Enhancement the efficiency of solar cell by using (Bpbpy) dye

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Abstract:
In this work, we studied the absorption and fluorescencespectrum of the (4,4'-((1E,1'E)-[1,1'-biphenyl]-4,4'-diylbis(diazene-2,1-diyl))bis(5-methyl-2,4-dihydro-3H-pyrazol-3-one)(Bpbpy)dye. Five differentconcentrations were prepared at room temperature after dissolving the dye into Ethanol with 99.99% purity.
The absorption and fluorescence spectra were measuredby usingUv-Vis Spectrophotometerand Spectrofluorometer with a wavelength range of (200 - 900) nm, theyshowed that the peaks of intensity of the absorption and fluorescence were increased with increasingthe concentration. At the same time, there is a shifting in the spectra peaks to high waves length (red shift), the fill factor (FF)was also calculatedfor all solutions.
The efficiency of solar cell was calculated before and after using the luminescent solar concentrator (LSC),the highest efficiency(η)was(15.86) for the solar cellwith concentration(1×10^{-4}) mol/L.
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Keywords: Dye solar cell; Fluorescence; dye; Efficiency cell.

تحسين كفاءة الخلية الشمسية باستخدام صبغةالـ(Bpbpy)

فارس عبد ياسين

قسم الفيزياء/ كلية العلوم/جامعة الكوفة

الخلاصة:
في هذه البحث تم دراسة طيفي الامتصاصية والفلورة لصبغة
(4,4'-((1E,1'E)-[1,1'-biphenyl]-4,4'-diylbis(diazene-2,1-diyl))bis(5-methyl-2,4-dihydro-3H-pyrazol-3-one) (Bpbpy)dye**.**
حضرت خمسة تراكيز مختلفة من صبغة الـ(Bpbpy)بعد اذابتها في محلول الايثانول ذي النقاوة 99.99%عند درجة حرارة الغرفة . قيست اطياف الامتصاصية والفلورة باستخدام جهاز مطياف الاشعة المرئية وفوق البنفسجية ومطياف الفلورة ضمن مدى الاطوال الموجية (200-900)نانومتر،لاحظنا زيادة فيشدة قمم طيفي الامتصاصية والفلورة بزيادة التركيز. وفي نفس الوقت لوحظ ان قمم طيف الفلورة قد ازيحت نحو الاطوال الموجية الطويلة (ازاحة حمراء) بزيادة التركيز حيث تم الحصول على طيف فلورة واسع.
تم حساب عامل الملئ(FF)لكافة المحاليل ،وحسبت كفاءة الخلية الشمسية (η)قبل وبعد استخدامالمركز الوميضي (LSC) ، ووجد ان اعلى كفاءة كان مقدارها (15.86) قد تحققت عند التركيز $(1\times10^{-4})\mathrm{mol/L}$.

الكلمات المفتاحية : اصباغ الخلايا الشمسية، الفلورة، الاصباغ ، الكفاءة الخلية

1. Introduction

A solar cell is a device that converts the sunlight to electrical power without applied voltage (photovoltaic PV) and without noise or pollution[1]. When the incident light ($hv > E_g$) strikes the solar cell, the electron-hole pairs will be created in the space charge region.[2] Holes in the valence band and electrons in the conduction band can contribute to produce the current under the electrical field which sweeps out and produces the photocurrent in the reverse bias direction.

Organic pigment is an organic chemical material that has the ability to absorb the visible electromagnetic spectrum. Almost these dyes are in form of powder would need to solve them in solvents to be solution.[3] . Plants, animals or metallic materials are the main sources of the organic pigments. These materials have attracted a great attention due to its low cost, abundance and high fluoridation. Therefore, many of research groups used organic pigments instead of inorganic pigments that are expensive, unavailable and most of them have low-lying with fluoridation[4].

The quantum efficiency of solar cell can be calculated using the following relation [5]:

$$Q_{fm} = \int F(v^-)dv^- / \int \in (v^-)dv^- \quad (1)$$

Where $\int F(v^-)dv^-$ is the total area under the curve of the fluorescence, while the term $\int \in (v^-)dv^-$ is the area under the curveof molar absorption coefficient.

The maximum power of solar cell can be determined as follows :

$$P_m = I_m V_m \quad (2)$$

where V_m is the voltage that produces theP_m, and I_m is the current when$V = V_m$.

Fill factor (FF) describes the degree of matching V_m withV_{oc}, and $I_m$withI_{sc}. Short circuit currentI_{sc}(short circuit current) and the open-circuit voltage V_{oc} are very important parameters that characterize the performance of a solar cell. I_{sc} is the current that flows through the solar cell when it is short-circuited (the resistance of load is zero) which leads to V = 0V;whereas V_{oc} is the maximum voltage produced from solar cell (the resistance reaches infinity) and the net current is zero. Fill factor is given by [6].

$$FF = \frac{I_m V_m}{I_{sc} V_{oc}} \quad (3)$$

The conversion efficiencyη of a solar cell is given by[7].:

$$\eta = \frac{P_m}{P_{in}} = \frac{I_m V_m}{P_{in}} = \frac{I_{sc} V_{oc} FF}{P_{in}} \quad (4)$$

In this work, we attemptedto increase the efficiency of solar cells by using luminescence solar concentrators (LSC) panels of organic dyes and find the best concentration of (LSC) panels.

2. Experimental part

The dye that used in this work is (4,4'-((1E,1'E)-[1,1'-biphenyl]-4,4'-diylbis(diazene-2,1 – diyl))bis(5 – methyl-2,4-dihydro-3H – pyrazol – 3 – one), it was prepared in chemistry lab in faculty of science-university of Kufa as following:

Dye preparation

Step1:a0.01 mol ofnitrite aqueous solution was added to an iced mixture of benzedine (0.006 mol) and4 M. ofHCl (15ml) with well cooling. The diazotized product was dropped while cooling with stirring over a mixture of ethylacetoacetate (0.006

mol).The precipitate was collected and washed with water and then dried.

Step2: Hydrazine hydrate (0.006 mol) was added to a suspension of compound step1 (0.006 mol) in ethanol(25 ml).The reaction was heated under reflux for (6-8)h. The precipitated solid was filtrated, washed, dried, andcrystallized and after that the dye was solute in Ethanol. The structure of the dye is shown in Fig. 1.

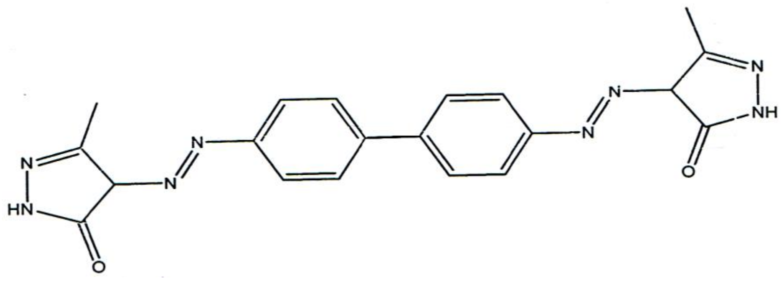

Figure 1: The structure of (Bpbpy) dye

Ethanol (C_2H_5OH), also called ethyl alcohol(99.99% purity) is used to solve the dye,itsstructural shown in Fig.2

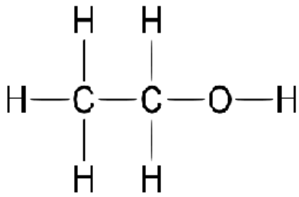

Figure 2: The structure of Ethanol.

Table 1: The main Properties of Ethanol [8]

Molecular Weightg/mol	Densityg/cm^3	Melting point(°C)	Boiling point(°C)	Refractive index (n)
46.07	0.789	-114	78.24	1.3614

The optical properties of prepared samples were investigated by Spectrofluorometer(SP8001-Metertech company) with a wavelength range of (200-900)nm. The power requirement of it is (220-110V/60 Hz)with cuvette of quartz and UV-Visible Spectrophotometer (F96 PRO-Shanghai Kingdak company) with a wavelength range of (200- 1100)nm. The power requirement of it is (220-240V) with cuvette of quartz. The electrical characteristics were measured by Solar Module Analyzerinstrument that supplied from INC company.

3. Results and Discussion

Figures (1-5) show the spectra of absorption and fluorescence of five different concentrations of prepared dye.The Bpbpy dye has an absorption spectra in the range of (300 -575)nm. At the lowest constriction (1×10^{-6}) mol/L the peak of absorption was at 415nm while it was around 444 nm for the highestconcentration (1×10^{-3}) mol/L. at the same time,the florescence spectra peaks were at 548 to 559 nm for the lowest and highest concentrations, respectively. Our dye has disunion (Stocks shift from 115 to 133 nm)between the absorption and florescence peaks as listed inTable 2. The quantum efficiency was calculated from equation (1), it should be less than unity, in general the quantum efficiency depends on radiative and non-radiative process, As shown in Table 2, the quantum efficiency was decreased with the increasing the concentration to be at high value (62%) for the lowest concentration (1×10^{-6}) mol/L.Because of the efficiency depend on concentration of the solution (Bert Lambert Law) in which the high order terns will neglect in the low concentrations , therefore the quantum efficiency will be higher for the low concentrations.

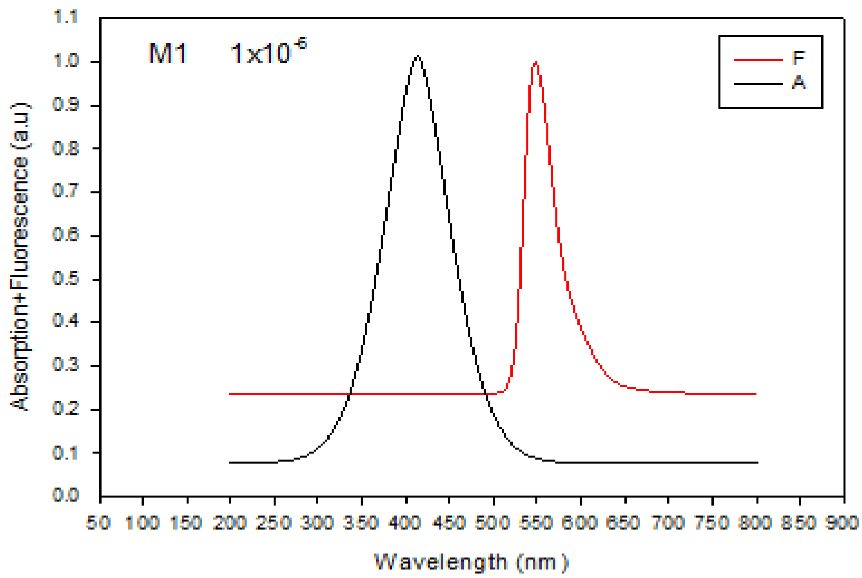

Figure (3) Absorption and Fluorescence Spectrum of Bpbpy dye for 1×10^{-6} mol/L Concentration.

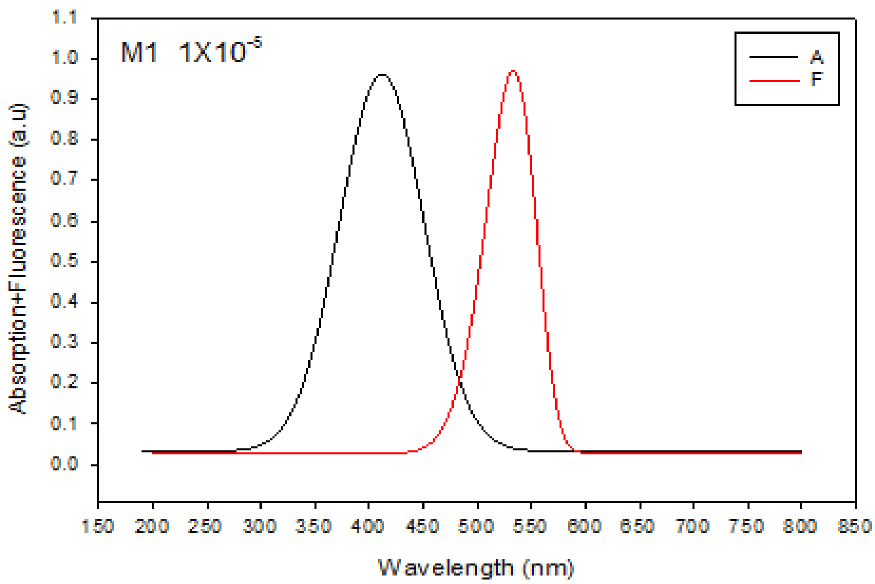

Figure (4) Absorption and Fluorescence Spectrum of Bpbpy dye for 1×10^{-5} mol/L Concentration.

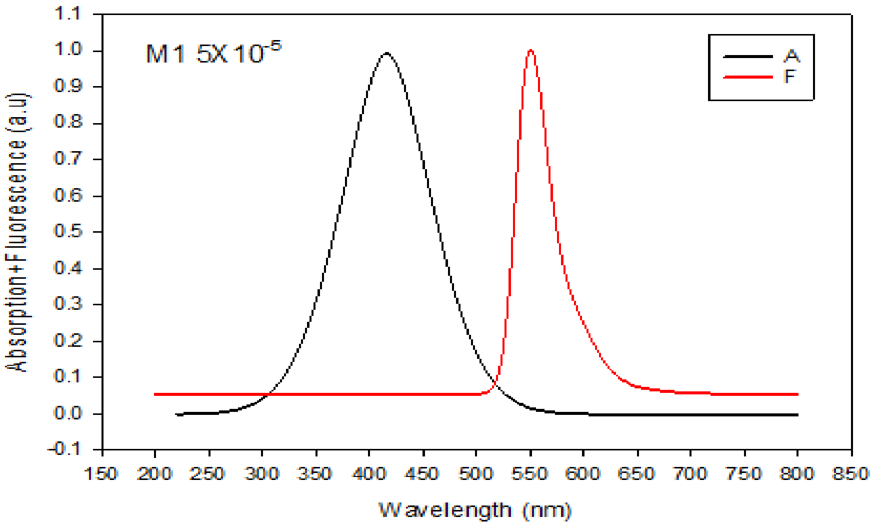

Figure (5) Absorption and Fluorescence Spectrum of Bpbpy dye for 5×10^{-5} mol/L Concentration.

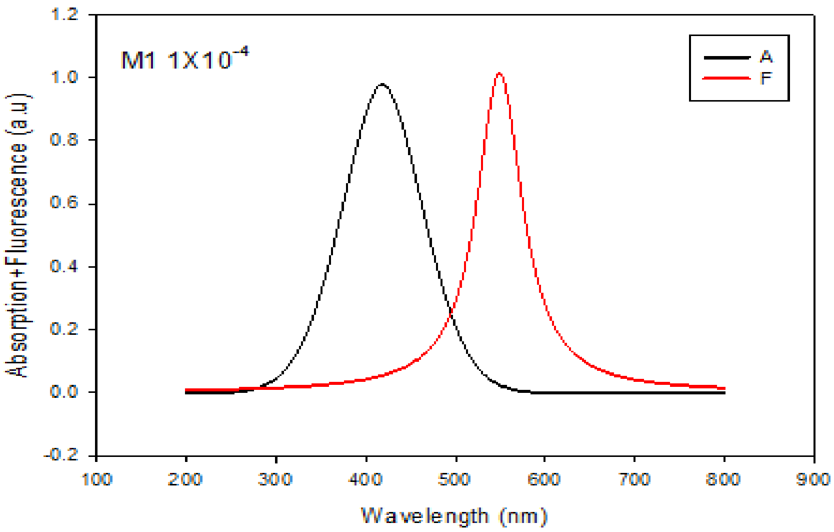

Figure (6) Absorption and Fluorescence Spectrum of Bpbpy dye for 1×10^{-4} mol/L Concentration.

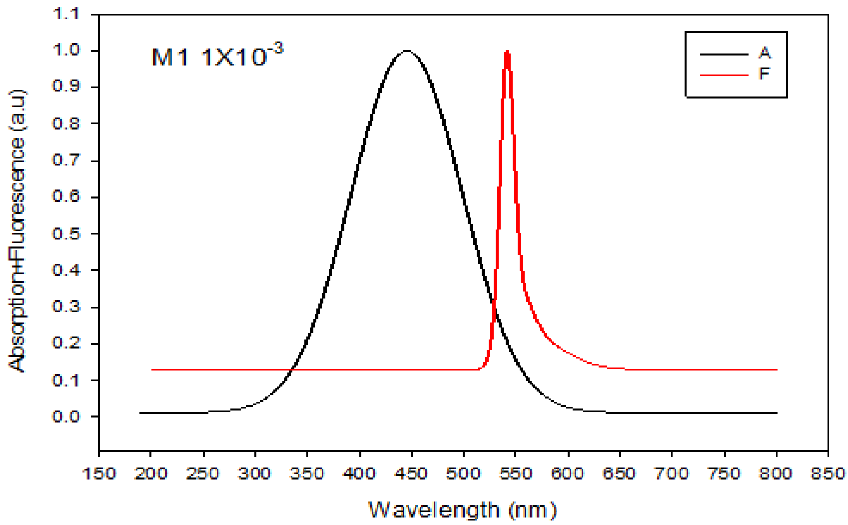

Figure (7) Absorption and Fluorescence Spectrum of Bpbpy dye for 1×10^{-3} mol/L Concentration.

Table (2) : Absorption and fluorescence spectra, Stock shift, and quantum efficiency of Bpbpy dye.

Concentration mol/L	Wavelenghth for A_{max}/nm	Wave lenghth for F_{max}/nm	Stokes Shift $\Delta\lambda=\lambda_{flo}-\lambda_{abs}$	The quantum efficiency% Q_{fm}
1×10^{-6}	**415**	**548**	**133**	**62%**
1×10^{-5}	**417**	**550**	**133**	**60%**
5×10^{-5}	**422**	**553**	131	**51%**
1×10^{-4}	**429**	**557**	**128**	**49%**
1×10^{-3}	**444**	**559**	**115**	**35%**

The electrical properties of solar cells based on the fabricated dyes were examined using LSC panels. This system is used to determine the electrical output parameters (V_m, I_m, V_{oc}, andI_{sc}) which are used to calculate the fill factor FF and conversion efficiencyη of the solar cell by applying Equations 3 and 4, respectively.

Figures (10-14) show the typical *I–V* characteristicswhen compared with the pure cell (without dye), the efficiency for solar cells with dye are increased, at the same time it increased with increasing the concentration until the concentration of 1x10^{-4} mol/Lto be at high value of 15.86% (highest $\Delta\eta$=5.7%), the author thinks that the dye is working as anti-reflection coating (ARC) layer on the solar cell which increasing the efficiency through trapping the incident radiation.This in turn leads to enhance the light conversion efficiency. The values of (V_m, I_m, V_{oc}, and I_{sc}), FF, and η for the cells pre- and post-dye were summarized in Table 3.

Table (3): Solar cell efficiency using (LSC) panels for0.5 mm thickness of Bpbpy dye**.**

SAMPLES	**FF**	**η%**	**Δη%**
Pure cell	0.840	15	**--**
Pure Epoxy Panels	0.747	14.26	-4.9%
1x10^{-6}	0.827	15.24	1.6%
1x10^{-5}	0.828	15.48	3.2%
5x10^{-5}	0.736	15.31	2%
1x10^{-4}	**0.749**	**15.86**	**5.7%**

$1x10^{-3}$	**0.793**	**14.64**	**-2.4%**

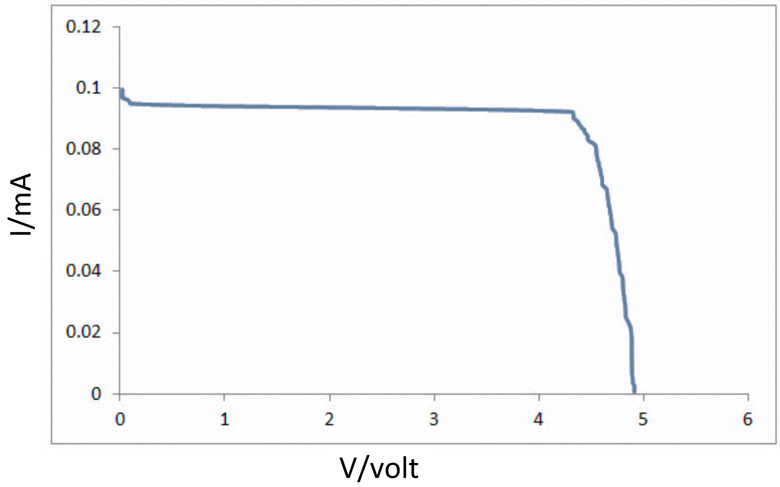

Figure (8) current – voltage curve for solar cell without dye

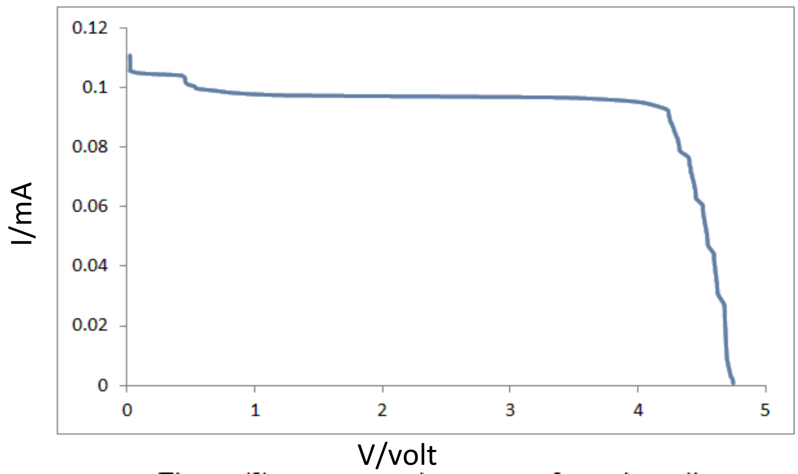

Figure (9) current – voltage curve for solar cell with epoxy resin

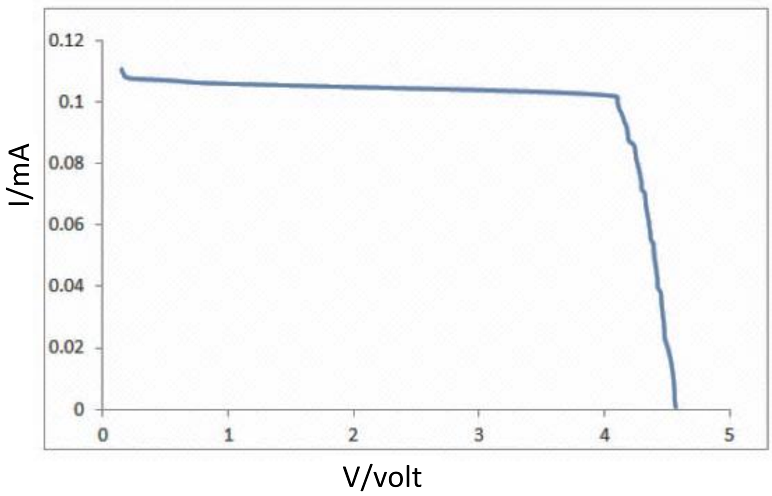

Figure (10) current – voltage curve solar cell using Bpbpy dye $1x10^{-6}$ mol/L.

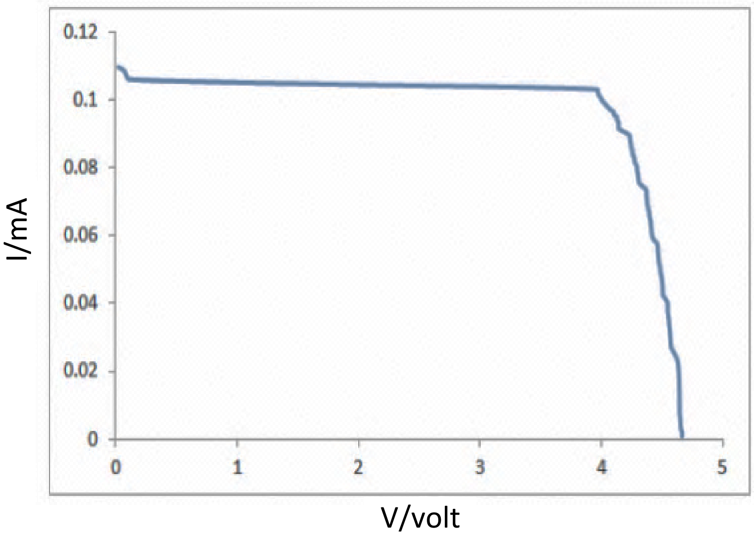

Figure (11) current – voltage curve solar cell using Bpbpy dye $1x10^{-5}$mol/L.

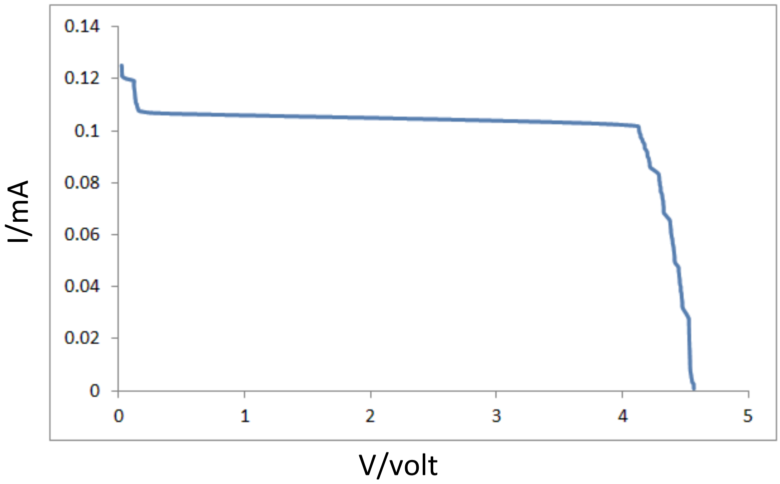

Figure (12) current – voltage curve solar cell using Bpbpy dye $5x10^{-5}$mol/L.

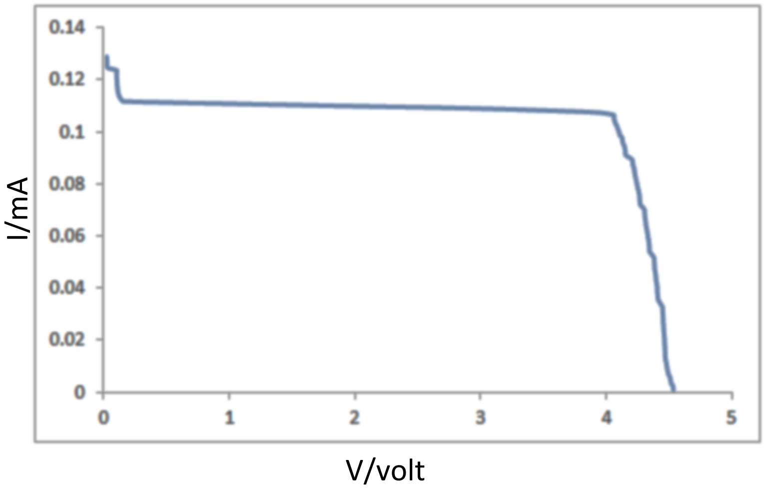

Figure (13) current – voltage curve solar cell using Bpbpy dye $1x10^{-4}$ mol/L.

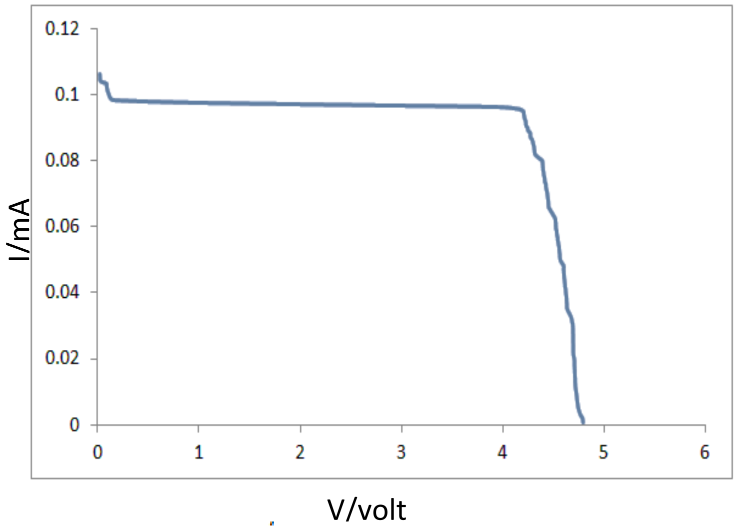

Figure (14) current – voltage curve solar cell using Bpbpy dye $1x10^{-3}$ mol/L .

4. Conclusion

Bpbpy dye with five different concentrations was successfully prepared at room temperature to enhance the efficiency of solar cell. This dye is good for solar cell applications because it has high fluorescence and absorption in the visible region. The conversion efficiency was increased with increasing the concentration until $1x10^{-4}$ mol/L to be at high value of 15.86% (highest $\Delta\eta$=5.7%).

We think that the dye is working as anti-reflection coating (ARC) layer on the solar cell which increasing the efficiency through trapping the incident radiation**.**

5. References

[1] Winter, C-J., Rudolf L. Sizmann, and Lorin L. Vant-Hull, eds. Solar power plants: fundamentals, technology, systems, economics. Springer Science & Business Media, 2012.

[2] Koster, Lambert JA, E. C. P. Smits, V. D. Mihailetchi, and P. W. M. Blom. "Device model for the operation of polymer/fullerene bulk heterojunction solar cells." Physical Review B 72, no. 8 (2005): 085205.

[3] Jocelyn H. Bruce-Gregorios M.D, Histopathologic Techniques, Pressing Quezon city, Philippine, 1974.

[4] Truant, J. P., W. A. Brett, and W. Thomas Jr. "Fluorescence microscopy of tubercle bacilli stained with auramine and rhodamine." Henry Ford Hospital Medical Bulletin 10: 287-296,1962.

[5]Gilles.U, Raymond Z. and AnthonyH. "The Chemistry of Fluorescent Bodipy Dyes: Versatility Unsurpassed", General & Introductory Chemistry, Vol 47 (7), pp: 1184–1201, 2008.

[6] Goetzberger, Adolf, Joachim Knobloch, and Bernhard Voss. Crystalline silicon solar cells. Chichester: Wiley, 1998.

[7] Fonash, Stephen. Solar cell device physics. Elsevier, 1981.

[8] Haynes, William M.,. CRC Handbook of Chemistry and Physics (92nd ed.). Boca Raton, FL: CRC Press. p. 3.246. 2011.