing methods involved; section 4 deliberates the results and finally, section 5 discusses the conclusion.

Literature Survey

Wang et al [19] analyzed the current attempts for improve the stability of PSCs. The parameters that affect the power conversion efficiency of perovskite solar cells highlighted in their paper. PSCs' PCE has risen dramatically from 3.8 percent to 23.7 percent, although inadequate stability is one of the key factors impeding their commercialization. Moreover, their paper provides succinct Structural effects, a photoactive layer, hole- and electron-transporting layers, electrode materials, and device encapsulation are all used to increase device stability. However, they conclude the current perovskite material for not enough to increase the stability; it needs new material and device for increase the stability of the PSCs.

Kai et al [20] investigate solution-based and vapor-phase coating methods for large-area perovskite films. The development of moisture- and thermally stable materials has increased the stability of PSCs. The spin-coating process, which is typically employ for small-area substrates (2.52.5 cm), may not be suitable for commercialization. Solution-based and vapor-phase coating techniques for large-area

perovskite films are examined in their study. Coating the perovskite solution on large-area substrates ($>100 \text{ cm}^2$) has mostly been done via a blade, slot-die, or spray. They conclude their investigation must prevent the leakage of Pb in the perovskite solar cell.

Singh et al [21] Using a simple, rapid, and low-cost dip-coating approach, construct a hybrid perovskite-based n-i-p solar cell. This process uses a hot solution and a pre-annealed substrate to cover the perovskite thin film, which then studied for structural and electrical characteristics. The band gap of the hybrid perovskite layer, which is 1.6 eV, is calculated using UV-vis spectroscopy. The creation of a hybrid perovskite layer confirmed by X-ray spectroscopy. The profilometer is used to measure the thickness of the perovskite layer as well as the surface roughness of the perovskite layer when the substrate temperature changes. However, their method is still needs a future work for optimizing the interface layer.

Chen et al [22] proposed a Single-Crystal MAPbI₃ Perovskite Solar Cells. Solar cells with power conversion efficiencies of 21.09 percent and fill factors of up to 84.3 percent can be made with a 20-micron-thick single-crystal methylammonium lead triiodide (MAPbI₃) perovskite (as an absorber layer) grown on the charge-selective contact using a solution spacelimited inverse-temperature crystal growth method. These devices establish a new record for perovskite single-crystal solar cells and pave the way for perovskite solar cells with high fill factors. However, their device has poor contacts with the transporting layer.

Tumen et al [23] demonstrates how vital it is to carefully manage the development of unreacted PbI₂ crystals in perovskite films in order to increase device operational stability. They reveal that under continuous light exposure, unreacted PbI₂ crystals expedite the breakdown of PSCs. Under light, unreacted PbI₂ undergoes photo-decomposition, resulting in the production of lead and iodine in films. In a DMF:DMSO (4:1 vol/vol) solution, PbI₂ and MAI were dissolved. These solutions with varying PbI₂ concentrations were agitated overnight at 70 °C. The solutions were spin-coated at 4000 rpm for 30 seconds on glass substrates coated with ITO and SnO₂. At 5 seconds after the spin programme began, 200 l of chlorobenzene was poured over the substrate. The substrates were annealed at 100°C for 30 minutes after the perovskite layers were deposited. However, their method must improve the stability of the PSCs.

Wang et al [24] analyzed on the alignment of energy levels in PSCs, with various sections: ELA derivation methodologies, perovskite semiconductor type, bottom layer-dependent energy level shift of perovskite, density of states-governed ELA, ELA for certain interfaces, instability-induced ELA variation, and defects and ion migration-induced ELA variation are all discussed. The future of accurately determining ELA, developing device architecture, and producing high-performance PSCs examined. They reached a high efficiency of over 10% by improving the perovskite film growing method; nevertheless, because to the lack of an electronic blocking layer at the perovskite/carbon interface, substantial interface charge recombination occurs, resulting in poor device J_{SC} and FF.

Junnan et al [25] select a cycle transition, the europium ion pair $\text{Eu}^{3+}-\text{Eu}^{2+}$ serves as a "redox shuttle," preferentially oxidising Pb₀ and reducing IO defects. Their resulting gadget has a power conversion efficiency of 21.52 percent (certified 20.52 percent) and is significantly more durable over time. Under 1-sun continuous illumination or heating at 85°C for 1500 hours, the devices kept 92 percent and 89 percent of the peak PCE, respectively, and 91 percent of the original stable PCE after 500 hours of maximum power point tracking. At the doped p-perovskite/n-TiO₂ interface, a built-in electric field produced, promoting efficient carrier separation and transport. However, when the dopant concentration rises, the extra Pb₂₊ created quickly converted to metallic Pb₀ under illumination, resulting in a deep level defect with decreased VOC and FF, lowering the PCE of the doped device significantly.

From the survey, for [19] needs new material and device for increase the stability of the PSCs, for [20] must prevent the leakage of Pb, for [21] still needs a future work for optimizing the interface layer, for [22] poor contacts with the transporting layer, for [23] must improve the stability of the PSCs . For [24] poor device J_{SC} and FF, and for [25] lowering the PCE of the doped device. Hence, as a result to overcome the complexity in perovskite solar cell the new device is introduced.

Multilayered Sandwiched Additive Composite Material Perovskite Solar Cell

In this research, a multilayered sandwiched additive composite material perovskite solar cell is introduced to increase the stability of the perovskite solar cell because the existing solar cells caused by the ion migration and the contains moistures of interface layers, result in instability of PSCs. In multilayered sandwiched additive composite material perovskite solar cell, a single walled CNT thin film employed to absorb light across a broad wavelength range, from visible to near infrared, and to have charge carriers (electrons and holes) which move quickly. In additionally the proposed device utilized Au for absorb the light because gold has a high thermal conductivity, which is 301 W/mK, and here the CNT is dip-doped on Au for penetrate the light therefore; the Au absorbed the same energy from the carbon nanotubes thereby it reduces the energy loss. After that, PCBM layer inserted into the device for reduce the ion migration and increase the system stability. Then the perovskite material inserted between PCBM layer and PTAA layer. Next, PTAA layer as a hole transport layer is added into the device for increasing the energy in charge carriers of the proposed inverted PSCs. Finally, the glass inserts into the device for increase the energy carrier. The proposed multilayered sandwiched additive composite material perovskite solar cell is show in figure 2.

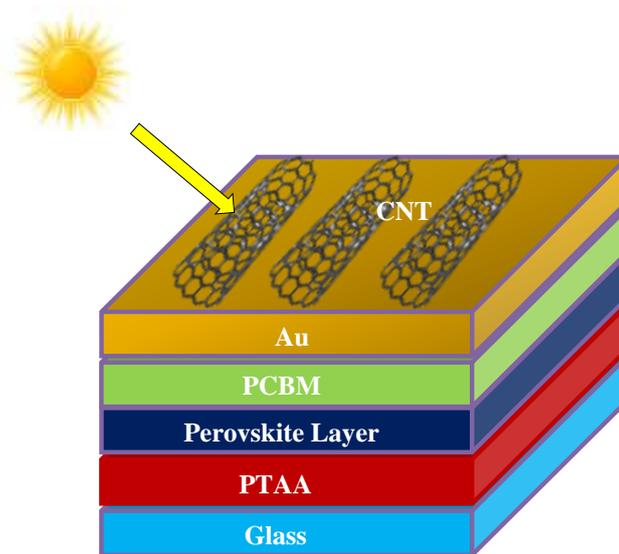


Figure 2: Multilayered sandwiched additive composite material perovskite solar cell.

In figure 2, electron transport layer is CNT-Au. CNT is dip-doped on Au in which dip coating is used to coat CNT and Au. Then, a single PCBM layer is inserted into the device which absorbs the photons from the CNT dip-doped Au layer and make more electrons and holes moves to produce energy as well as reduce the ion migration of perovskite material. After that, perovskite material that is methyl ammonium lead iodide is inserting below the electron transport layer (ELT). Then PTAA act as the hole transport layer that is insert into the device to generate more energy carrier. Finally, glass is added to the multilayered sandwiched additive composite material perovskite solar cell to produce more energy. The multilayered sandwiched additive composite material perovskite solar cell and their characteristics were explained in below subsequent section.

Materials and their characteristics

The materials used in multilayered sandwiched additive composite material perovskite solar cell and their characteristics were explained in this section. The inverted PSCs architecture is modeled as *CNT-Au/PCBM/CH₃NH₃PbI₃/PTAA/Glass* sandwich layer architecture.

CNT is made up entirely pure carbon atoms that held together by strong carbon-carbon chemical interactions to form a unique geometric structure. The CNT has strong photo absorption from infrared to ultraviolet wavelengths, as well as high carrier mobility and low carrier transport scattering. Moreover, CNT have high thermal conductivity, high electrical conductivity and mechanical property. The structure of carbon nanotube (CNT) is show in figure 3.

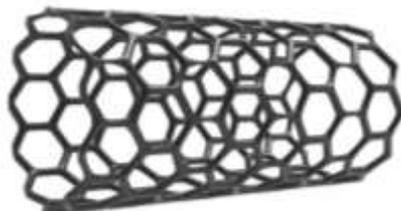


Figure 3: Structure of CNT.

The isopropyl alcohol, commonly called as 2-propanol, is one of the most prevalent chemical molecules in the alcohol family. The isopropyl alcohol has a melting point at 82.5 °C, density is 786 kg/m³, and molecular weight is 60.1 g/mol. The chemical structure of isopropyl alcohol is show in figure 4.

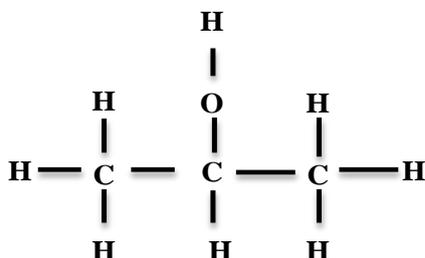


Figure 4: Structure of 2-propanol.

Then the Au (gold) has high electrical conductivity, resistance to corrosion and it is increase the efficiency of solar cells. The properties of gold tabulated in table 1.

Table 1: Properties of Au.

Properties	Metric
Density	19.32g/cm ³
Melting point	1064.43°C
Boiling Point	2000°C
Tensile strength	120 MPa
Poisson's Ratio	0.42
Elongation at break	30%
Thermal Conductivity	301 W/mK

The PCBM polymer material was chosen because it contains n-type semiconductors and shares the same solvent as P-Phenylene Vinylene (PPV). PCBM contains 5.1 eV HOMO orbitals and 3.7 eV LUMO orbitals. The chemical structure of [6,6]-phenyl-C61-butyric acid methyl ester is shown in figure 5.

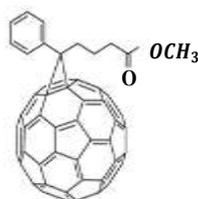


Figure 5: Chemical structure PCBM [25]

PTAA, or poly (triaryl amine), is an organic p-type semiconductor with hole mobility's ranging from 103 to 102 cm² V⁻¹ s⁻¹ and excellent carrier mobility. For thick film diodes, it is a stable glassy polymer with strong ionization potential. The linear formula of PTAA given by

$$[C_6H_4N(C_6H_2(CH_3)_3)C_6H_4]_n \quad (1)$$

Methylammonium lead iodide (CH₃NH₃PbI₃, MAPbI₃) is a kind of organic-inorganic halide perovskites (OIHPs) with unique electrical and optical properties. Methylamine and hydrogen iodide

combine at 0°C for 120 minutes, and then evaporated at 60°C for obtain methylammonium iodide crystals. The chemical structure given by

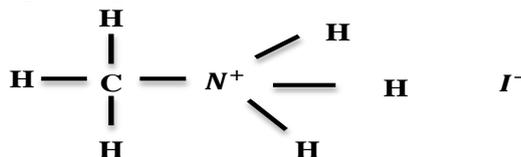


Figure 6: Chemical structure of Methylammonium lead iodide.

Poly[bis(4-phenyl)(2,4,6-trimethylphenyl)amine Poly(triarylamine) improves the open circuit voltage (V_{OC}) and fill factor (FF) of the solar cells. The chemical structure of the PTAA is shown in figure 6.

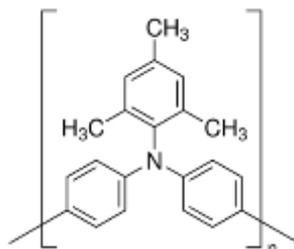


Figure 7: Chemical structure of PTAA.

The glass is a vital barrier it protects solar photovoltaic cells from harmful external elements including water, mist, and dirt and low reflection, high transmissivity, and high strength are all features of the glass. The proposed multilayered sandwiched additive composite layers perovskite solar cell performance explained in the following section.

Photovoltaic Performance

An inverted planar PSCs is introduced to increase the stability of the solar cell and eliminate the out-diffusion of cationic components. A single-walled CNT thin film is used to absorb light across a wide wavelength range, from visible to near infrared, and to have fast-moving charge carriers (electrons and holes). The CNT is dip-doped on Au to penetrate the light; the suggested device use Au to absorb the light. As a result, the Au absorbed the same energy from the carbon nanotubes, reducing energy loss. In the inverted PSCs device using nitric acid and sulfuric acid, CNT is oxidized to introduce oxygen functional groups to the carbon surface. To eliminate impurities, 5 g of CNT is fluxed in a 250 mL solution comprising concentrated HNO_3 (63% wt) and H_2SO_4 (98%) at 130 degrees Celsius for 2 hours. Then the liquid allowed for cooling after the acid treatment. To eliminate surplus acid solution, the residue was rinsed many times with hot distilled water until the pH reached as 7. The acid treated CNT then dried for 24 hours at 100 degrees Celsius. CNT-treated refers to CNT that has been acid changed. 24 mL isopropanol (IPA) solvent and 1 mL Nafion solution (5 percent) added to the treated CNT. Because it enhances dispersion using ultrasonic forces, high shear mixing, or other dispersion techniques, Nafion (5%) provides for greater nanotube dispersion. To get a homogenous suspension an Ultrasonication technique used for 1 hour. The homogenous suspension then utilized to coat the Au. To make the coating solution, different quantities of treated CNT (0.01, 0.025, 0.04, and 0.05 g) utilized. The Au was dip-coated on the suspension with soaking durations of 1, 30, 60, 120, and 180 minutes after obtaining the ideal CNT concentration. The samples dried for 24 hours in a vacuum oven at 70 degrees Celsius. Carbon nanotube is dip-coated on gold at substrate 5000 rpm for 30 s. After dip coating, the film annealed at 140 °C for 10 min. Then the perovskite material (159 mg CH_3NH_3I , 461 mg PbI_2 , 600 mg DMF, and 78 mg DMSO) insert upon a single PCBM substrate by using dipping. The CNT dip-doped Au is shown in figure 7.

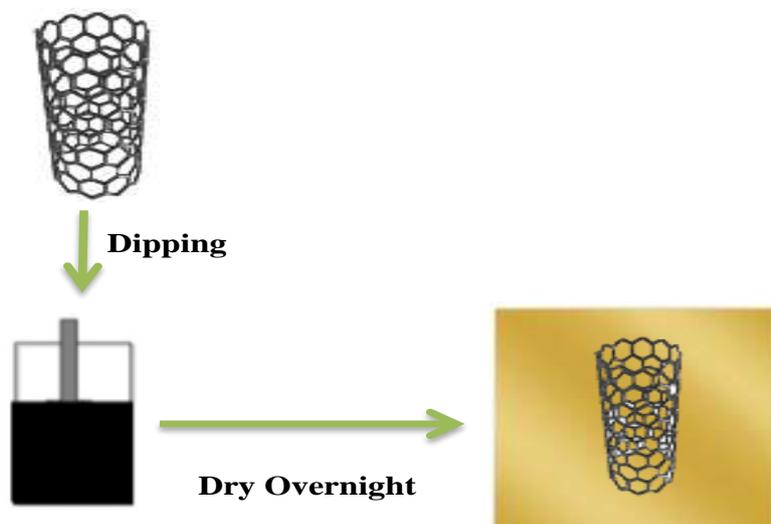


Figure 8: CNT dip-coated on Au.

This perovskite material collects ultraviolet and visible light from the PCBM layer and turns them into energy with high efficiency. Perovskite materials have an intrinsic ion migration influence due to their ionic conductor nature, loose crystal structures, and the occurrence of vacancies and other defects. For that reason, the proposed device adds a single PCBM layer for reduce the ion migration. A single PCBM layer reduces the ionic migration, eliminate the hysteresis in PSCs and improve the photovoltaic solar cells. When a PCBM layer inserted between perovskite and the electron transport layer, the power conversion efficiency of solar cell is increase the fill factor and open circuit voltage V_{OC} of the proposed device. The power conversion efficiency is calculate by using the formula

$$PCE (\eta) = \frac{J_{SC} \times V_{OC} \times FF}{P_{in}} \quad (2)$$

Where,

J_{SC} – Short circuit current density

V_{OC} – Open circuit voltage

FF – Fill factor

P_{in} – Total incidence irradiance

The PCBM layer absorb the light from the CNT dip-doped Au layer, also the electrons and holes move quickly therefore the energy is increased. The PCBM layer reduces the trapped charges at the surface of the perovskite layer for efficient suppression of electron-hole recombination in solar cells. Then the PTAA layer is inserted upon glass by using dip-coating method, PTAA is as a hole transport layer of the proposed device. The PTAA layer also absorb the same level of photons from the PCBM layer therefore the electrons and holes are moving fast thereby the energy is increased. Moreover PCBM has the ability to freely interact or inter-diffuse inside a perovskite film therefore it minimizing ionic migration and thereby hysteresis. Consequently, it improves the stability of the proposed device. Finally, the glass is absorbing the photons; the glass has a low reflection and the proposed device produce the high energy without sacrificing stability of the device. Then, a simple perovskite solar cell device is developed to achieve high-performance PSCs that provide the high stability of the PSCs. The proposed device strategy dramatically boosts the PCE to 23.76% with the maximum V_{OC} of 1.21V in a ~1.53 eV perovskite system.

Overall, in the Inverted PSCs, the CNT dip-doped Au absorbs and penetrates the high amount of light and the PCBM layer also absorb the same energy from the electron transport layer, the PCBM layer mitigate the ion migration. Therefore, it makes a way to improve the stability of the inverted PSCs and the methyl ammonium iodide used as the perovskite material of the inverted PSCs. Then the PTAA is as the hole transport layer is used to make more moves on electrons and holes to generate the highest amount of energy and finally the glass also used to make energy carrier in the inverted PSCs thereby it increase the stability of the PSC, reduce the voltage loss, leakage of materials and eliminate the ion migration.

Result and Discussion

This segment provides a detailed description of the implementation results as well as the performance of the proposed system.

Experimental Setup

This work has been implemented in the working tool of Matlab with the following system specification and the simulation results are discussed below.

- Tool** : Matlab
- OS** : Windows 8
- Processor** : 64-bit Intel i3-core processor
- RAM** : 8 GB RAM

Performance metrics of the proposed method

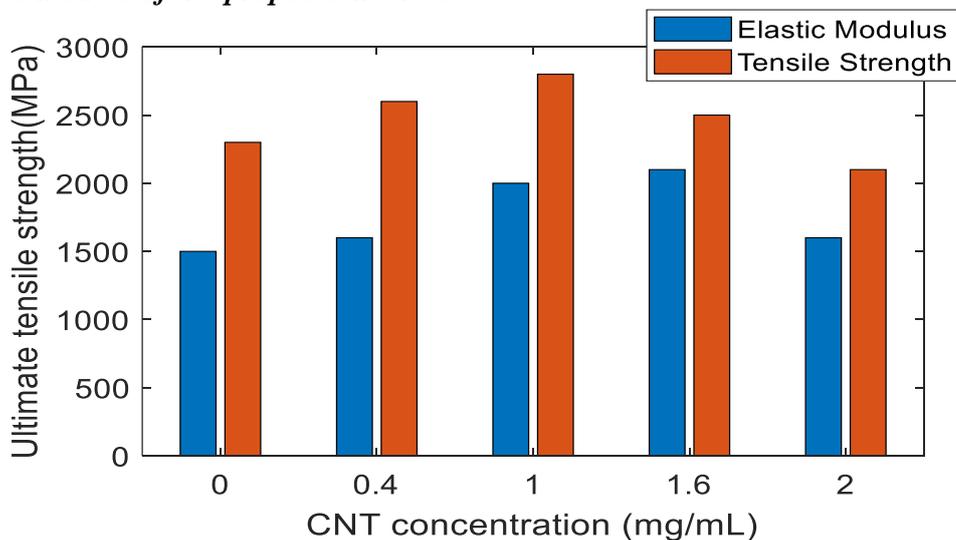


Figure 9: Tensile strength and Elastic Modules of proposed device.

When CNT is dip-doped with Au, the ultimate tensile strength and elastic modules are clearly seen in Figure 8. According to the graph, 0.4 percent CNT concentrated can achieve 2600 MPa tensile strength and 1600 GPa elastic modules, 1% CNT concentrated can achieve 2800 MPa tensile strength and 2000 GPa elastic modules, 1.6 percent CNT concentrated can achieve 2500 MPa tensile strength and 2100 GPa elastic modules, and 2% CNT concentrated can achieve 2100 MPa tensile strength and 1600 GPa elastic modules. Finally, a 1% CNT concentration may offer the proposed device the best tensile strength, while a 1.6 percent CNT concentration can give the proposed device the maximum elastic module. Table 2 lists the tensile strength and elastic module values.

Table 2: Tensile strength and Elastic Modules of proposed device.

CNT concentration (mg/mL)	Tensile Strength (MPa)	Elastic Modulus (GPa)
0	2300	1500
0.4	2600	1600
1	2800	2000
1.6	2500	2100
2	2100	1600

The carbon nanotubes absorb and penetrate light the most efficiently, and Au has the same property, the suggested device paints CNT on Au using a simple dip-coat procedure to absorb and penetrate light. As a result, the Au absorbs the same amount of energy as the CNT. Because of the high energy it creates and the device stability, the suggested device can cause more electrons and holes to traverse.

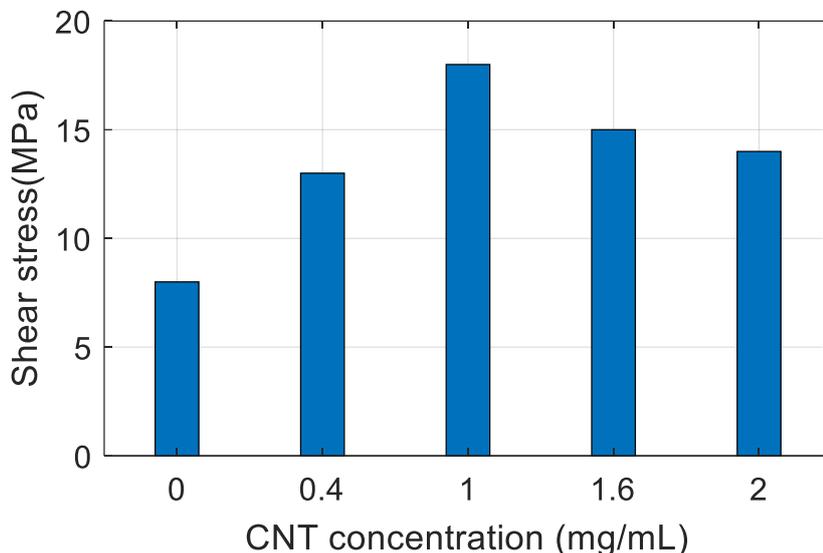


Figure 10: Shear Strength of proposed device.

The shear strength of the proposed device is shown in figure 10. Appropriate nanotube attachment on the Au can improve the strength against moisture, air, and temperature. However, when the shear strength increase the device may be cracks but the proposed device shear stress value between 0 and 18 therefore the proposed device cannot easily broke. CNT coated on Au with a simple procedure to boost its tensile strength in the proposed device. The shear strength of the proposed device values tabulates in table 3.

Table 3: Shear Strength of proposed device.

CNT concentration (mg/mL)	Shear Stress (MPa)
0	8
0.4	13
1	18
1.6	15
2	14

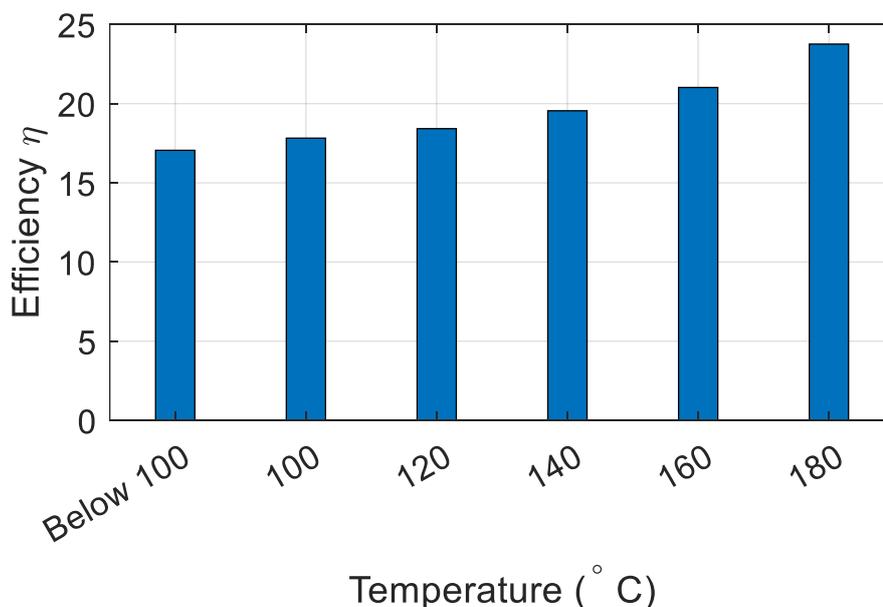


Figure 11: Efficiency of the proposed device.

The power conversion efficiency of the proposed device is shown in figure 11. Table 4 includes the efficiency value of solar cell performance derived from the J–V curves. Figure 11 demonstrates that as the temperature of the substrate rises, the efficiency of perovskite rises as well, resulting in a

significant increase in solar cell efficiency from 100 to 180 degrees Celsius. The proposed device can efficiently absorb and penetrate the light therefore it make more electrons and holes moves to generate more energy without voltage loss.

Table 4: Efficiency of the proposed device.

Temperature °C	Efficiency (η)
Below 100	17.053
100	17.82
120	18.42
140	19.55
160	21.02
180	23.76

Moreover, the proposed device used a single PCBM layer; this PCBM layer has the capacity to freely interact or inter-diffuse inside a perovskite film and it has the bandgap 1.3 eV to 1.9 eV, which may reduce ionic migration and thereby hysteresis. As a result, the proposed device's stability can improve as well as improves the PCE to a whopping 23.76 percent.

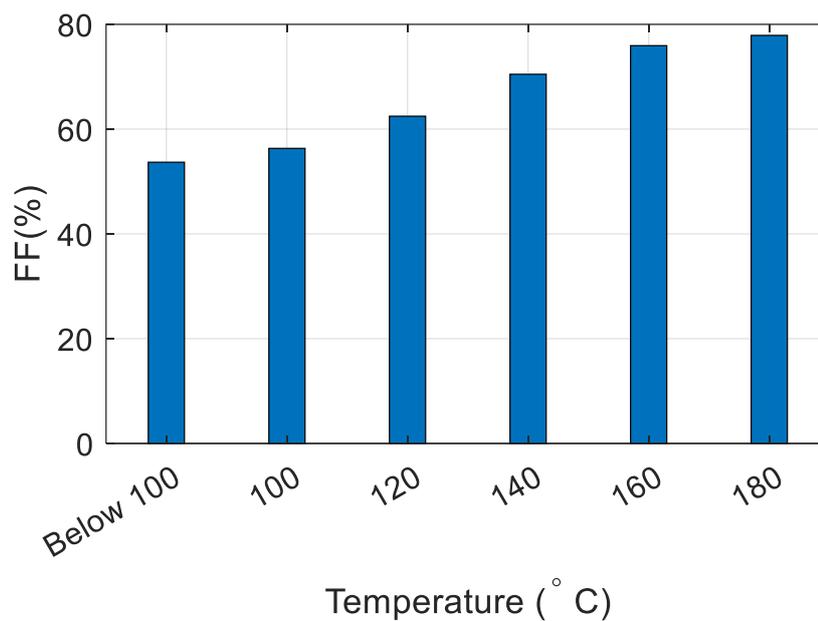


Figure 12: Fill Factor of the proposed device.

Figure 12 depicts the fill factor of the proposed device. The fill factor of perovskite increases as the temperature of the substrate rises, resulting in a considerable increase in solar cell fill factor from 100 to 180 degrees Celsius. The proposed device can efficiently absorb and pierce light, so it can create more energy by moving more electrons and holes without losing voltage.

Table 5: Fill Factor of the proposed device.

Temperature (°C)	FF
Below 100	53.68
100	56.32
120	62.46
140	70.47
160	75.93
180	77.89

Because carbon nanotubes have the maximum absorption and penetration of light, and Au has the same feature, the proposed device coats CNT on Au using a simple dip-coat process to absorb and penetrate the light. As a result, the Au absorbs the same energy as the CNT absorbed energy. Consequently, the proposed device can make more electrons and holes to travel thereby the high energy it generates as well as the device stability can maintain. The fill factor value of solar cell performance determined from the J–V curves shown in Table 5.

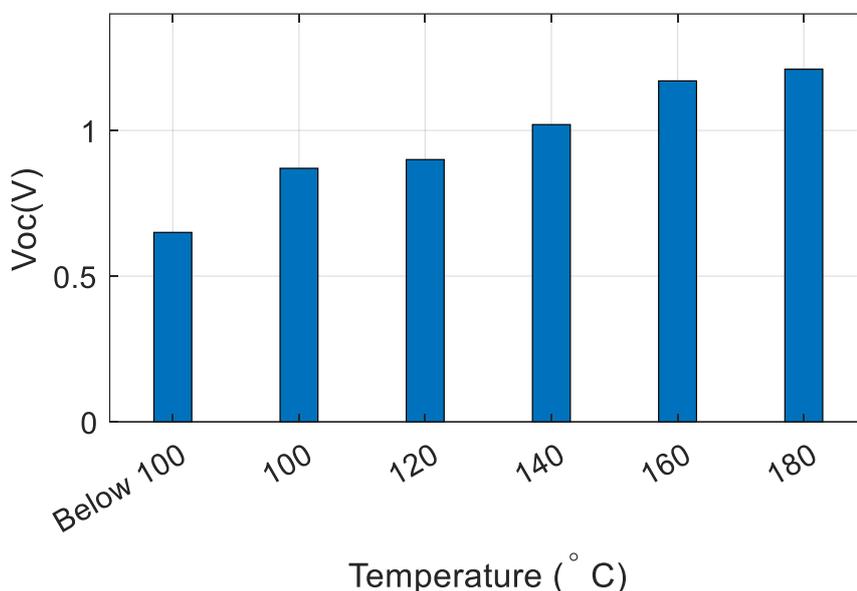


Figure 13: V_{oc} of the proposed device.

The open circuit voltage of the proposed device is depicted in Figure 13. As the temperature of the substrate rises, the open circuit voltage of perovskite increases, resulting in a significant increase in solar cell, open circuit voltage from 100 to 180 degrees Celsius. The proposed device can absorb and penetrate light effectively, allowing it to generate more energy by transporting more electrons and holes while maintaining voltage.

Table 12: V_{oc} of the proposed device.

Temperature (°C)	V_{oc}
Below 100	0.65
100	0.87
120	0.90
140	1.02
160	1.17
180	1.21

The PCBM layer absorbs light from the CNT dip-doped Au layer as well, causing the electrons and holes to flow swiftly and boost the energy. The PTAA layer is acting as the proposed device's hole transport layer. The PTAA layer absorbs the same number of photons as the PCBM layer, causing the electrons and holes to move faster and the energy to rise. Furthermore, PCBM has the capacity to freely interact or inter-diffuse inside a perovskite film, which reduces ionic migration and thereby hysteresis. As a result, the proposed device's open circuit voltage can increase as well as stability can improve.

Overall, the stability of the inverted perovskite solar cell can increase by 23.76% at 180-degree Celsius, the fill factor of the inverted perovskite solar cell can increase by 77.89% at 180-degree Celsius, the open circuit voltage of the inverted perovskite solar cell can increase 1.21eV at 180-degree Celsius by a method of stability enhancement in inverted perovskite solar cell using sandwiched composite materials in interface layers.

Conclusion

In this research, inverted PSCs developed using CNT dip-doped on Au, PCBM, Perovskite, PTAA, and glass. To penetrate the light and boost the energy carrier of the proposed device, dipping utilized to coat a CNT and Au. A single [6,6]-phenyl-C61-butyric acid methyl ester (PCBM) layer was also put into the device to limit ion migration in the perovskite material, since the PCBM layer absorbs photons from the CNT dip-doped Au layer and increases the number of electrons and holes moving to create energy. Furthermore, the PTAA layer is inserted into the device as a hole transport layer to increase the charge carrier in which the PTAA absorbs the same amount of light as the perovskite layer, allowing electrons and holes to move quickly. Finally, the glass is introduced into the device

that has a low reflection and absorbs light from the hole transport layer, causing electrons and holes to flow in the glass layer, resulting in a high energy output and greater stability of the proposed device and increase the power conversion efficiency is 23.76%.

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