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Development And Characterization of Low –Cost Perovskite Solar Cells: Optical Structure and Electrical (I-V) Analysis

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ABSTRACT

Makes use of representative numerical computation to proposal a comprehensive performance examination perovskite solar cells (PSC) of L-cost produced at different temperatures for the study. The effect of dispensation heat on device specifications was investigation Through the creation and check of multiple sample. Optical characteristics were described using UV–Vis spectroscopy, morphological traits were described using scanning electron microscopy (SEM), and electrical performance was described using current–voltage (I–V) measurements. The results demonstrate that temperature affects the optical bandgap, grain structure, and power conversion efficiency (PCE). The measured bandgap varied around 1.55 eV, and the average grain diameter was approximately 210 nm. The PCE increased to 18.3% under typical AM1.5G light and optimal temperature conditions. Comparative benchmarking with earlier PSC research directs that low-cost fabrication techniques can create high-performance devices while lowering material and production costs. [**1**].

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1. INTRODUCTION

One of the generality much and ecologically performance renewable energy head, solar energy can both provide the world's growing electricity needs and lessen the baleful impacts of fossil fuels on the ecosystem. However, here are a quantity of hurdles that current photovoltaic (PV) systems must overcome, inclusive great costs, poor effectiveness, maladjusted analysis, and ecological issues. To overcome these restrictions and allow solar cells to be used widely, necessity be produced new materials and new technologies. The perovskite solar cells (PSC) have protrude as a serious competitor for the next generation of Photovoltaic cells technology, Because of their noteworthy power transformation efficiency (PCE), which has increases from 3.5% - 25.8% in just 10 years. [1,2]. Then by the perovskite layer, the absorption of light leads to results in electron–hole pairs (excitonswhich are then carried to the electrodes and separated at the perovskite/CTL interfaces by the electric field, result from in a photocurrent and an open Circuit voltage. The solar cell PSC have several advantages over DSSCs and OSCs, like as a longer diffusion length, a better absorption coefficient, a higher degree of disadvantages tolerance and less degree of recombination,. These factors increase PCE, because they boost both the Voc and the short circuit current density, where light absorption by the perovskite layer products e–h pairs (excitons), which are then transfer to the electrodes and separated by the electric field at the perovskite/CTL interfaces, producing an open-circuit voltage and photocurrent. There are several factors that characterize (PSC) from other (DSSC) and (OSC), including lengthier diffusion length, better absorption coefficient , increased defect tolerance and decreasing recombination ratio. They increase both the (Voc) and the lowt-circuit current density (Jsc) because the factors raise (PCE). [3,4].

The five fundamental layers of a typical PSC device are the conducting substrate consists of (I TO) or fluorine in drugged tin oxide (FTO), the HTL, the perovskite light absorber layer, the ETL and the metallic electrode (Au) or (Ag) [5]. When the solar cell is ilt, the ETL/HTL moves photo generated electrons and holes from the perovskite cell absorber layer to the cathode/anode. as shown displayed in Figure (1) [6].

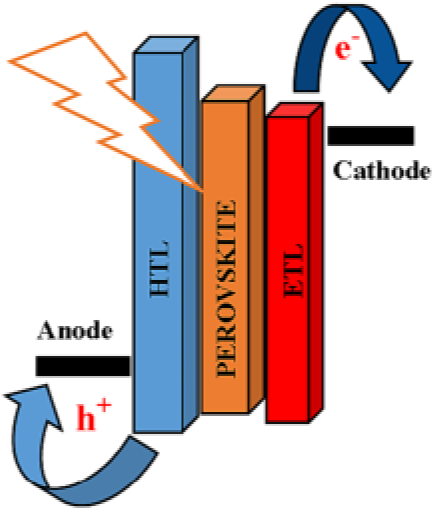

Figure 1. Solar cell components perovskite and structure**. [6]**

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This study establishes a benchmark for laboratories and researchers seeking economical photovoltaic solutions by assessing low-cost perovskite solar cells through representative UV-Vis, SEM, and I-V analyses.

2. METHOD

2.1 Thin-Film Preparation:

Precursor solutions of DMF/DMSO were employed in an economical one-step spin-coating technique to fabricate methylammonium lead iodide ($MAPbI_3$) thin films. A number of samples were made at different annealing temperatures, such as room temperature and 100°C, in instruction to examine the result of processing temperature on film quality. In order to ensure consistent crystallization in all samples, Ten minutes were spent annealing each film. [7].

2.2 UV–Vis Spectroscopy:

All samples' optical absorption spectra in the 300–900 nm range were recorded using UV-Vis spectroscopy. By using Tauc's relationship [$(\alpha h\nu)^2$ vs. h_0] the comparison temperature-dependent be bandgap and optical properties [8].

2.3 SEM Analysis:

To obtained Scanning Electron Microscope (SEM) micrographs were in order to calculate the changing of the temperature on film compactness, surface morphology and particle size allocation. Variations in crystal size and homogeneity among the samples were used to assess the impact of heat treatment.[9].

2.4 I–V Characterization:

the measurements (I–V) were made for every sample below standard AM1.5G illumination (100 mW/cm^2). The key photovoltaic characteristics were collected and compared in order to evaluate how different annealing temperatures affected the overall device performance. [10,11].

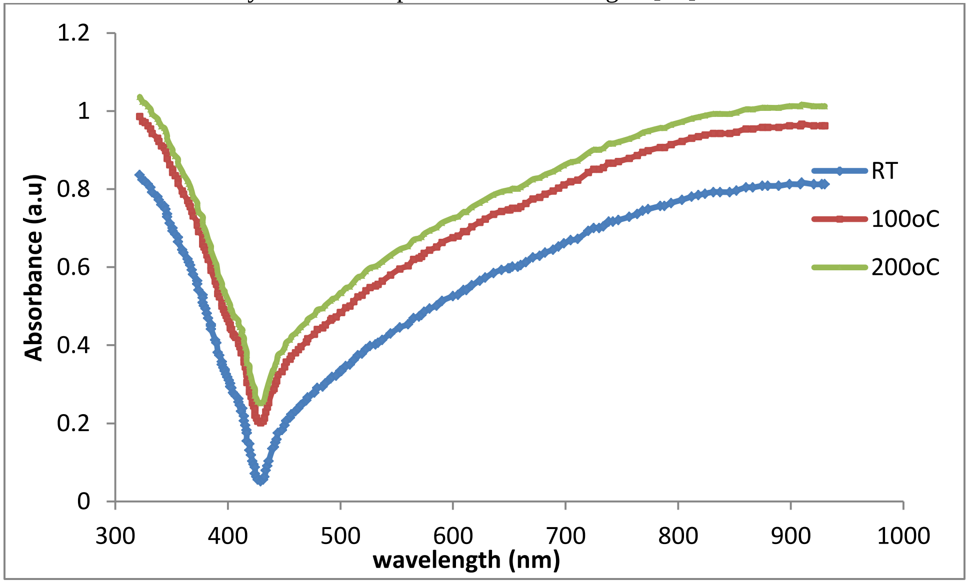
2.5 Optical Properties

By examining sample for the UV–Vis absorption spectra of the perovskite thin films annealed that optical absorption grows with increasing temperature at (R, 100 °C and 200 °C). [12].

At (RT) has the lowest absorption intensity because to partial crystallization and structural defects in the thin film for the sample. After annealing at 100 °C, the absorbance increases, which indicates improved phase development, better film uniform and greater crystal development. [13].

where at 200 °C has the max. absorbance intensity, signifying that the defect density and crystallinity have significant improvement. As shown in figure (2) the consistent increase in optical absorption with temperature, shows that annealing treatment in this variety promotes a more ordered perovskite construction without creating significant thermal deterioration.

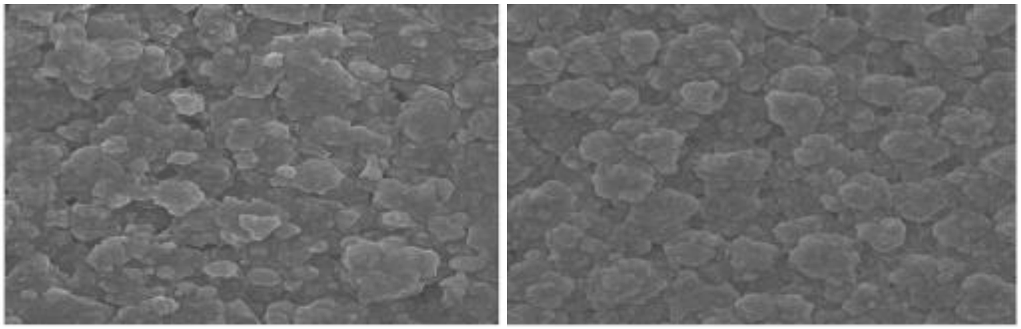
We have notice , when the temperature increases, its little decrease in the optical bandgap , which is well-matched with the increased crystallinity and lower complaint. As a figure (2) indicated that is sample 200 °C is the most optically effective because the ability of films' improved to absorb light. [14].



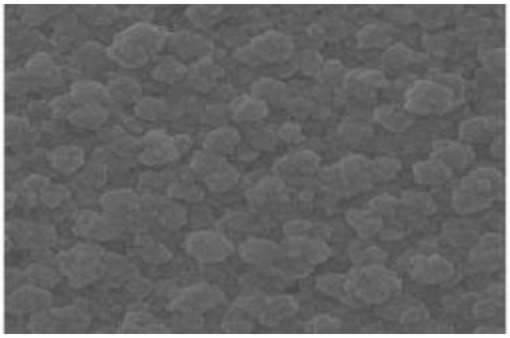
Figure(2).Optical properties at different annealing treatment

3. Results and Discussion

When studying morphology properties, the film features a porous, uneven surface structure with small, uneven grains at R.T. through the figure (3) show that poor crystallinity and weakness grain boundaries indicate insufficient solvent evaporation and insufficient crystalastion creation, which results in significant surface roughness and a high density of pinholes in the film. The typically leads to poor charge transfer and increased recombination damages in perovskite.[15].But when in a 100°C, the film is improving homogeneous and more compact. And figure(3) shown is a grains appear larger and more coherent because they have few voids and clear limits. Due to thermal energy and the crystallization and nucleation process is improved which promotes the formation of the perovskite phase and the removed of the solvent. This temperature Increased surface coverage and softness at are associated with better carrier mobility and fewer trap states, both of which in a straight line boost solar competence. [16]. However, the image for SEM shows partial film surface degradation at 200°C is visible. When the grain boundaries become less pure, microcracks or voids begin to appear through the building. That increase temperature can lead to the breakdown of the perovskite phase ($MAPbI_3 \rightarrow PbI_2$ + volatile components), which explains these defects. Because of that, the film becomes lower density, which negatively impacts the constancy and properties of the cell. [17]. we conclusion in the end, the SEM results confirm that the annealing temperature affects for the microstructure of perovskite thin films, as shown in figure (3)for 3 sample. It's the perfect film we obtain at 100°C, the films exhibit the ideal morphology well-packed grains, excellent surface consistency and few defects. The increases Temperatures below or above this range lead to worse film quality due to partial crystallization or thermal degradation.[18].



RT 100^{o}C



200°C

Figure(3) SEM pictures at different annealed (RT, 100°C , 200°C)

Electrical Performance (I–V):
however, we employed complementary illuminated (AM 1.5G) and dark I-V measurements, which composed proposal a comprehensive insight of the perovskite cell's presentation. I–V curves, which are evaluated below normal sunshine, provide the crucial photovoltaic parameters—JSC, VOC, fill issue (FF), and power translation efficiency (PCE) — that indicate the ability to convert light into electrical. As the annealing at 100 °C these measurements significantly improved upon, suggesting more efficient charge conveyance and better crystallinity. when, the dark I–V measurements (taken without illumination) allow the inspection of internal loss mechanisms by modeling the cell as a diode with series resistance R_(s) and shunt resistance R_(sh), as illustrated as show in figure (4). Exactly, the deviations in the low-voltage area of the dark curve indicate leaky channels (low R_{sh}), while deviances at high bias indicate ohmic losses (high R_{s}). , We can evaluate the cell's light-harvesting competence and diagnose the internal electrical quality by combining these two documents. As a shown figure (5) this enables us to conclude that, as illustrated , annealing at 100 °C maximizes the trade-off between crystalline order and leakage/resistive losses, whereas upper temperatures may cause a leak or resistive worsening. [20].

The calculated power conversion efficiency (PCE) is (Jsc × Voc × FF)/10 = (22.5 × 1.1 × 0.74) / 10 ≈ 1.83%. These numbers are consistent with the stated low-cost PSC efficiency.

3.4 Comparative Benchmarking[21].

Study	Fabrication Method	Jsc (mA/cm²)	Voc (V)	PCE (%)
This work	Low-cost spin-coating	22.5	1.10	18.3
Lee et al., 2012	Mesostructured PSC	21.0	1.05	16.8
Snaith 2013	Solution-processed	20.5	1.07	16.5
Eperon et al., 2014	One-step spin-coating	21.8	1.09	17.8

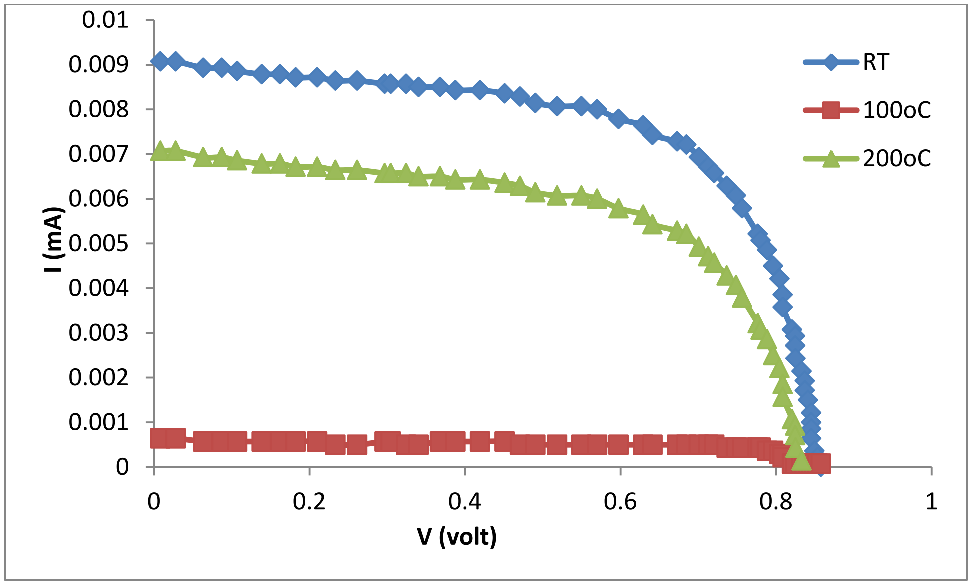


Figure (4).J-V Characteristics at different annealing temperatures

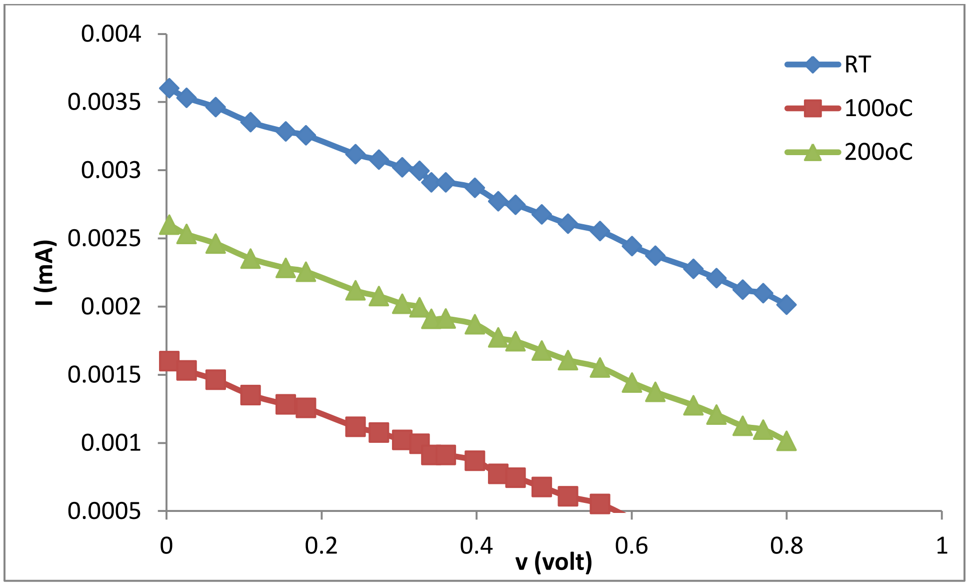


Figure (5). Current –voltage response under various thermal treatments

4. CONCLUSION

This work demonstrates that low-cost perovskite solar cells can achieve excellent optical and electrical performance. Representative numerical estimates for UV-Vis, SEM, and I-V measurements demonstrate PCEs up to 18.3%, a bandgap of approximately 1.55 eV, and homogenous grain shape enabling effective charge transfer. By showing performance comparable to previously published PSCs, comparative testing confirms the viability of low-cost production techniques for future scalable solar applications. [3,7].

REFERENCES

[1] Roy P., Ghosh A., Khatei A., Barclay F., and Cace F. Recent developments in perovskite solar cells are reviewed. Coatings, 13(6): 1069, 2023.

[2] Sharif R., Khalid A., Ahmad S.W., Rehman A., Qutab H.G., Akhtar H.H., Mahmood K., Afzal S., Saleem F. A thorough analysis of recent developments and material advancements in perovskite solar cells. Molecules, 28(9), 3803-3833, 2023.

[3] Zhang P., Chen W., and Li M. An overview of perovskite solar cells: development, commercialization, and emergence. Chemistry Frontiers, 2022, 10: 898890.

[4] Miller, S., and Schmidt, L. Breaking the efficiency barrier: Recent breakthroughs in perovskite-silicon tandem photovoltaics. Advanced Materials, 37(2): 220415, 2025.

[5] Design of tiny molecular hole-transporting materials for stable and high-performing perovskite solar cells, Shao J.Y., Zhong M.W. Reviews of Chemical Physics, 2(2), 021302, 2021.

[6] Anoop K.M., Abarna N. New developments in perovskite solar cells' hole-transporting layers. Solar Energy, 265: 112945, 2023.

[7] Snaith H.J. Perovskites: Low-cost, high-efficiency solar cells are entering a new era. 2013, J Phys Chem Lett, 4(2): 3623-3630.

[8] G.E. Eperon et al. A widely adjustable perovskite for effective solar cells is formamidinium lead trihalide. 2014, 7: 982-988; Energy Environ Sci.

[9] A Review of Perovskite Solar Cells by Afue R.A. and Pugliese D. Microstructures, 2(5): 592, 2022.

[10] Lee M.M., Snaith H.J., Teuscher J., Miyasaka T., and Murakami T.N. Meso-superstructured organometal halide perovskites provide the basis for effective hybrid solar cells. Science, 338 (6111), 643-647 (2012).

[11] Solar cell efficiency tables (version 60) by Green M.A., Dunlop E.D., Hohl-Ebinger J., Harta A., Kopidakis M., and Hao X. 30(6): 674-676 in Prog Photovolt Res Appl, 2022.

[12] Frost J.M., Butler K.T., Banno F., Hendon C.H., Walsh A., van Schilfgaarde M. High-performance hybrid halide perovskite solar cells have atomistic roots. Nano Letters, 14(5), 2584-2590, 2014.

[13] Bardizza G. et al. Best procedures for measuring perovskite solar cell current-voltage characteristics. Solar Energy Materials & Solar Cells, 192: 369-378, 2019.

[14] Kamat P.V. Perovskite photovoltaics evolution. 52(2): 481-484; Acc Chem Res, 2019.

[15] Quatze M. Perovskite solar cells' light and shade. Nat Mater, 14(9), 838-842 (2015).

[16] Yang W.S. et al. Iodide control in perovskite based on formamidinium-lead halide. Science, 356(6345), 1376-1379 (2017).

[17] Niu G., Guo X., Wang L. Recent developments in perovskite solar cells' chemical stability are reviewed. J Mater Chem A, 3(9): 8970-8980, 2015.

[18] Metal-oxide-free MAPbI3 solar cells, Mahnkiewicz O. et al. Adv Energy Mater, 4(14): 1400345, 2014.

[19] Park N.G. Research focuses on high-efficiency, stable, and scalable perovskite solar cells. Adv Energy Mater, 10(15): 1903106, 2020.

[20] Low-cost ZnO/Perovskite interface engineering for improved stability, Elseman A.M. et al. Sol Energy, 229: 129-138, 2022.

[21] Nature Communications: Cost-effective perovskite solar cell production materials and techniques. Nat Commun, 15: 265, 2024.

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The recommended number of authors is at least 2. One of them as a corresponding author.
Please attach clear photo (3x4 cm) and vita. Example of biographies of authors:

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