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Optimization of Power Conversion Efficiency for Perovskite Solar Cell using GPVDM

Muhammad Aitezaz Hussain[1], Sobab Khan[2], Ahtasham Rahim[3], Azam Jan[4], Mudasar Rashid[5]
[1,2,3,5]Centre for Advanced Studies in Energy (CAS-E), University of Engineering and Technology Peshawar, Pakistan
[4]Department of Mechatronics Engineering, University of Engineering and Technology Peshawar, Pakistan
aitizazk36@gmail.com[1], mrsobabkhan@gmail.com[2], khanshami361@gmail.com[3], jannnazam@gmail.com[4], mudasar_uetian@yahoo.com[5]

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***Abstract*—** The perovskite solar cell has been analyzed by through mechanism and its equivalent circuit model. The software which is used in the simulation of an IV characteristic of Perovskite solar cell was developed by the GPVDM software .The increase in Power Conversion efficiency (PCE) has been shown through numerical modelling and is caused by when we increase the thickness of the absorbing or active layer. Hence efficient charge separation occurs. Apart from that effect of the electrical parameters such as series resistance Shunt resistance, band gap etc. on its I-V characteristics, Jsc and Voc is also simulated and its effect of efficiency has been noted.

***Keywords*—** Photovoltaics, Perovskite, Simulations, Solar cell Efficiency

I. Introduction

The free, sustainable and unlimited source of energy for the earth is sun from which we can get solar energy. Now a day's some latest technologies are been introduced to get energy from the sun. These new technologies already proved itself throughout the world and being using to extract energy from the sun instead of using energy from non-renewable and traditional resources. The comparison between the renewable resources other than hydro for 2015 is shown in Figure 1.

According to the different studies solar energy have enough potential to complete and fulfil the energy requirements and demands of the entire world if the technologies used to extract solar energy from sun is fully matured and will use these technologies throughout the world [1].the quantity of solar energy reaches to the earth per year is near about 4 million exa-joules, from which we can convert or extract nearly about 5×10^4 exa-joules [2]. Although we have so much huge potential of solar energy and also the technology to convert this solar energy is available but the contribution of solar energy in the overall energy is still very less [3].

Another reason of moving towards conventional resources from non-conventional resources is the environment because by using conventional resources the amount of carbon emission is very low which has very great impact on Environment, and social life of the people in the recent years [3]. For example if we consider the case of California the amount of carbon dioxide reduced is 696,545 metric tons due to the huge amount of installation of solar projects which are 113,534 small projects for houses [4]. So moving towards to the solar energy will significantly reduce the carbon contents in the environment and also give us the free and secure energy and provide the employment opportunities. It is also noted that by using the solar energy in transportation sector the dependency on the fossil fuel will reduced significantly.

The Main renewable energy resources from which we can get enough amount of heat and energy for the generation of power are solar, biomass and geothermal. Among these three resources the most available and abundant resource is the solar energy and the other two like geothermal is dependent on the location and available at some specific locations and the availability of biomass in the nature is not constant so the most important source is solar energy [5]. There are different factors like latitude and longitude of the area, season, climate change and the environment which are responsible for the availability of solar energy and also responsible for the amount of solar energy reaches from sun to the earth [6].

Generally solar energy can be divided into two categories (1) photovoltaic technology (2) solar thermal technology [7]. In the present days the use of semiconductor materials in the photovoltaic technology to convert sun light in the electricity is one of the best option [8]. There are different kinds of solar cells which are using but perovskite solar cell is one of the best options and has greatest efficiency among all other solar cells like thin film etc. The latest efficiency achieved by perovskite solar cell is up to 28 % [9].The factors which make perovskite solar cell more important are annihilation constant and the diffusion length which is more than 1 µm [10], also for the deposition of perovskite solar cell we use spin coating technologies. Presently the highest efficiency is achieved by the tandem perovskite solar cell. In this report we give all the information about electrical and optical properties of perovskite solar cell and discuss the methods and techniques to achieve the high efficiency by optimizing the thickness of active layer and other supporting layers with optoelectronic modelling.

Perovskite solar cells (PSCs) have speedily exceeded equally dye sensitized solar cells (DSSC) and quantum dot solar cells (QDSC) in enactment and efficiency, which take place them in the predicament in the photovoltaic research field [8] .Its efficiency in 2009 was 3.8% and now it has touched above 25% in 2019 [9]. So it is concluded that perovskite solar cells are the future of solar technology. In this report we identified that by increasing the thickness of active layer Jsc also increases, but fill factor FF and open circuit voltage Voc decreases with increase in thickness so we have to select an optimum thickness to achieve the highest efficiency of perovskite solar cell. In this report we also use the hybrid composition of organic and inorganic perovskite material of large band gap for achieving the high efficiency.

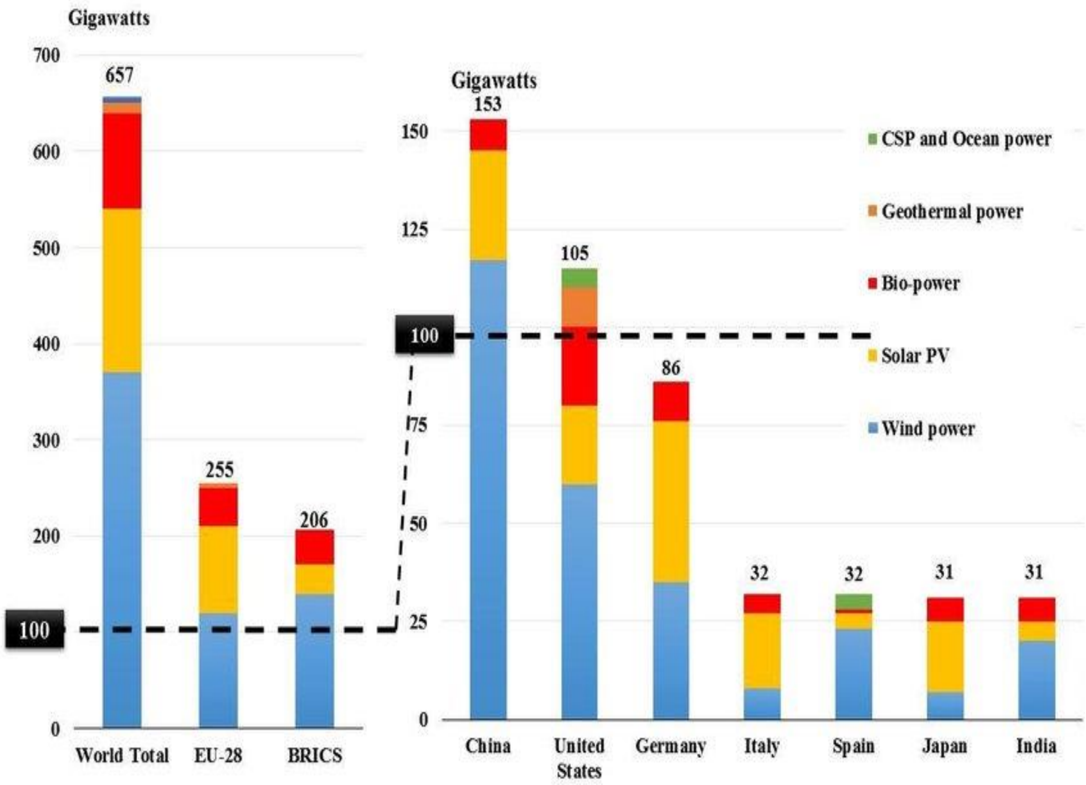

Figure 1: Comparison between renewable energy resources for year 2015

II. Methodology

1) To get full knowledge and better understanding that how the increased efficiency using multiple layers including contact condition layers along with the active layer. So we are going to use the GPVDM. It has the capability of both the optical and electrical properties simulations. GPVDM is solar cell simulation software which solves the following equations in 1D and in time domain [11].

$$\frac{d}{dx}.\varepsilon_0\varepsilon_r.\frac{d\phi}{dx} = q(n-p) \tag{1}$$

$$J_n = q\mu_c n\frac{\partial E_c}{\partial x} + qD_n\frac{\partial n}{\partial x} \tag{2}$$

$$J_p = q\mu_h p\frac{\partial E_v}{\partial x} - qD_p\frac{\partial p}{\partial x} \tag{3}$$

$$\frac{\partial J_n}{\partial x} = q\left(R_n - G + \frac{\partial n}{\partial t}\right) \tag{4}$$

III. Numerical Modelling

The layers or materials which are used in the designing and bandwidth values data of the layers are given in the table 1 below.

TABLE I. TABLE 1: MATERIALS AND THEIR CHARACTERISTIC ARE GIVEN IN TABLE

2) **Layer name**	3) **Optical material**	4) **Layer type**
5) Sio2	6) Oxides/ sio2	7) Other
8) FTO	9) Oxides/ fto	10) Contact
11) Perovskit e	12) Perovskite/std_pe rvoskite	13) Active layer
14) Spiro	15) Small molecules/ Spiro-OMETAD	16) Other

17) Ag	18) Metal/Ag	19) Contact

Figure 1 shows the overall structure of the solar cell material that would be investigated and simulated in GPVDM. We have used material of oxides called sio2 which is used as anti-reflecting coating layer used to help the absorbing the light. Below sio2 we have another conducting layer called FTO.

We can use ITO instead of FTO but here we used FTO due to few advantages over ITO like: FTO is more transparent having larger conductivity and suitable in heating so more stable. Also it is cheaper than ITO. Then we have our active layer which is the main absorbing layer and below this layer we have Spiro-OMETAD which is being used as hole transport layer HTL and hen we have back contact layer of silver in last. The initial Electrical parameters of simulations for the required structure are listed in the Figure 2. It consist of glass, window layer, absorbing layer and back surface field. Typically SiO_2 is used as a glass, oxide like FTO are used as window layer. Spiro-OMETAD has been the most efficient back surface field layer for Perovskite. At the end we have a some metal contact like; Ag which acts as a contact.

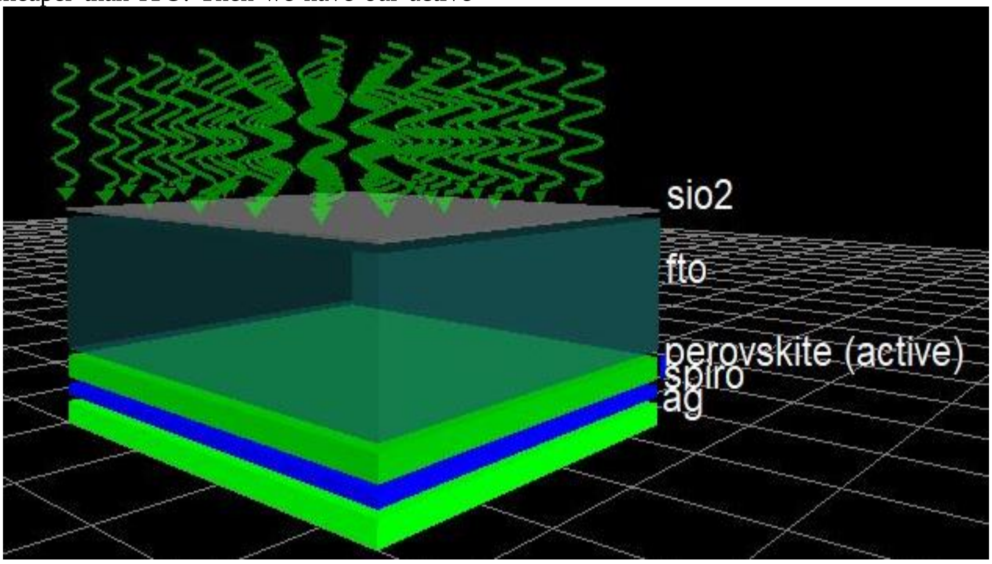

Figure 2: Initial Structure of planer heterojunction of the examined solar cell

IV. Results and Discussions

The main and important physical thing to be taken under consideration in photovoltaics while designing a cell are the charge carrier concentration that are electrons and holes that totally depend on the absorption of light. So we have tried different optimum thickness of our active layer and other electrons transport layer and as well as hole transport layers with different band gap of perovskite has been simulated to get optimum efficiency. Fig 3 shows initial thickness of all layers in meters.

Layer name	Thicknes	Optical material	Layer type
sio2	2.5e-08	oxides/sio2	other
fto	1.2e-06	oxides/fto	contact
perovskite	2e-07	perovskites/std_preovskite	active layer
spiro	1e-07	small_molecules/spiromeotad	other
ag	2e-07	metal/ag	contact

Figure 3: Initial optical parameters with thickness.

Now Before optimization the simulation results are given below in Figure 5 and Figure 6.

V. Optimization of Results

A. Thickness of Abosrbing Layer VS. Efficiency

The method of optimization in our research is that we will fix all electrical and optical parameters and then we will try to change to modify one by one to see which one bring the efficient change that give is maximum power conversion efficiency.

```
Voc= 0.453533 (V)
Jsc= -267.464567 (A/m^2)
Pmax= 90.171487 (W/m^2)
Pmax Voltage= 0.377125 (V)
FF= 74.335104
Efficiency= 9.017149 percent
```

Figure 4: simulations for Initial output parameters

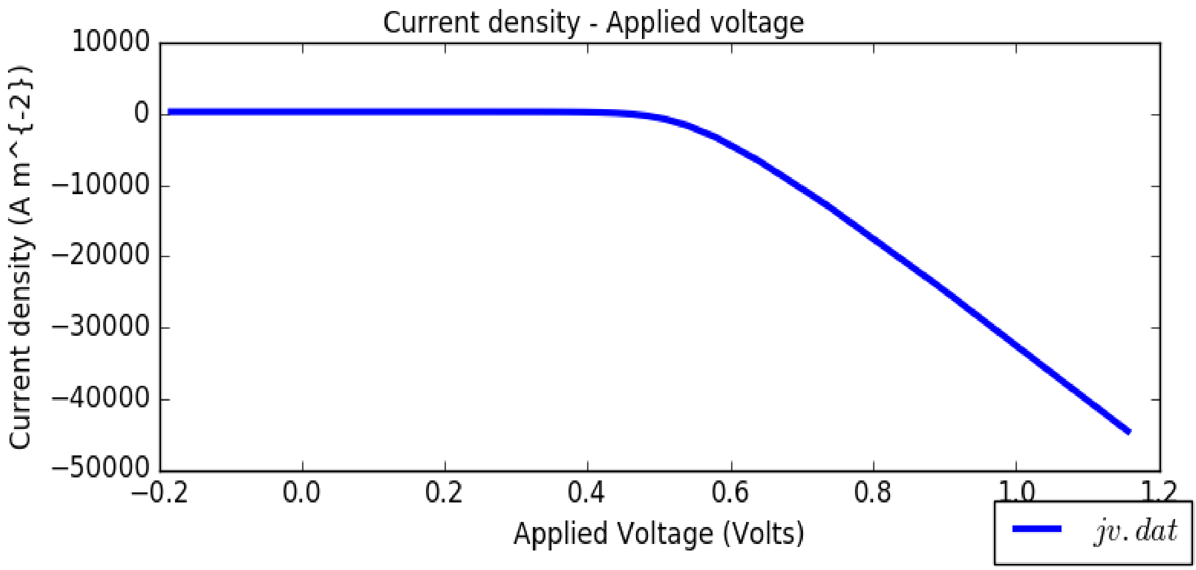

Figure 5: J-V Characteristics curve for initial simulations

Fig 6 and Fig 7 shows by fixing all other parameters fix, we have noted that the maximum PCE and FF is only on the thickness 2×10-7m and above this thickness it results in recombination of charge carriers thus effecting overall performance of the cell .

B. *Thickness of Window layer VS. Efficiency*

In 2nd step of optimization we changed the FTO layer thickness and observed the output results. The Figure 8 shows the other output details. It is we get Maximum PCE 12.21 % at thickness of 2.3×10-14 m. The JV curve has been shown in the Figure 9.

```
Max possible Jsc = -320.613645
Voc= 0.447214 (V)
Jsc= -319.916030 (A/m^2)
Pmax= 105.406904 (W/m^2)
Pmax Voltage= 0.356445 (V)
FF= 73.674576
Efficiency= 10.540690 percent
```

Figure 6: output parameters after for thickness of 2×10-7m

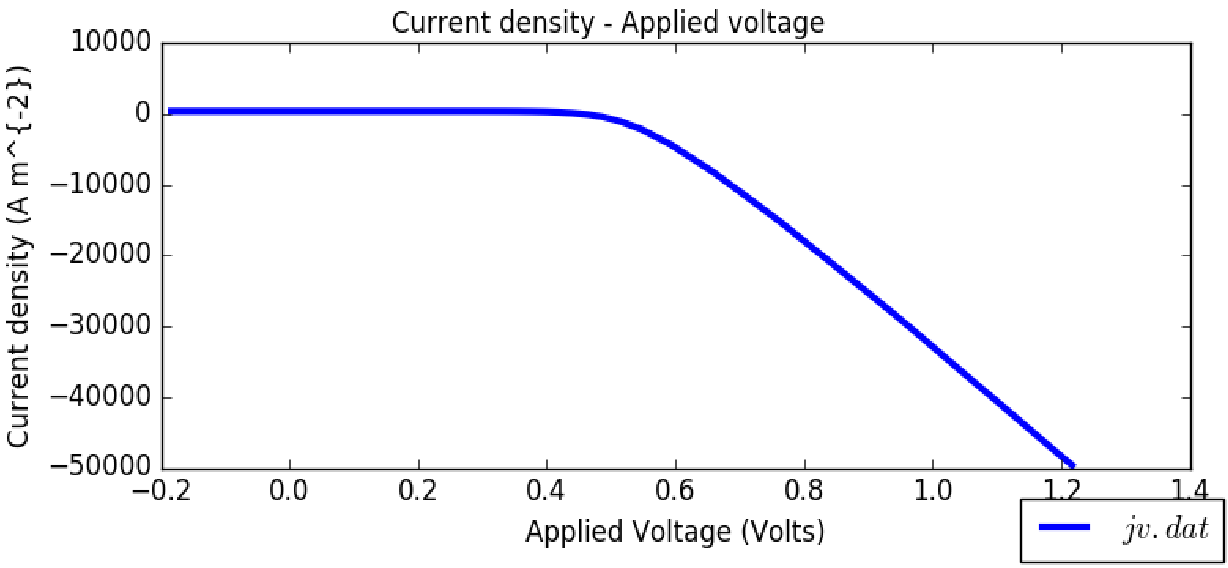

Figure 7: J-V characteristic curve for thickness of 2×10-7m

C. Thickness of Buffer Layer VS. Efficiency

In step 3rd now FTO layer thickness has been fixed to 2.3×1014m and Sio2 thickness has changed. The optimized obtained results are listed in the below figures. Figure 10 shows that at thickness 1.0×10-7 m the simulations gives highest PCE 13.02 %. The J-V curve of the simulation is given Figure 11.

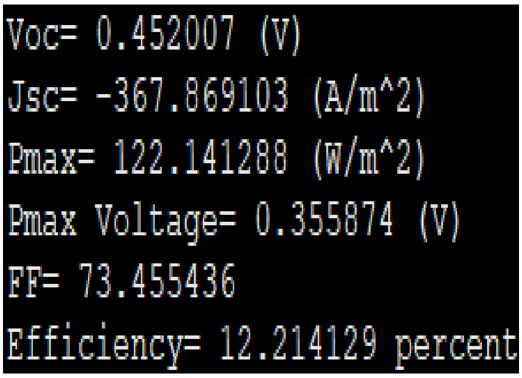

Figure 8: Output parameters for thickness of 2.3×10-14 m

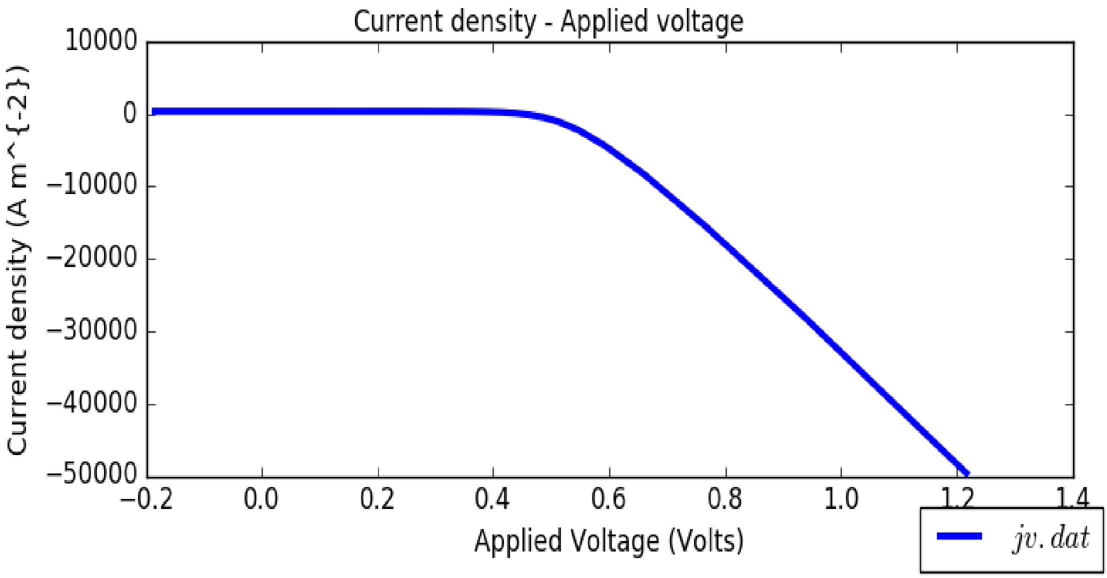

Figure 9: J-V characteristic curve for thickness of 2.3×10^{-14} m

D. Thickness of Back Surface Field VS. Efficiency

Fixing the Sio2 and changing the Spiro-OMETAD layer to thickness from the initial value i.e. 1.0×10-7 m the PCE decreases instead of improving. Now by changing the thickness of the Silver Ag we will investigate the output curve and same case has been observed in PCE %.

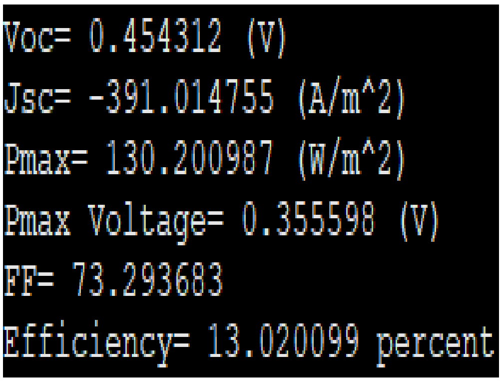

Figure 10: Power conversion efficiency at 1.0×10-7 m

A. Bandgap VS. Efficiency

Final and optimized structure of the examined solar cell is given in Fig 12. Last modification has done through optimum band gap for perovskite. Bandgap of 1.55 eV has been used to observe further increases in efficiency which has been increased from 1.50. And this bandgap has been proved to be most ideal from literature. Fig 13 shows the maximum possible efficiency of 25.59 % with 83.58 % FF, Jsc -391.53 A/m2, Voc = 0.90 v and maximum power of 295.95 W/m2 is achieved. The results obtained in our simulations are comparable with the latest work done in reference [12] on perovskite.

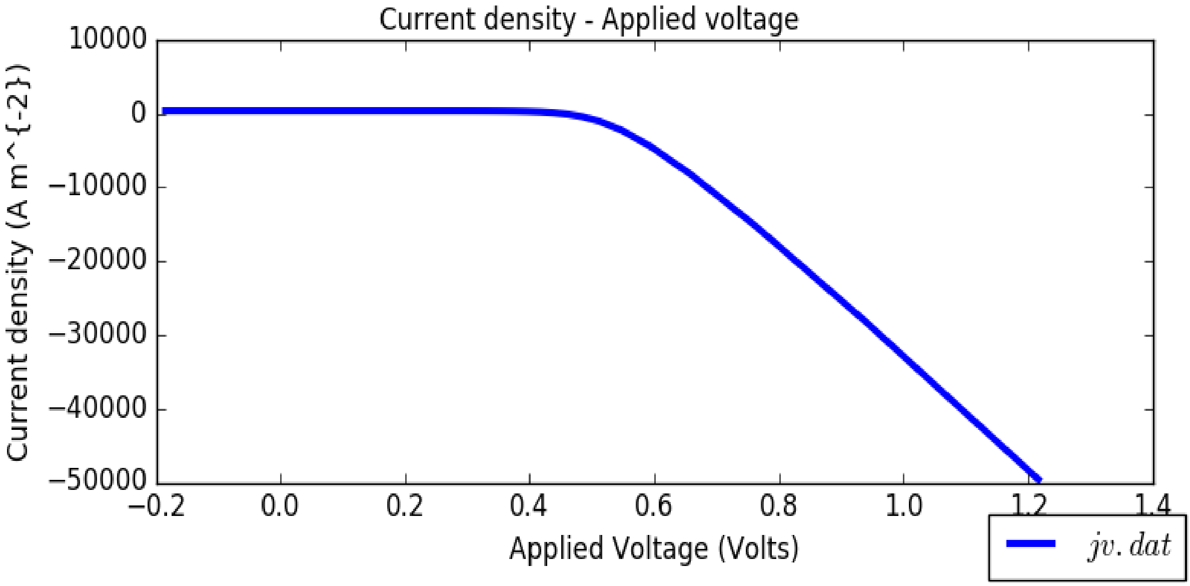

Figure 11: J-V characteristic curve for thickness of 1.0×107m

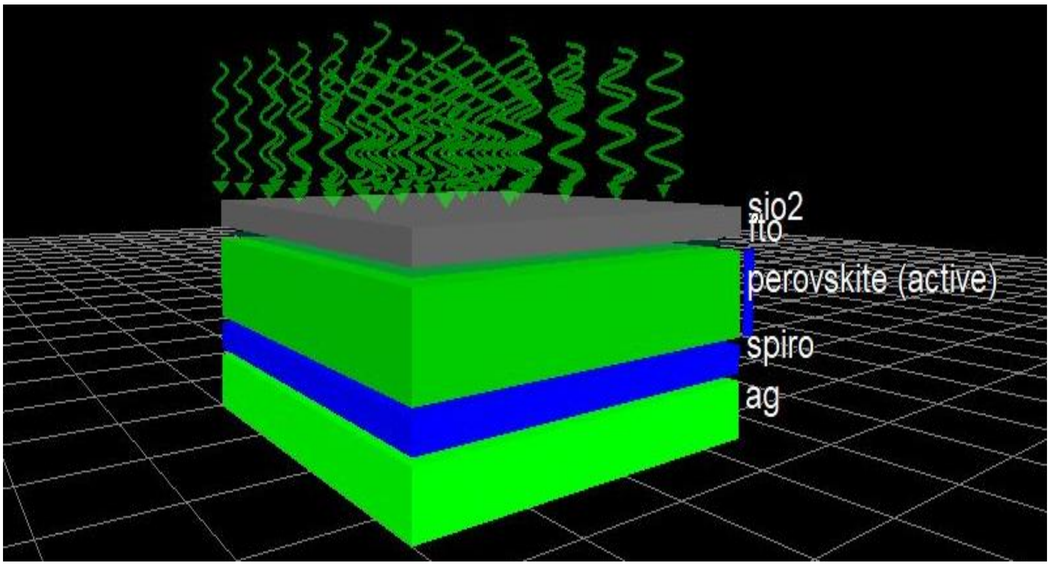

Figure 12: Final modified Structure of cell

Further change in bandgap decrease the efficiency. Because increasing bandgap further will give raise to wastage of photons thus decreasing Voc. Moreover we need to keep the series resistance as much as low while the shunt resistance as much as high. We have simulated the structure while increasing the shunt resistance which didn't show any effective change in PC.

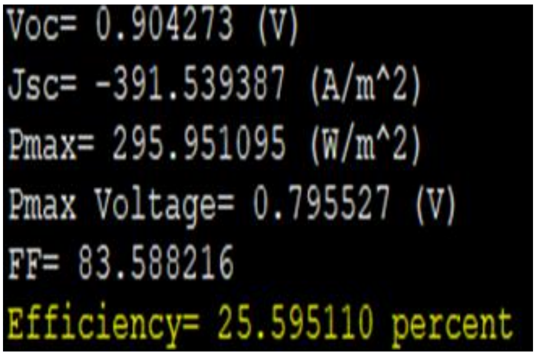

Figure 13: the maximum possible efficiency of Perovskite solar cell under the bandgap of 1.55 eV

VI. CONCLUSIONS

The Power conversion efficiency was monitored using GPVDM software. We have found out that the optimum thickness of the layers will result in increase in output power conversion efficiency. In our simulations it has been observed that PCE is increased from 9 % to 13 % by selecting the best thickness of the layers. It is due the fact increasing thickness of a material will give room for a device to absorb more light. This will result in generation of higher number of electro-hole pairs thus it enhances Isc. and from the efficiency definition increase in Isc improves the overall efficiency Moreover the optimum band gap plays essential role in the Power conversion efficiency as the efficiency is abruptly change and improved from 13.2 % to 25.59 %. The bandgap has a direct effect on Voc .This increasing bandgap to optimum value increases Voc and thus working of cell improved. By changing Shunt and series resistances we didn't notice any effective change in performance. Further study in changing structure optimally and temperature control parameter can enhance the PCE efficiently.

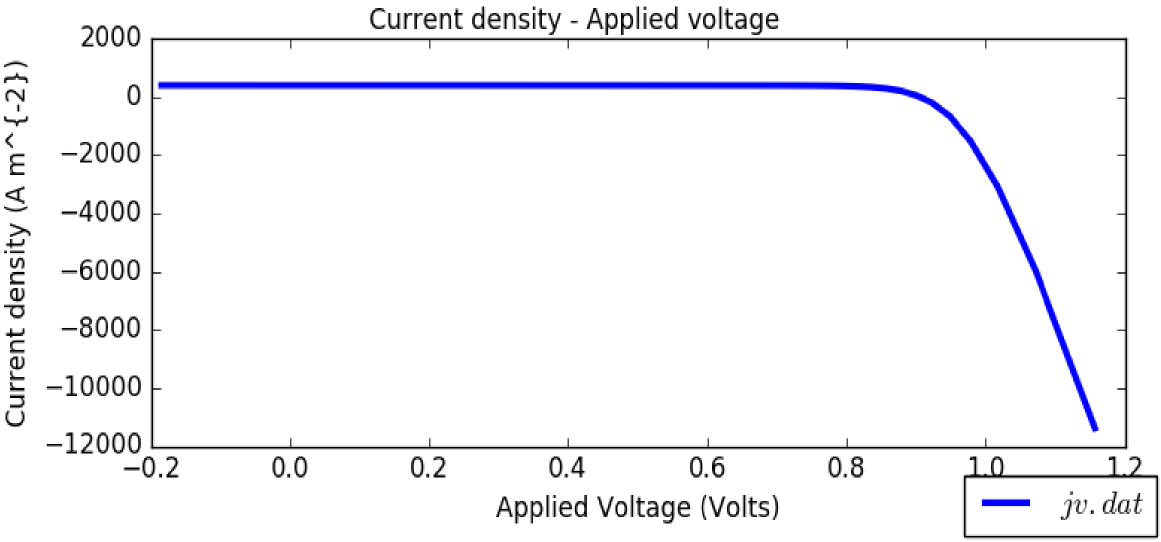

Figure 14: Final optimum J-V characteristic curve.

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