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Light absorption of a polymer based single/multi junction solar cell model

***Abstract**. In this paper, a detailed study and simulation modelling on light absorption using PDMS material in a single/multi-junction solar cells is carried out. Since PDMS material is a good absorber of light, it is used as an active layer of a solar cell. We choose PDMS because its properties, mainly exceptional intrinsic stability against thermal and ultraviolet light, induced good mechanical properties and stress over a wide range of temperatures. Good transmittance due to the absence of UV absorbers is one of its best characteristics. With the help of the transfer matrix method, which is used for optical modeling of an organic solar cell, inspired by the McGehee Group in Stanford University. The result and simulation is done using MATLAB and in the end we are going to draw a conclusion about the ideal materials that a good solar cell has to have good absorption.*

Streszczenie.** W niniejszym artykule przeprowadzono szczegółowe badania i modelowanie symulacyjne absorpcji światła przy użyciu materiału PDMS w jedno-/wielozłączowych ogniwach słonecznych. Ponieważ materiał PDMS jest dobrym pochłaniaczem światła, jest używany jako aktywna warstwa ogniwa słonecznego. Wybieramy PDMS, ponieważ jego właściwości, głównie wyjątkowa stabilność wewnętrzna w stosunku do światła termicznego i ultrafioletowego, indukowały dobre właściwości mechaniczne i naprężenia w szerokim zakresie temperatur. Dobra przepuszczalność ze względu na brak absorberów UV jest jedną z jego najlepszych cech. Za pomocą metody przeniesienia macierzy, która służy do optycznego modelowania organicznego ogniwa słonecznego, inspirowanej przez Grupę McGehee na Uniwersytecie Stanforda. Wynik i symulację wykonano przy użyciu MATLAB, a na koniec wyciągniemy wniosek na temat idealnych materiałów, które dobre ogniwo słoneczne musi mieć dobrą absorpcję.* ***(Absorpcja światła polimerowego jedno-/wielozłączowego ogniwa słonecznego)

Keywords: Transfer Matrix, Organic Solar Cell (OSC), Absorption.
Słowa kluczowe: organiczne ognowo fotowoltaiczne, absorpcja światła

Introduction

A Photovoltaic cell is one of the methods used to convert solar energy into usable electrical energy [24]. The method used to convert this solar radiation into direct current is known as photovoltaic effect. The amount of energy or power generated by the solar cell depends on the active area of the cell exposed to solar radiation. The output energy is obtained by multiplying the voltage (V) with the solar cell current (I). As we know, solar cells will play an important role in future technology that will consume charge from the sun and convert it into electrical power to charge our technologies. Here we are going to use PDMS, which is also known as a polydimethylsiloxane material.

Due to the many users because of its properties especially its versatility silicon based organic polymer PDMS is used. Some of its most significant qualities are its uncommon natural flow properties and the fact that it is nonflammable, optically clear, non-toxic and inert. The study shows us that PDMS is a good absorber of light. The main aim and objective of this project is to improve the light absorption of the solar cell from designing and studying the materials for a single-junction polymer and multi-junction polymer design. Polydimethylsiloxane (PDMS) will be used as a polymeric material. To study this, Matlab is used to design and simulate the working of these solar cell and from it we are going to draw a conclusion about the materials that a good solar cell must have for good absorption of light.

Aterials and methods

To construct a basic solar cell, we have used the design flow in mat lab using the basic concept shown from the diagram below Figure1. Using this basic structure, we have designed the single junction and multi junction solar cell absorber by adding an extra active layer before the Cathode layer as shown in figure 1. The Materials used inside the Cell for other layers for this are listed below in the Table 1.

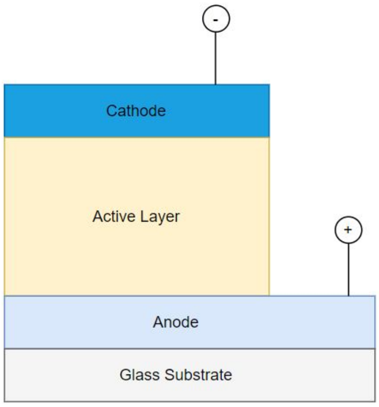

Fig 1. Basic Solar Cell Structure

Table 1 Materials Used

Symbol	Name	Material
SiO2	Silicon dioxide	Inorganic
PDMS	Polydimethylsiloxane	Organic
TiO2	Titanium dioxide	Inorganic
ITO	Indium tin oxide	Mixed Crystal
P3HT	Poly(3-hexylthiophene)	Mixed Organic
P3HTPCBMBlendDCB	Poly(3-hexylthiophene) [6,6]-phenyl-C_{61}-butyric acid methyl ester	Mixed Organic
PEDOT : PSS	Poly (3,4-ethylenedioxythiophene) polystyrene sulfonate	Mixed Organic
PCBM	[6,6] – phenyl - C_{61} - butyric acid methyl ester	Mixed Organic
Pbs	Lead Sulfide	Inorganic
Al	Aluminium	Inorganic
Ag	Silver	Inorganic

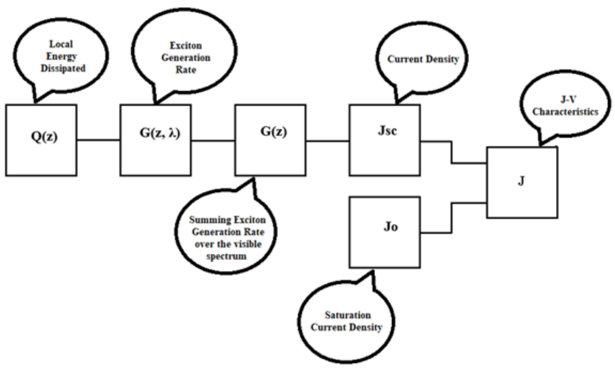

Fig 2 **Design Flow**

From the given figure 2 above, we can construct our code using these mathematical formulae. The theory for the calculation is described in detail [11].
To get the J-V characteristics we need to calculate the equation below

(1) $$J = Jsc - Jo(\exp(\frac{q(V+J.Rs)}{KT}) - 1) - \frac{V+J.Rs}{Rsh}$$

where, q is the elementary charge; k is the Boltzmann constant; T is the temperature (K); Jsc is the short circuit current density; V is the output voltage; Voc is the open circuit voltage; Rs is the serial resistance = 0.1 W cm^2; Rsh is the semiconductor resistances and a shunt resistance = 1000 W cm^2.

For calculating the saturation current density Jo under reverse bias

(2) $$Jo = \frac{Jsc}{(\exp(\frac{q.Voc}{KT}) - 1)} \quad (mA/cm^2)$$

For calculating the current density Jsc

(3) $$Jsc = q\int_0^t G(z)dz \quad (mA/cm^2) \qquad 3$$

where: t is the active layer thickness.

For calculating G(z) which is the summing of all exciton generation rate from the given wavelength.

(4) $$G(z) = \sum_{\lambda=350}^{\lambda=800} G(z,\lambda)$$

G (z, λ) is the exciton generation rate as a function of depth and wavelength is given by:

(5) $$G(z,\lambda) = \frac{Q(z,\lambda)}{\sim hw}$$

h is the plank constant meanwhile ~h is calculated by $\frac{h}{2\pi}$

Q(z) is the local energy dissipation

(6) $$Q(z) = \frac{1}{2} c\varepsilon_0 \alpha\, n\, |E(z)|^2$$

Where: E is the optical electric field at the point z; n is the real index of refraction; α is the absorption coefficient for which $(\alpha = \frac{4\pi k}{\lambda})$; c is the speed of light; ε_0 is the permittivity of the vacuum; λ is the wavelength; k is the extinction coefficient.

As we know local energy dissipation takes place when there is an angular frequency strikes the solar cell. Therefore, our matlab code depends on these equations to get our desired output and by using equation (1) to (6) we can find our short circuit current.

Results and discussion
SINGLE JUNCTION ABSORBER

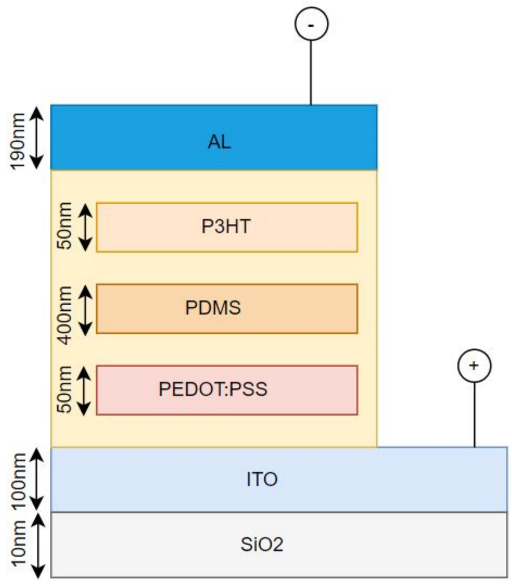

Fig 3 **Single Junction Solar Cell Design**

From the above figure 3, we are using the dimensions given by:SiO2(10nm)/ITO(10nm)/PEDOT:PSS(50nm)/PDMS(400 nm)/P3HT(50nm)/Al(190nm) to design the cell using these optical properties. From the below figure 4, as we can see that the single active layer PDMS covers the spectrum with wavelength of 350- 800nm we can determine from it that the absorbed light is above 16.44%.

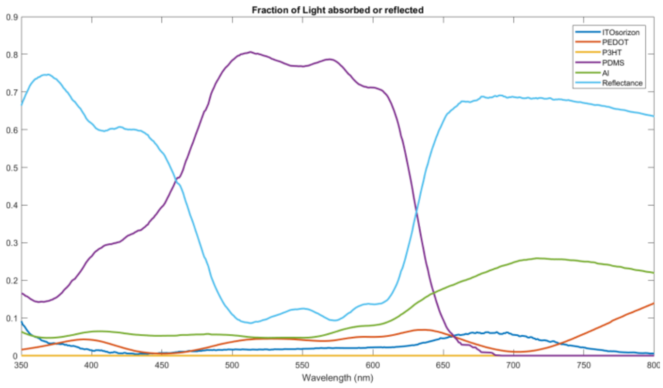

Fig 4 **Fraction of Light absorbed or reflected**

From the diagram shown below figure 5, the Current density is 12.345975 mA/cm^2 from the solar cell. Similarly, we can also calculate for multi junction polymer solar cell by adding an extra active layer to it. Using the Matlab code we have an estimation for the active layer thickness.

At the Electric Field intensity in the device, we can notice that in the PDMS Layer shown in figure 6, the waveform gets an additional boost to improve the intensity of the device and helps us to get good absorption.

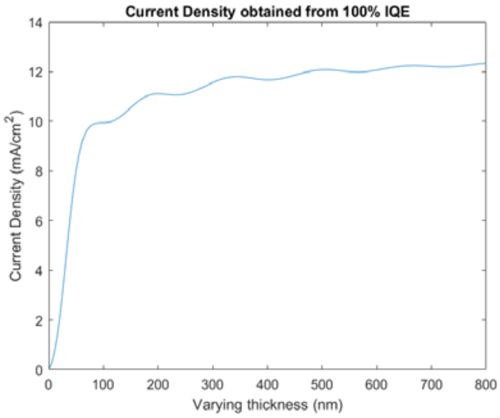

Fig 5 IQE of Current Density

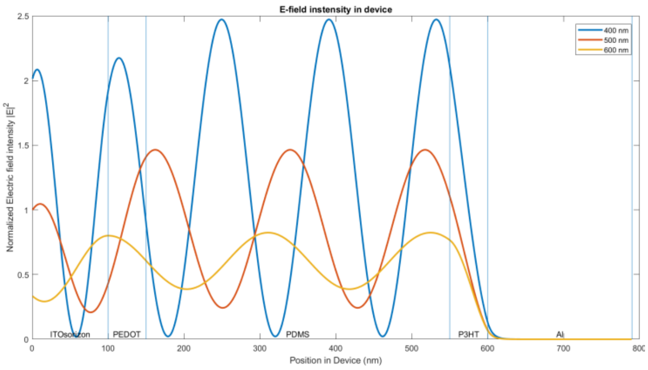

Fig 6 **E-Field intensity in Device**

3.2 FOR MULTI JUNCTION

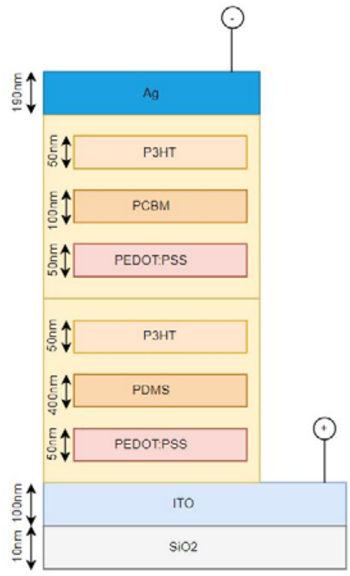

Fig 7 Multi **Junction Solar Cell Design**

From the above figure 7, we are using the dimensions given by:Glass(10nm)/ITO(100nm)/PEDOT:PSS(50nm)/PDMS(250nm)/P3HT(50nm)/PEDOT:PSS(50nm)/PCBM(250nm)/P3HT(50nm)/Ag(180nm) to design the cell using these optical properties. From the below figure 8, as we can see that the single active layer PDMS covers the spectrum with wavelength of 350- 800nm we can determine from it that the absorbed light is above 65.69%.

From the diagram shown below figure 9, the maximum total current is 12.426728 mA/cm^2 from the solar cell. Using the Matlab code we have an estimation for the active layer thickness.

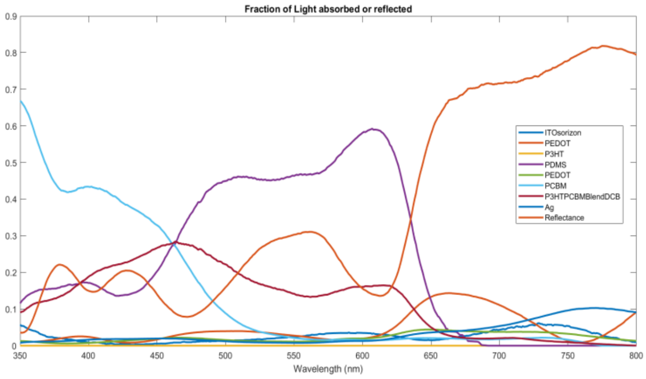

Fig 8 **Fraction of Light absorbed or reflected**

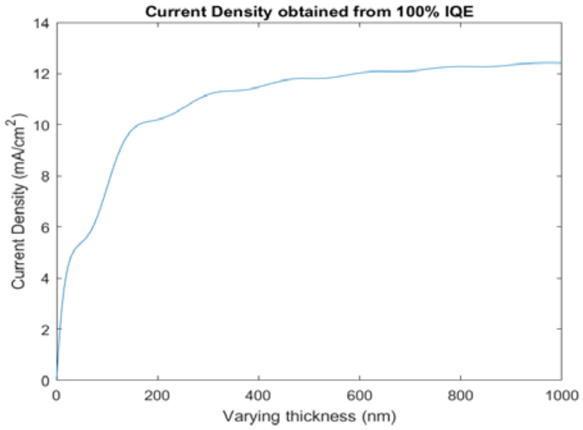

Fig 9 IQE of Current Density

At the Electric Field intensity in the device, we can notice that in the PDMS Layer shown in figure 10, the waveform gets an additional boost to improve the intensity of the device and helping us to get a good absorption.

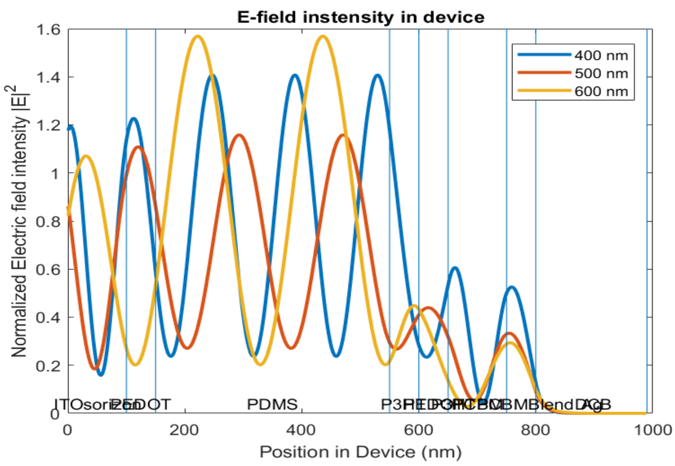

Fig 10 **E-Field intensity in Device**

Conclusion

The basic results we take for comparison with the results of the basic cell described at the beginning of the paper, from there we go gradually to draw conclusions about the ideal settings to build an efficient solar cell for absorption. From the obtained results, we conclude that when using PDMS polymer in two junctions which have different materials also, we have high absorption and low reflectance till a wavelength of 650nm for the solar cell. Compared to a single junction with just the PDMS polymer whose reflectance decreases as the wavelength increases and in turn increases absorption as a result.

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