Investigation of Organic Solar Cell at different Active Layer Thickness and Suns using GPVDM

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Abstract - *The organic photovoltaic device has been electrically simulated by GPVDM software model at different active layer width with different value of suns (intensity of light). Organic bulk heterojunction solar cell consists of the mixture of electron donor (P3HT) and electron acceptor (PCBM) materials as active layer, ITO (indium tin oxide) is a transparent electrode, PEDOT: PSS is electron blocking layer and Al is a back electrode. Electrical simulation has been done at different active layer thickness 100,150,200,250 & 300 nm.The simulation for each of the above thickness was repeated for 1suns, 10suns, 20suns, 30suns and 40suns. In this study it has been observed that J-V characteristics are affected by active layer thickness and light intensity (suns). The power conversion efficiency is maximum at active layer thickness of 200nm for the light intensity of 1suns, 10suns, 30suns and a thickness of 100nm for light intensity of 20suns and 40suns. The maximum short circuit current density observed at 200nm active layer thickness for light intensity of 20suns, 30suns and 40suns.*

Key Words: **solar cell, active layer, simulation, suns, power conversion**

1. INTRODUCTION

In the recent year, the consumption of fossil fuel has been increased due to industrialization, population, and economic development. The over utilization of fossil fuel is lead to the environmental pollution, global warming, resource depletion and energy shortage in the next generation. The world is switch over to utilize the renewable natural resource to produce the power. Renewable energy resources are generating energy from the natural resources such as sunlight, wind hydro, tide, geothermal and biomass. These natural resources are replenished naturally. There are many technologies used to extract the power from these natural resources. Also, many factors are influencing to produce the power from these natural resources such as atmospheric temperature, pressure, wind speed and climatic condition [1].

Among renewable energy resources, solar energy is the fastest growth in the world in many developed and the developing countries in the last 20 years. There are two types of technology used to convert the solar energy such as solar thermal and solar cell. Solar energy provides the opportunity to generate power without emitting any greenhouse gas. The photovoltaic system technologies have increasing roles in electric power technologies, providing more secure power sources and pollution-free electric supplies. Photovoltaic power generation system can directly convert solar energy into electrical energy [2]. The research activity and development in photovoltaic field has usually been focused on solar radiation analysis, efficient operating strategies, design and sizing of these systems. Cell efficiency can even become a criterion of principal system feasibility. As a basic parameter, cell efficiency serves as an input in calculating the optimal system configuration, e.g., as a cost related trade-off between the storage unit and its lifetime, photovoltaic size and its efficiency, and finally the demand side [3].

Among the different type of solar cells, organic solar cells based on a bulk heterojunction (BHJ) composites of conjugate polymers P3HT (poly 3-hexylthiophene) and PCBM (phynyl-C70 butyric acid methylester) that allow the maximum absorption of light and have been reported among the highest performing material for researchers investigation and studies [4-9] for improving their power conversion efficiencies. In organic solar cell, bulk heterojunction (BHJ) formed by an interpenetrating of a conjugate polymer and electron accepting molecules constitute a very promising route towards cheap and flexible solar cells [10-11] as recently exhibited in progress of automated roll-to-roll processing and solar cell stability [12-13].

Therefore, inconsideration the organic solar cell stated and factors affect solar cell efficiency. This paper examines factors that affecting power conversion efficiency of organic solar cells according to scientific literature. These factors are thickness of active layer and light intensity (suns). The investigation was carried on by using GPVDM solar cell simulator.

A. Electrical Simulation

The electrical simulation has four different layers including the active layer. The layers from top to bottom are ITO/PEDOT:PSS/P3HT:PCBM/Al.This bulk heterojunction solar cell has been done at different active layer thickness for different value of light intensity (suns) by using GPVDM Software. The layers are shown clearly in the figure below.

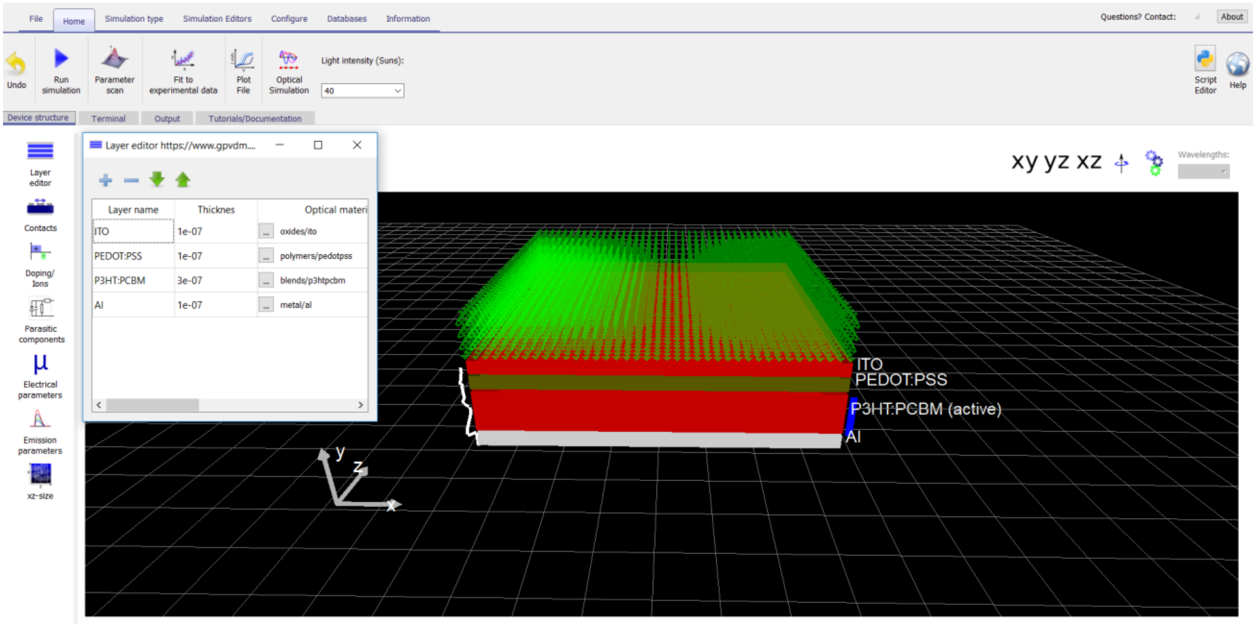

Figure 1: Electrical simulation window in GPVDM

The software was run for the following layer thickness and light intensity (suns) to record the values of power conversion efficiency, fill factor, maximum power, open circuit voltage and short circuit current density.

Table 1: Thickness and number of suns of the four layers

No.	Layer	Layer Thickness (nm)	Number of suns
1	ITO	100	100,150,200,250,300
2	PEDOT:PSS	100	
3	P3HT:PCBM (Active layer)	100	
		150	
		200	
		250	
		300	
4	Al	100	

Table 2: Parameters set for GPVDM simulation

The simulation for different layer thickness and number of suns carried on by setting the following parameters for electrical simulation

No	Parameters	value	Units
1	Electron trap density	3.8×10^{26}	$m^{-3}eV^{-1}$
2	Hole trap density	1.45×10^{25}	$m^{-3}eV^{-1}$
3	Electron mobility	2.48×10^{-7}	$m^{2}V^{-1}s^{-1}$
4	Hole mobility	2.48×10^{-7}	$m^{2}V^{-1}s^{-1}$
5	Trapped electron to free hole	1.32×10^{-22}	m^{-2}
6	Trapped hole to free electron	4.67×10^{-26}	m^{-2}
7	Free electron to trapped electron	2.5×10^{-20}	m^{-2}
8	Free hole to trapped hole	4.86×10^{-22}	m^{-2}
9	Temperature	300	K

10	Shunt Resistance	$1.9x10^5$	ohms
11	Series Resistance	19.5	ohms

Result and Discussion

I. J-V Characteristics at Different light intensity (suns)

A. J-V Characteristics curve when the active layer thickness is 100nm

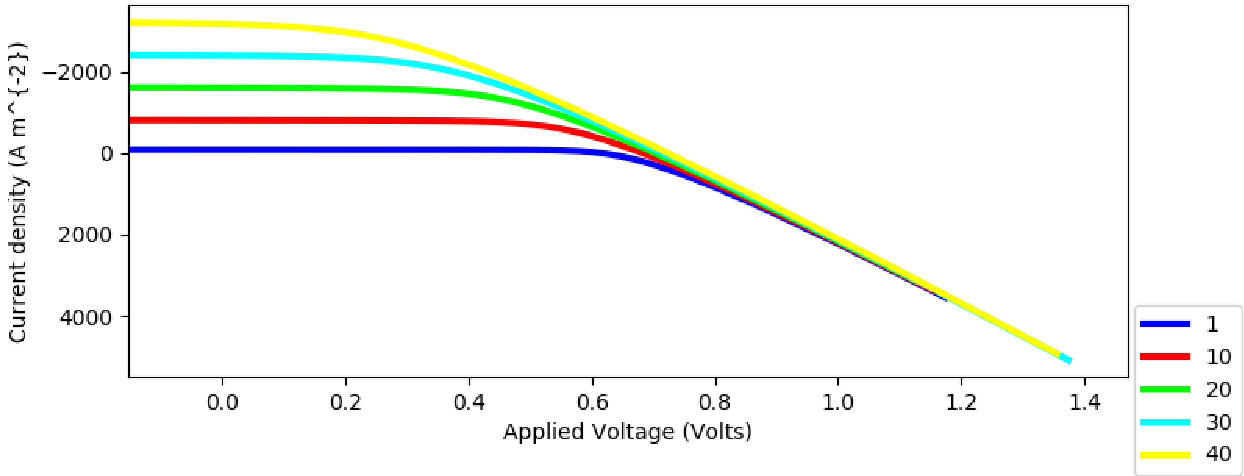

Chart- 1: JV curve of organic solar cell for active layer thickness is 100nm

The above JV curve was drawn only for 1sun.The different color shows the different value of suns. The light intensity (suns) are 1suns, 10suns, 20suns, 30suns and 40suns.The better performance was observed at 40suns which indicated by a yellow color.

B. J-V Characteristics curve when the active layer thickness is 150nm

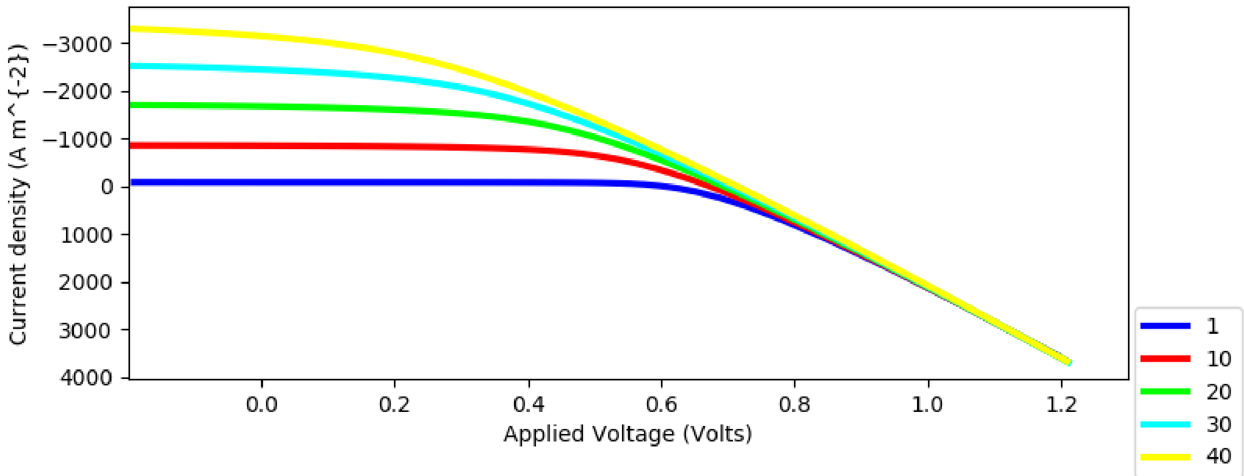

Chart- 2: JV curve of organic solar cell for active layer thickness is 150nm

C. J-V Characteristics curve when the active layer thickness is 200nm

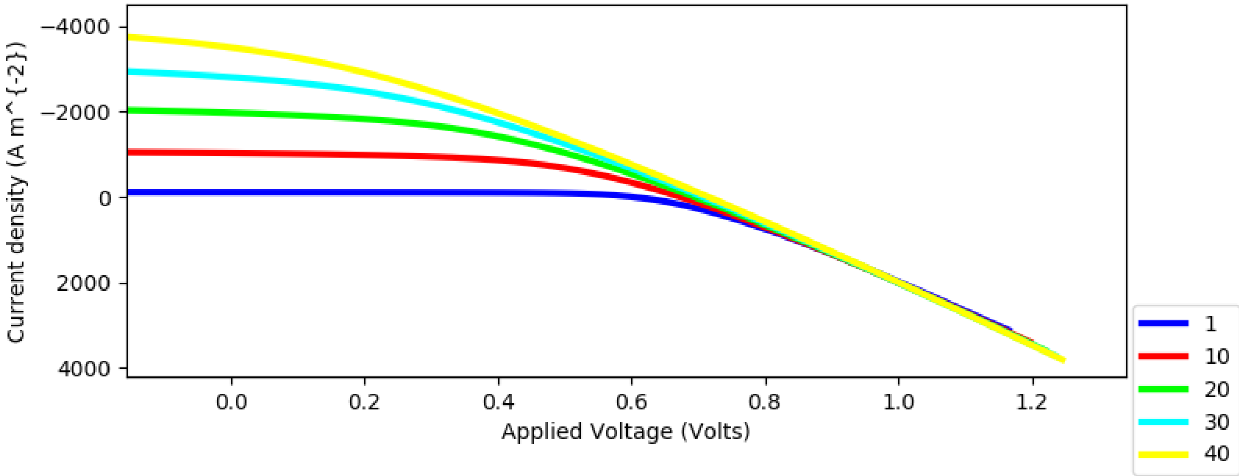

Chart- 3: JV curve of organic solar cell for active layer thickness is 200nm

The above graph shows JV curve for the variation of light intensity from 1suns to 40 suns. The good performance was observed at 40 suns.

D. J-V Characteristics curve when the active layer thickness is 250nm

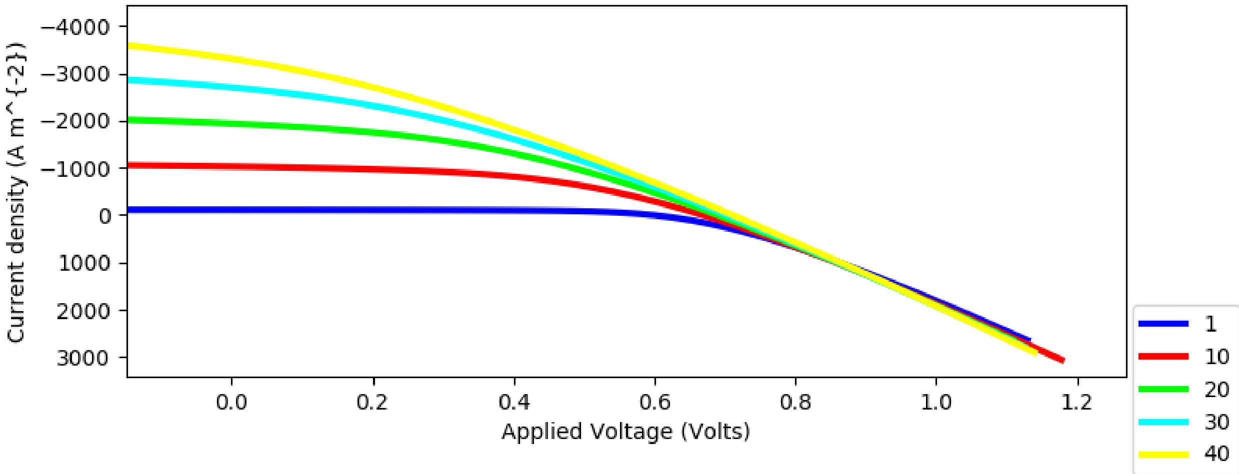

Chart- 4: JV curve of organic solar cell for active layer thickness is 250nm

E. J-V Characteristics curve when the active layer thickness is 300nm

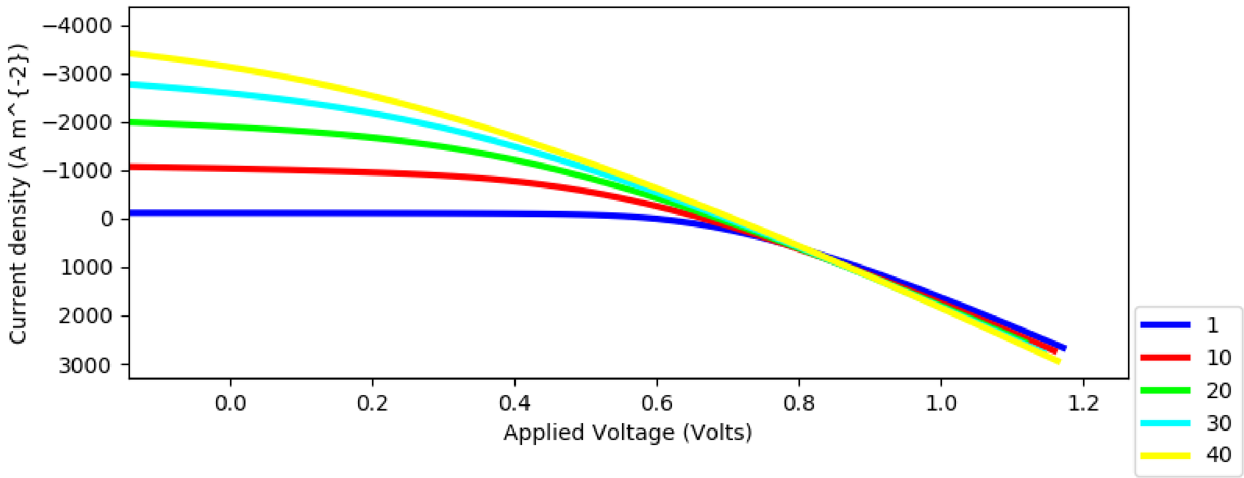

Chart- 5: JV curve of organic solar cell for active layer thickness is 300nm

II. Power conversion efficiency at different active layer thickness

The following table shows the result of fill factor, power conversion efficiency, maximum power, open circuit voltage and short circuit current density at different light intensity (suns) with the variation of active layer thickness.

Table 3: Efficiency affecting factors with different suns

Suns	Active layer thickness (nm)	Fill Factor (au)	PCE (%)	Max Power (Watt)	V_{oc} (V)	J_{sc} (A/m^2)
1	100	0.765	3.765	37.646	0.612	80.44
	150	0.728	3.769	37.698	0.603	85.86
	200	0.681	4.346	43.455	0.602	105.9
	250	0.647	4.202	42.026	0.598	108.7
	300	0.613	4.101	41.018	0.594	112.6
10	100	0.642	3.517	351.679	0.682	803.8
	150	0.573	3.289	328.942	0.673	853.1
	200	0.513	3.544	354.393	0.673	1026
	250	0.479	3.291	329.104	0.668	1027
	300	0.450	3.085	308.511	0.666	1029
20	100	0.532	3.001	600.184	0.703	1605
	150	0.472	2.751	550.103	0.693	1681
	200	0.414	2.838	567.699	0.695	1974
	250	0.389	2.605	521.083	0.689	1938
	300	0.373	2.421	484.209	0.687	1892
30	100	0.444	2.535	760.594	0.715	2397
	150	0.401	2.313	693.883	0.706	2455
	200	0.352	3.337	700.974	0.707	2814
	250	0.336	2.143	642.762	0.702	2720
	300	0.329	1.987	596.138	0.699	2589

40	100	0.377	2.161	864.311	0.723	3172
	150	0.349	1.972	788.673	0.714	3159
	200	0.312	1.969	787.542	0.716	3523
	250	0.307	1.813	725.154	0.711	3322
	300	0.303	1.686	674.402	0.708	3141

A. Power conversion efficiency for light intensity of 1suns

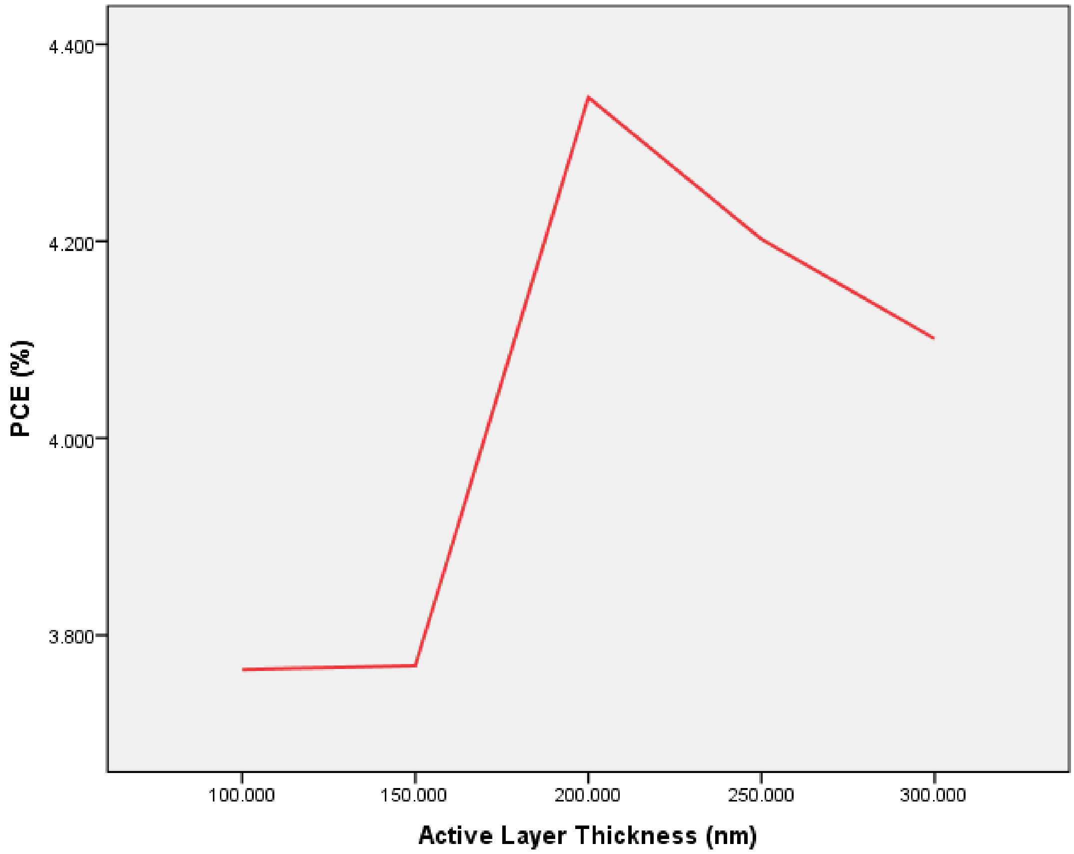

Chart- 6: PCE versus active layer thickness for 1suns

The power conversion efficiency as can be seen from the graph increases from 100nm to 200nm and decreases when we go from 200nm to 300nm.This means that the maximum power conversion efficiency observed when the active layer thickness is 200nm.

B. Power conversion efficiency for light intensity of 10suns

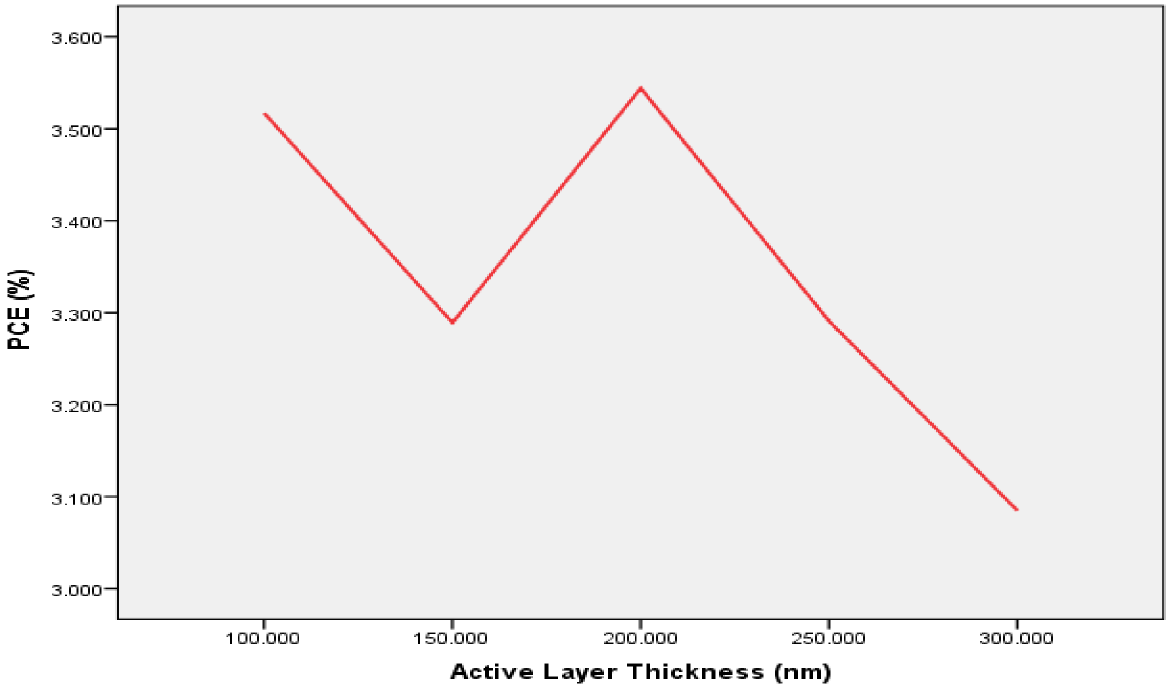

Chart- 7: PCE versus active layer thickness for 10suns

Again the maximum power conversion efficiency observed at 200nm of active layer thickness. A fluctuation of PCE observed between 100nm to 200nm but above 200nm the value of PCE shows a sharp decrease.

C. Power conversion efficiency for light intensity 20suns

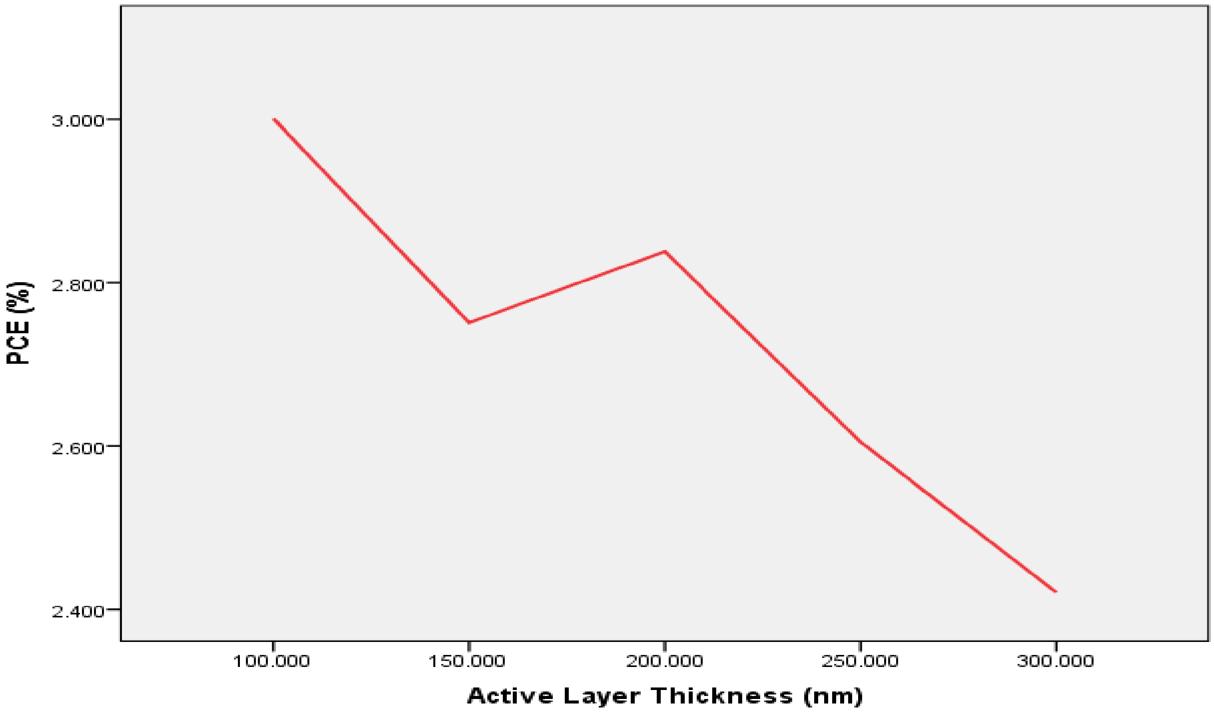

Chart- 8: PCE versus active layer thickness for 20suns

The graph generally shows a decrease in the value of PCE for an increase in the active layer thickness, except the variation observed between 150nm and 200nm.

D. Power conversion efficiency for light intensity of 30suns

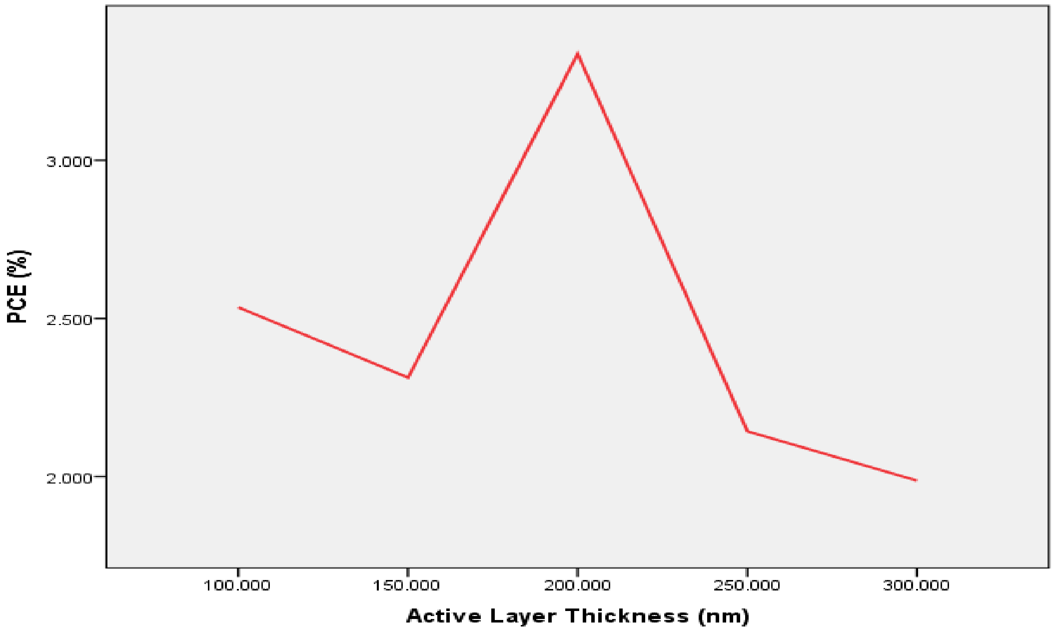

Chart- 9: PCE versus active layer thickness for 30suns

According to the above graph the maximum power conversion efficiency observed when the active layer thickness is 200nm.Below and above the thickness of 200nm the value of PCE decreases.

E. Power conversion efficiency of light intensity 40suns

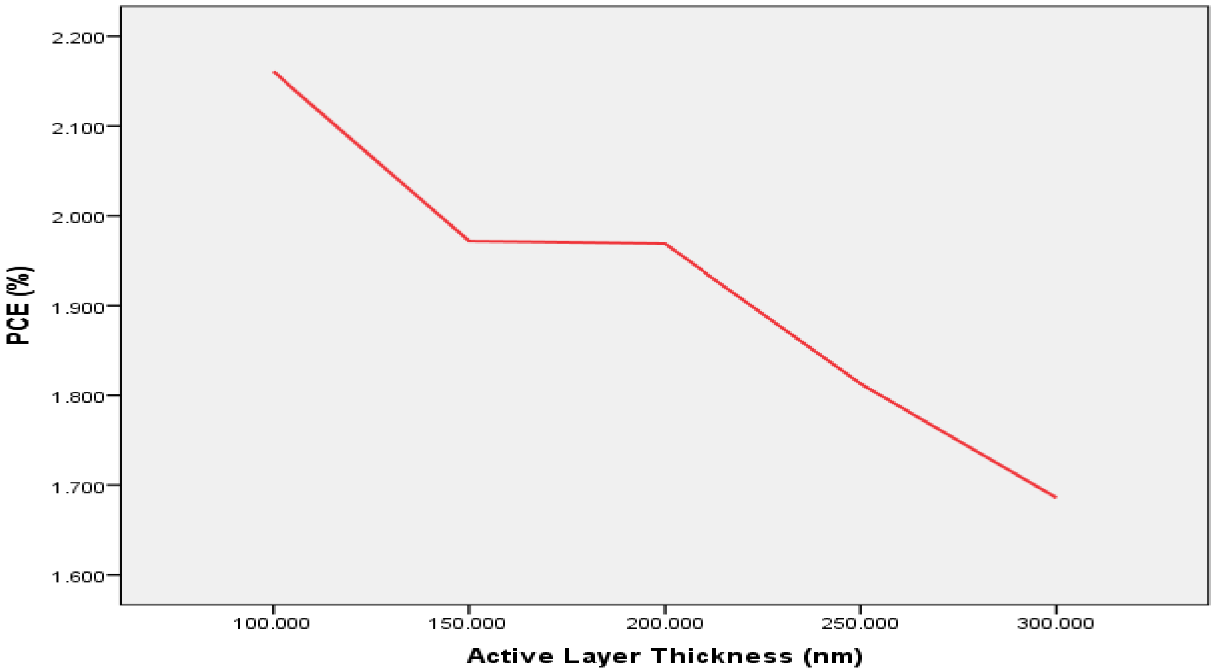

Chart- 10: PCE versus active layer thickness for 40suns

The above graph which is drawn for 40suns indicates that increase of active layer thickness for the light intensity of 40suns brings a decrease in power conversion efficiency.

III. Short circuit current density at different active layer thickness

A. Short circuit current density for light intensity of 1suns

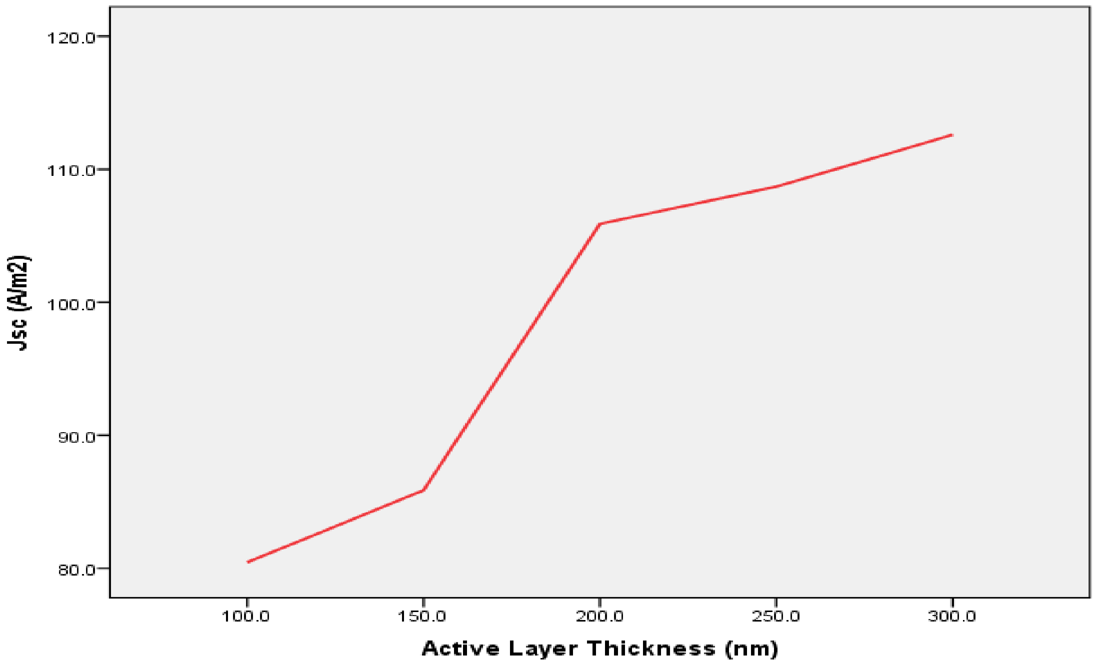

Chart- 11: Current density at different active layer thickness for 1suns

The above graph indicates that there is a direct relationship between the active layer thickness and short circuit current density.

B. Short circuit current density for light intensity of 10suns

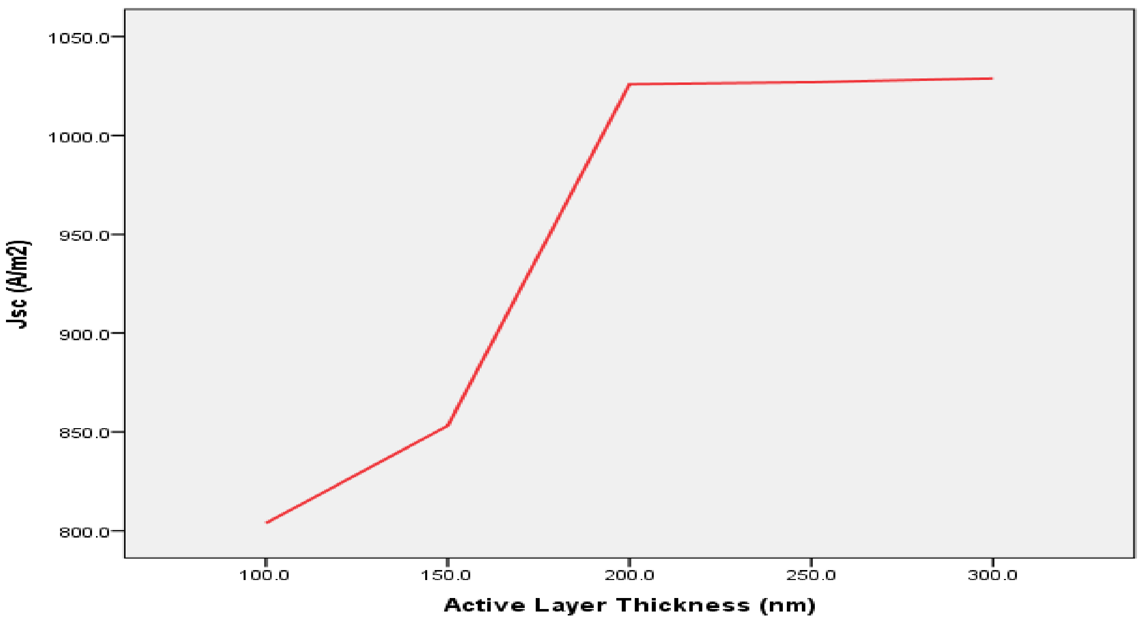

Chart- 12: Current density at different active layer thickness for 10suns

The is an increase in the value of short circuit current density from 100nm to 150nm of active layer thickness. This increase is very large from 150nm to 200nm of active layer thickness. Above 200nm there is a very small increase in the value of short circuit current density for a change of layer thickness from 200nm to 300nm.

C. Short circuit current density for light intensity of 20suns

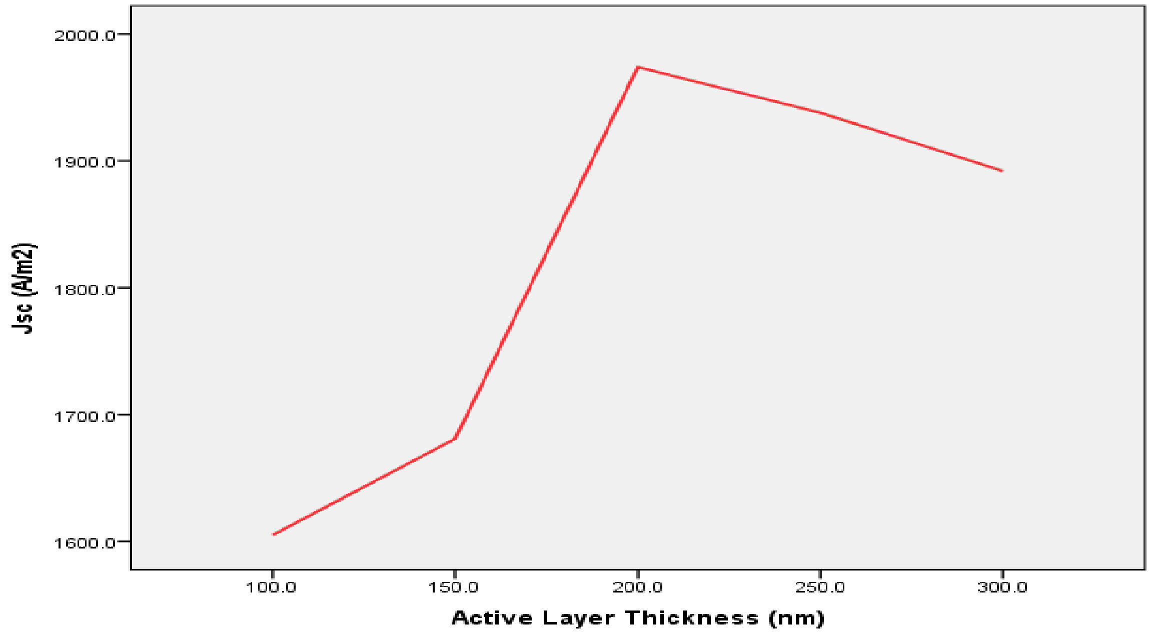

Chart- 13: Current density at different active layer thickness for 20suns

According to the above graph the value of short circuit current increases for an increase of active layer thickness but this value that is current density decreases from 200nm to 300nm of active layer thickness.

D. Short circuit current density for light intensity of 30suns

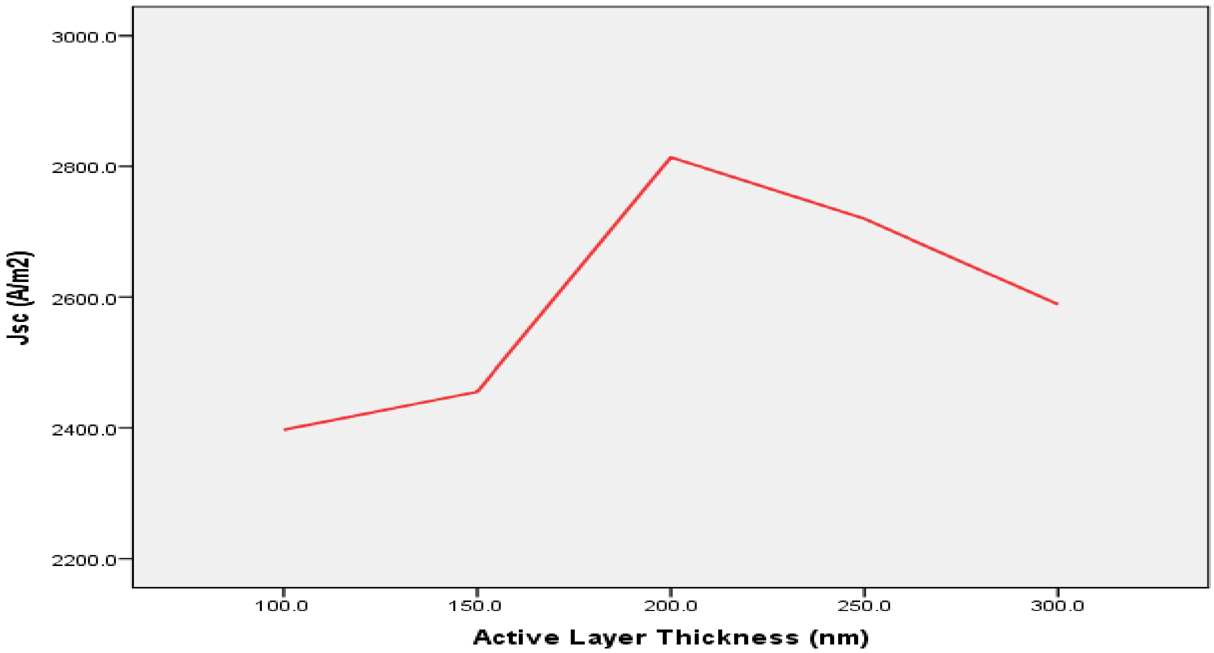

Chart- 14: Current density at different active layer thickness for 30suns

Below and above 200nm the value of short circuit current density decreases. This means that the maximum value of curret density observed at 200nm of active layer thickness.

E. Short circuit current density for light intensity of 40suns

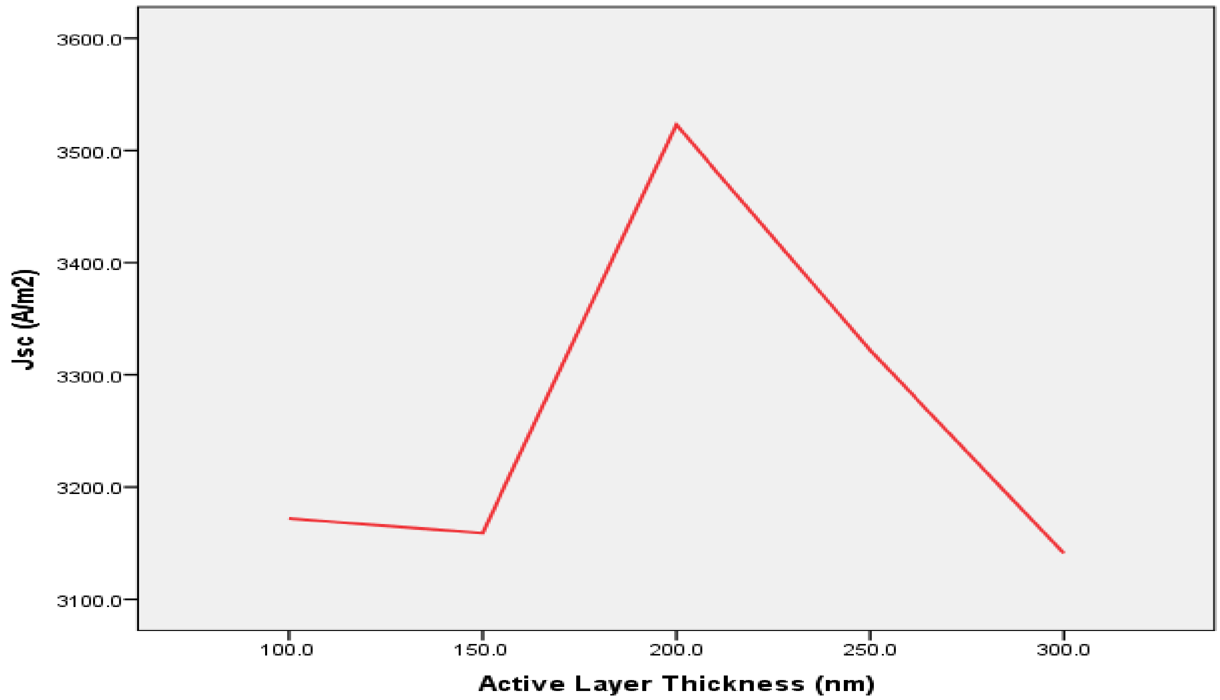

Chart- 15: Current density at different active layer thickness for 40suns

The maximum value of short circuit current observed at 200nm for the light intensity of 40suns.

Conclusion

A change was observed in current density versus voltage graph for the variation of the change in thickness of active layer and light intensity (suns). The maximum result was observed at 40suns for the active layer thickness of 100nm,150nm,200nm,250nm and 300nm.The power conversion efficiency is maximum at active layer thickness of 200nm for the light intensity of 1suns, 10suns,30suns and a thickness of 100nm for light intensity of 20suns and 40suns.The maximum short circuit current density observed at 200nm active layer thickness for light intensity of 20suns,30suns and 40suns.For 1suns and 10suns of light intensity the maximum short current density observed at the maximum of active layer thickness that is 300nm.

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