Comprehensive Study and Analysis of $(FA)_3Bi_2I_9$ based Perovskite Solar Cell

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***Abstract* – In this article, we have studied the device modeling and optimization of perovskite solar cell with Formamidinium Bismuth Iodide $(FA)_3Bi_2I_9$ as the absorber layer, PEDOT: PSS (poly (3,4 -ethylenedioxythiophene) polystyrene sulfonate) as the hole transport material and C_{60} (Fullerene) as the electron transport material. Rigorous theoretical investigation has been performed for the device parameter optimization especially the ETL, HTL and active layers. Different aspects of design strategies like temperature, carrier density, series and shunt resistance have been analyzed. The optimized device structure shows maximum ETA of 30.81% with the FF of 83.53% for (FA)3Bi2I9 based perovskite solar cell.**

Keywords – simulation, hole transport layer, electron transport layer, perovskite, solar cell.

I. INTRODUCTION

. In the recent year of development, perovskite based solar cell have shown significant and satisfactory results in efficiency increment, and this technology have also witnessed the ecofriendly lead (Pb) free perovskite with the Halide based perovskites. In the growth of different solar cell material for effective utilization of solar spectrum, there is transition from traditional silicon material to Perovskite material. In the research of perovskite material to build a solar cell model, we have developed double perovskite material i.e. Formamidinium Bismuth Iodide [$(FA)_3Bi_2I_9$], which shows promising jump in the ETA under ideal conditions. The research ground has been shifted from Germanium and Tin based perovskite to the Bismuth and Antimony based perovskite. The electron transport material (ETM) used in this model is Fullerenes (C60) and as Hole Transport Material (HTM) is PEDOT: PSS(Poly(3,4-ethylenedioxythiophene) polystyrene sulfonate). In this paper we have study about the temperature dependence on the performance of the solar cell and the influence of thickness of ETM, HTM and absorber layer. We have also studied the effect of linear thickness grading of the layers, especially the effect of grading the thickness of absorber layer.

II. MODEL STRUCTURE

The structure of the model provides an idea of different layer arrangements in order to investigate the optoelectronics properties and performance of cell module. As the sun strikes the surface of absorber layer, penetrating the ITO and hole transport layer, there is electron hole pair generation takes place in the absorber layer. Once the e-h hole pair created, HTL facilitates the hole mobility and ETL facilitates the mobility of electron before the recombination of the electron and hole to compute the device parameters.

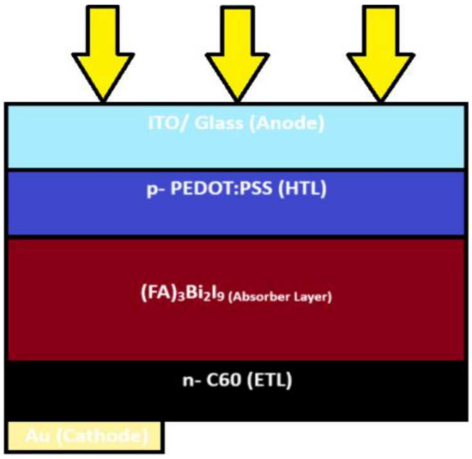

Fig. 1. Structure of the model

III. DESIGN STUDY

Device simulation helps us to understand the behavior and properties to realize the cell structure. This work has been carried out using SCAPS-1D software tool. This tool provides the idea of effectiveness of model in the ideal conditions and allows us to design solar cells, limited up to seven semiconducting layers. Parameters for the hole transport layer, electron transport layer and the ITO layer is as mentioned in the "TABLE I". The effective bandgap of the absorber layer was 1.9 E_g (eV).

TABLE I. SIMULATION PARAMETERS

Parameters	HTL	ETL	ITO
T_{nm}	25-100	25-100	100
E_g (eV)	1.800	2.400	3.600
χ(eV)	3.400	3.900	4.100
ε_r	4.00	4.00	10.00
μ_n ($cm^2V^{-1}s^{-1}$)	0.01	0.01	50
μ_h ($cm^2V^{-1}s^{-1}$)	0.01	0.01	75
N_c	5.00E+19	5.00E+19	2.00E+18
N_v	5.00E+19	5.00E+19	1.80E+18
N_a(cm^{-3})	5.00E+18	-	1.00E+18
N_d (cm^{-3})	-	5.00E+18	1.00+12

IV. Results And Discussions

A. Effect of Absorber Layer Thickness

The absorber layer thickness of perovskite was varied from 200 nm to 400 nm. On the basis of the trend, we studied with the help of simulation data we point out that, the fill factor (%) of the model increases from 81.50 % to 83.19% with the increase in thickness. The efficiency (%) of the model increases from 23.00 % to 30.13 % with increase in the thickness. The short circuit current (J_{sc}) density and open circuit voltages increases with thickness.

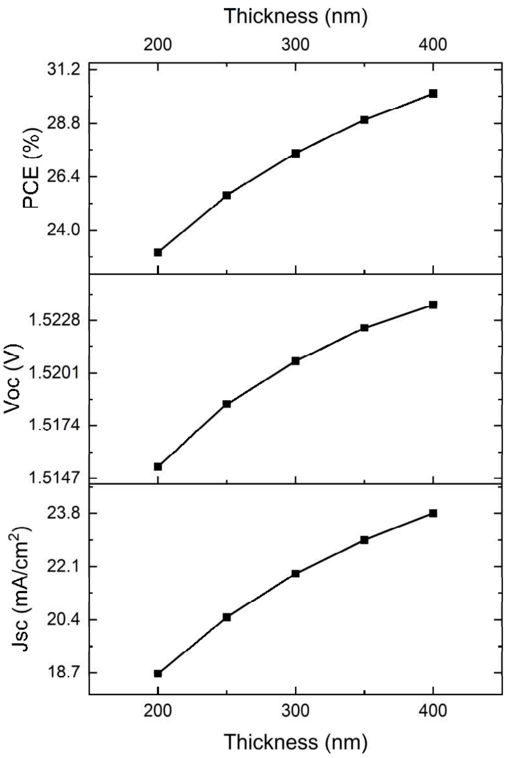

Fig. 2 Effect of absorber layer model performance

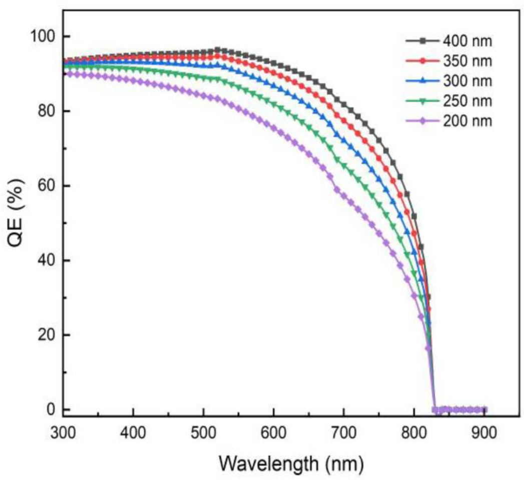

Fig. 3 Effect of absorber layer thickness on Quantum Efficiency of the model

B. Effect of Series Resistances on the Model

The impact of varying series resistances which ranges between, 0 Ω to 6 Ω was observed as shown in fig 4. The efficiency of the cell decreases with the increase in of the resistance, the open circuit voltage slightly increases with the decrease in resistance whereas the short circuit current shows the similar trends like efficiency with the increase in series resistance value. The study of series resistances variation on the performance of the model is given in Fig. 4.

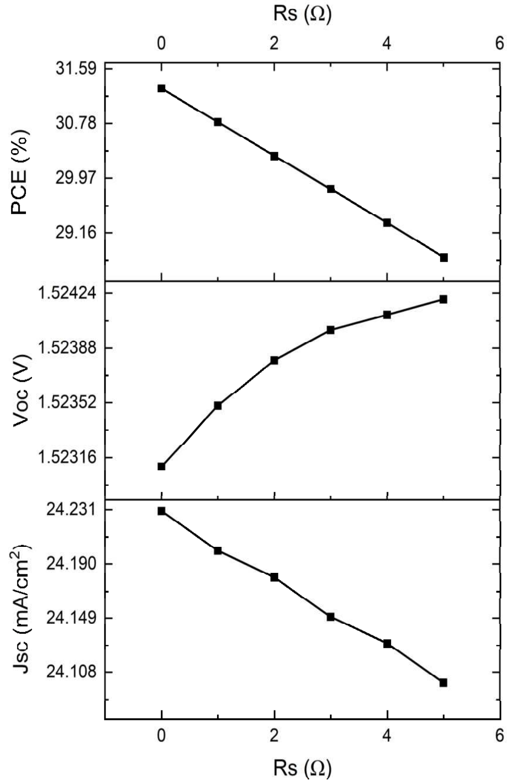

Fig. 4. Effect of series resistance on device performance

CONCLUSION

The present study deals with the design and analysis of perovskite solar cell using device simulation software. The optimal values of different performance factors have been analyzed for device module. To summarize, the optimal efficiency was found to be 30.8% with Fill Factor 83.53%. The results will provide guidelines for choosing suitable materials for highly efficient eco-friendly and flexible perovskite solar cell.

REFERENCES

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