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Performance Optimization Assessment of Different Polymer based PV Cells

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***Abstract*—** Solar power has become a very attractive topic among scientist in the past three decades as the requirement for alternative energy schemes with extremely less carbon emission have become necessary. Organic PV cells are promising device for the flexible and low-cost solar cells. Polymer based PPV/PCBM and Perowskite solar cell can be a good alternate of si based cells. This paper describes the Design of device structure and assessment of both the properties (optical and electrical) of organic solar cells to further enhance their power conversion efficiency. It basically presents simulation of electrical & optical characteristics of polymer (donor)/fullerene based organic materials and PPV/ PCBM bulk heterojunction PV cells devices & extraction of figures of merits like ƞ , Voc, Isc & fill factor**.**

Keywords*—*PPV/PCBM, Perowskite bulk heterojunction PV cells.

I. INTRODUCTION

Silicon based PV cell is leading the way in PV cell technology. Mono-polycrystalline silicon have been mainly used and can be found everywhere PV panels on roofs, street light and even on electric cars. Today, silicon based PV cells used and account for 98% of all the PV cells(Leung et al., 1998). With conversion output of the devices peaks up to more than 25% and theoretical value predicted to be more than 30%, inorganic PV cells has become the most great approach to reap power source later on. In any case, the assembling cost and extremely hard to create has become its disadvantage [1].

The organic cell offers the plausibility of minimal effort manufacture on a huge size of PV cell collecting PV energy. Aside from that, these polymer gadgets have the adaptable capacity, for example, light weight and it is precisely bendable [2]. These components open up greater probability of other PV cell application in our day by day use. 0rganic material has been broadly researched consistently and viewed as the answer for supplant inorganic material to turn into a high efficiencies PV cell. Acknowledgment of the advantages of inexpensive materials and preparing just as enormous territory conformal development have additionally put high enthusiasm for organic solutions for PV applications.

II. MODELLING AND SIMULATION

PPV/PCBM

When a photon is absorbed by an active material, it forms excited-state excitons, an electron-hole pair found in the local environment. These excitons can be transmitted through matter that diffuses into life-limited matter, allowing the distance it can travel before it collapses. Usually it is only 10 to 20 nanometers in size. This means that the optimal size structure in the active material must also lie in the order of the material, which is referred to as bulk heterojunction or macrophage separation. The sequence of donor, polymer (donor) and acceptor is located in several domains, in which holes and electrons can propagate. All types of polymer solar cells (donor solar cells) are constructed with double-layer geometry. Therefore, in the manufacture of solar cells, a layer consists of the polymer (donor) donor and the acceptor, which also means that the exciton have to travel a long distance. The exciton migrate to the phase boundary between the donor and acceptor material, where charges can be separated, electrons can migrate to the acceptor material, and holes in the polymer (donor) material can migrate and pass through the two through the electrode kind of material. Charge carriers need to move to multiple electrodes instead of moving randomly to generate electricity. An internal electric field creates by using different electrode materials with different energy levels and also by using an intermediate layer, which preferably transports electrons or hole charge carriers in the correct direction of electrode. In this manner, the energy change conversion output shouldn't be as high as the normal cell's viability. A broad utilization of organic PV cells could add to the expanded utilization of PV energy universally and make sustainable power sources user friendly.

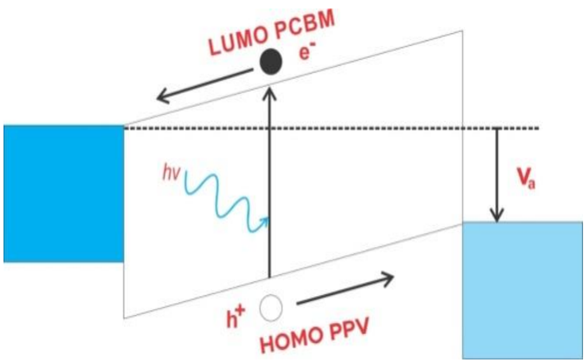


Fig 1(a): LUMO-HOMA of the energy levels,

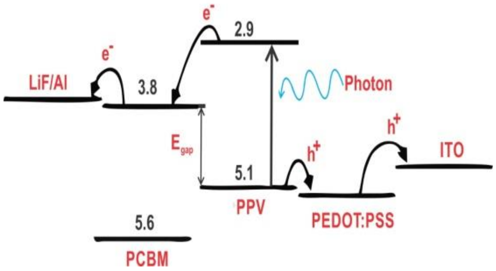


Fig 1(b): Proposed PV cells process diagram with positive applied bias

Phenyl-C61-butyric acid methylester-PCBM has turned into positive (p-type) materials with fullerene composition as it has shown extraordinary potential and has been comprehensively inspected as a working layer in polymer PV cell subject to mass heterojunction thought. These blends have shown a promising result and has the most raised display to date diverged from various materials. PPV has some one of a kind electrical and optical properties over other polymer PV cells high holes mobility, and higher capacity of absorption in the specific color(pink) region. Geminate and bimolecular recombination is major factors that strongly influence the efficiency of polymer based solar PV cells

The electrical properties of organic PV cells (OSC) have been investigated to understand the charge loss mechanisms impacting the overall conversion output. The power conversion effciency of a PV cell is dependent upon the I_{sc} , $V_{oc,}$ and FF.

The model incorporates the standard float dissemination of Poisson's condition and gap conditions) expanded by the singlet exciton continuity condition: (Nawaz & Ahmad, 2012)

$$\frac{ds}{dt} = G_{ph} - \text{KNRS.EXCITONS} \cdot \text{S} - \text{R}_\text{D}np + R_L np \tag{1}$$

$$R_D np = \frac{3r_L}{4\pi A.SINGLET}\exp\left(-\frac{S.BINDING}{kT}\right)\frac{J_I(2\sqrt{-2b})}{\sqrt{-2b}} \tag{2}$$

$$b = \frac{q^3|E|}{8\pi\xi_r\xi_o k^2T^2} \tag{3}$$

We likewise included a parameter, QE.EXCITON that depicts the portion of consumed photons that generate singlets (instead of electron gap sets). These include geometric ray tracing, c, pillar propagations and limited contrast time space techniques.

Simulation of organic PV cell

Poison equation

$$\frac{\partial^2}{\partial x^2}\forall(x) = \frac{q}{\varepsilon}\left[n(x) - p(x)\right] \tag{4}$$

Current continuity equation

$$\frac{\partial}{\partial x}J_n(x) = qU(x) \tag{5}$$

$$\frac{\partial}{\partial x}J_p(x) = -qU(x) \tag{6}$$

$$J_n = -qn\mu_n\frac{\partial}{\partial x}\forall + qD_n\frac{\partial}{\partial x}n \tag{7}$$

$$J_p = -qn\mu_p\frac{\partial}{\partial x}\forall - qD_p\frac{\partial}{\partial x}p \tag{8}$$

$$D_{n.p} = \mu_{n.p}V_t \tag{9}$$

$$V_t = k_B Tlq \tag{10}$$

The average net generation rate

$$<u> = \frac{1}{L}\int_0^L U(x)dx = \frac{J_n(L) - J_n(0)}{qL} \tag{11}$$

PV cells structure

With respect to photo generation, the creators recommended a constant photo generation rate all through the gadget of 2.7x1021 cm-3s-1. AM 1.5 values are used as reference for optimization & TCAD Simulation of Organic PV cells. The last worth disregards front reflections or light going through the gadget. In view of the recommended parameter esteems we ran the recreation.

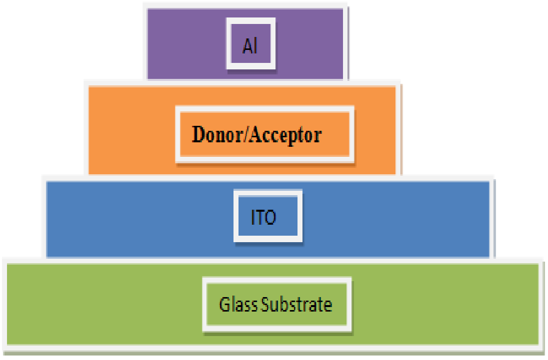


Figure 2: Structure of a bulk heterojunction organic PV cell

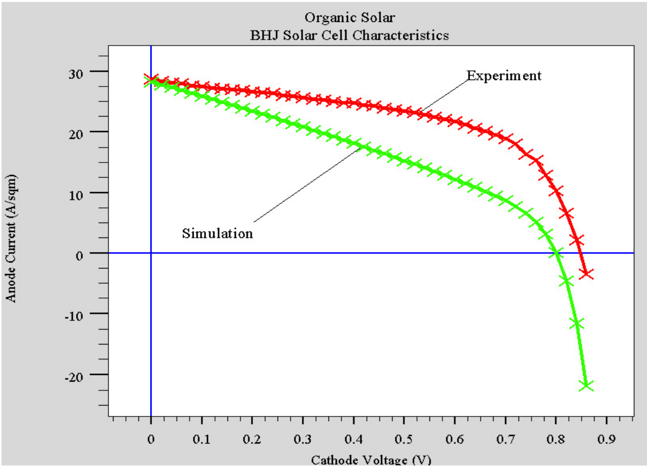


Figure 3. Organic PV Cell comparison of current-voltage characteristics.

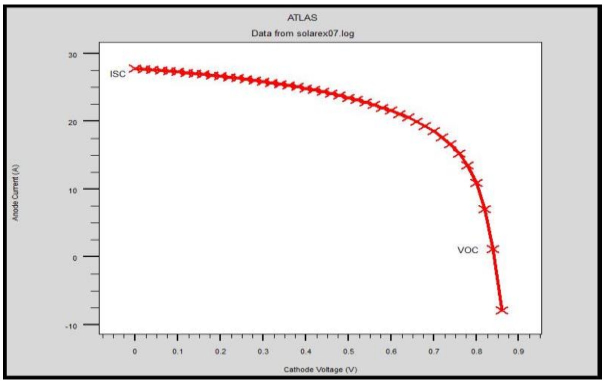


Fig. 4: VI & VP Characteristics for PPV/ PSBM PV cell

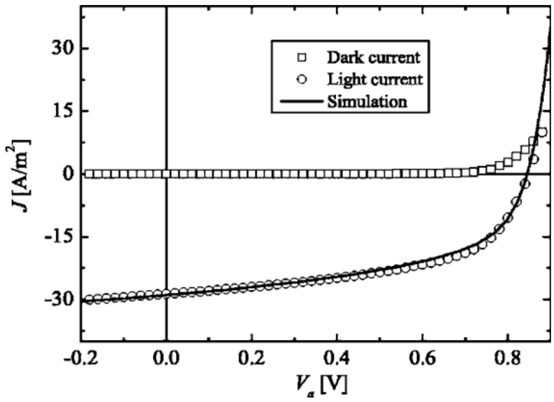


Fig. 5: Dark and Illuminated Characteristics for PPV/PSBM PV cell

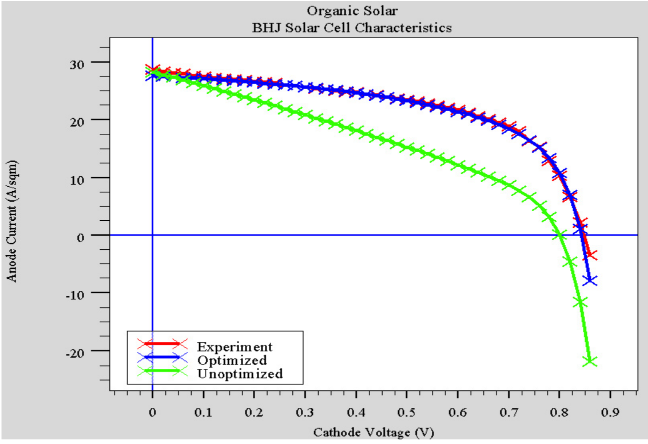


Figure 6. Organic PV Cell comparison of current-voltage characteristics.

The coupling energy has changed fairly yet we can breathe easy in light of the way that worth utilized by Korster et al[3] was not given. At long last we see that the photogeneration rate was decreased to generally 58% of the recommended worth. As for examination this appears to be sensible since the accepted steady age rate was presumably not estimated. In all we are very happy with the tuning investigation and feel certain that such a methodology can be applied to different gadgets/materials.

III. MODELLING AND SIMULATION

Perowskite Heterojunction PV Cell

A Perowskite sharpened PV cell was reproduced utilizing SILVACO ATLAS programming and final outcomes were contrasted and the exploratory information. The recently demonstrated Perowskite sharpened PV cell with Perowskite structure by concentrating on photogeneration, carrier separation and photo-current creation forms gave promising outcomes the change conversion output of 11.73% and the Fill Factor (FF) of 73% .

As of late, the Perowskite-based PV cells have pulled in incredible consideration because of their great light-reaping attributes. These cells are promising contender for next generation cells with ease and higher-conversion output. We reenact a PV cell with Perowskite structure and contrast the reproduction results and exploratory information announced.

Device Structure:

Perowskite designed as inside the inherent layer which is between the TiO2- PEDOT respectively N and P type. The intake of photons by sensitizer makes excitons (or electron-gap sets). The 2D arrangement and Meshing structure of reenacted PV cell are appeared in Figure 7, separately. Then again, making a thicker mesh builds the re-enactment time. Along these lines, as appeared in figure 1b, better meshing is presented close to districts, for example, junctions, material limits, and electrodes.

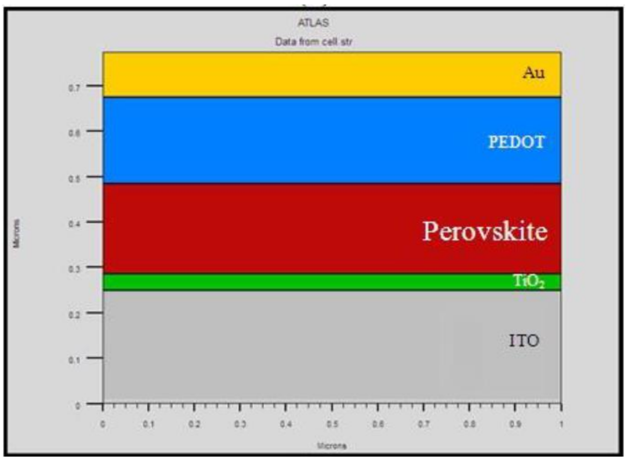


Figure 7: Perowskite sensitized PV cell Device structure

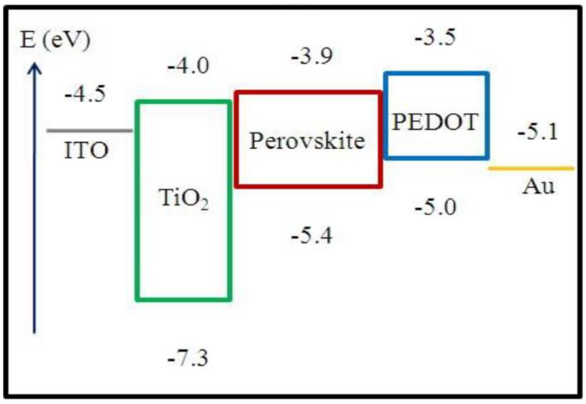


Figure 8: Perowskite sensitized PV cell Energy band diagram

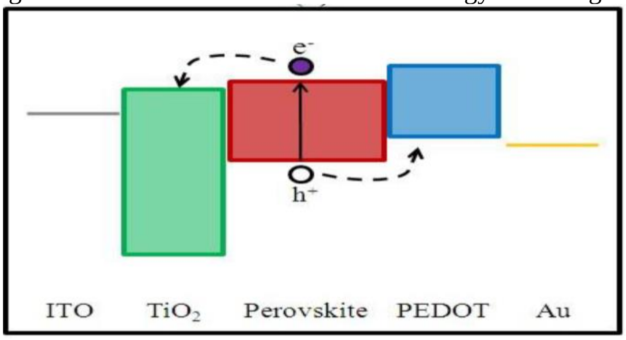
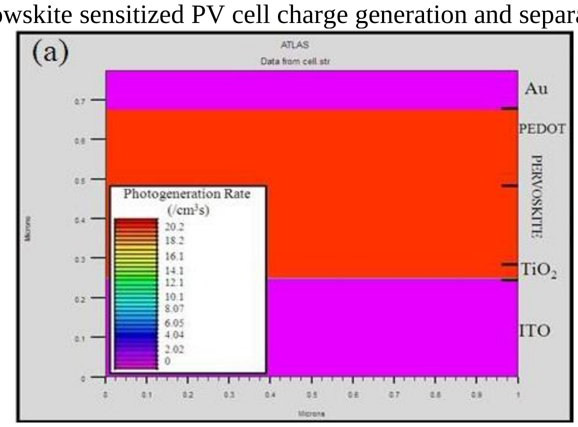


Figure 9: Perowskite sensitized PV cell charge generation and separation processes



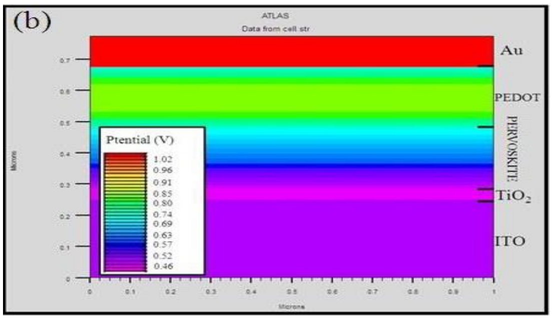


Figure 10: Perowskite sensitized PV cell (a) The photo-generation rate, (b) Potential

Characteristics of (J–V) execution of reproduced PV cell with Perowskite structure under AM 1.5 daylight light (100mW/cm2) is appeared in figure 11(a). Outside quantum conversion output (EQE) which decides the occurrence photon to change over electron proportion was reproduced for Perowskite sharpened PV cell is appeared in figure 11(b).

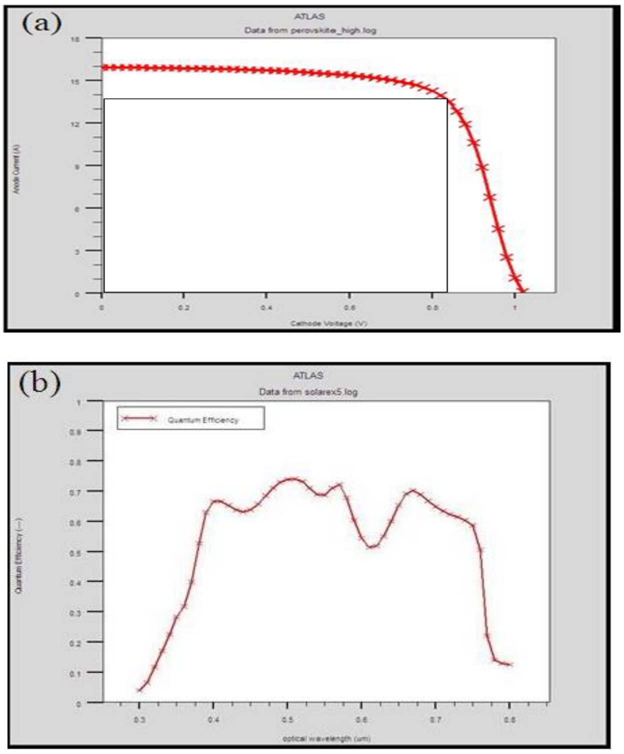


Figure 11: (a) Density of photo-current–voltage (J–V) presentation and (b) EQE spectram of Perowskite PV cells

Parameters/ Materials	V_{oc} (V)	J_{sc} (mA/cm2)	V_{max}	I_{max}	FF (%)	η (%)
PPV/ CBM	0.846	28	0.66	20.2	0.56	13.33
Perowskite	1.02	15.92	0.83	14.2	0.73	11.79

Table 1: Figure of merit extracted from TCAD

IV. Conclusion

Simulation of electrical & optical characteristics of polymer/fullerene based Organic materials PPV/ PCBM & Perovskite bulk heterojunction PV cells devices have been presented. The electrical properties of polymer PV cells (OSC) have been investigated to understand impact of charge loss on overall efficiency. PPV/PCBM lead to a maximum attainable efficiency of 13.33% which was only 5% in the previous Researches. With the help of TCAD software extraction of the optical and electrical parameters before fabrication is possible with ease. Perovskite demonstrated the efficiency of 11.79 %.

References

[1] Ahmed, N. M., Sauli, Z., Hashim, U., & Al-douri, Y. (2009). *IJNeaM_2_2_7_189-195*. *2*, 189–195.

[2] Hameiri, Z. (2018). Photovoltaics literature survey (no. 141). *Progress in Photovoltaics: Research and Applications*, *26*(3), 234–238. https://doi.org/10.1002/pip.2995
[3] Kester, L. J. A., Smlts, E. C. P., & Bl0m, P. W. M. (2OO5). Device model for the 0peration of polymer/fullerene bulk heter0junction PV cells. *Physical Review B - Condensed Matter and Materials Physics*, *72*(8), 1–9. https://doi.org/10.1103/PhysRevB.72.085205
[4] Mehrabian, M., & Dalir, S. (2017). 11.73% efficient Perowskite heterojunction PV cell simulated by SILVACO ATLAS software. *Optik*, *139*, 44–47. https://doi.org/10.1016/j.ijleo.2017.03.077
[5] Iqbal, Mohammad. and Sunil Kumar Gupta (2020). Comparative analysis between numerical simulation of PPV/PCBM and InGaN based solar cells. Materials Today: Proceedings. 10.1016/j.matpr.2020.05.519.
[6] Iqbal, Mohammad Asif, and Sunil Kumar Gupta. "TCAD Based Simulation and Performance Optimization of PPV/PCBM and Perovskite PV cells." International Journal of Computing and Digital Systems 10 (2020): 2-7.
[7] Mohammad Asif Iqbal, “Study of Organic PV Cell,” *ICONIC Res. Eng. JOURNALS*, vol. 1, no. 10, pp. 29–32, 2018.
[8] Mohammad Asif Iqbal, “Investigations of Indium Gallium Nitride Properties For Enhancement of Performance of PV Cells,” *Int. J. Creat. Res. Thoughts*, vol. 6, no. 1, pp. 605–608, 2018.
[9] Mohammad Asif Iqbal, “Conversion output Improvement Approach of InGaN Based PV Cell by Investigating Different Optical and Electrical Properties,” *SSRN Electron. J.*, vol. 1, no. 1, pp. 1–9, 2019, doi: 10.2139/ssrn.3355989.
[10] Mohammad Asif Iqbal, “TCAD Based Simulation and Performance Optimization of InxGa(1-X)N based PV Cell,” *Glob. J. Res. Eng. F Electr. Electron. Eng.*, vol. 19, no. 4, pp. 27–33, 2019.

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Mohammad Asif Iqbal Awarded Ph.D. Degree from Poornima University, Jaipur India in 2021. He is working as Associate Professor in Department of Electrical Engineering, at Poornima College of Engineering, Jaipur. His research interests include Hybrid Energy, Photo detectors Materials and Power system.