مجلة الدراسات التربوية والعلمية - كلية التربية - الجامعة العراقية
العدد الثاني والعشرون - المجلد الثاني - علوم الفيزياء - أيلول 2023 م
doi.org/10.52866/esj.2023.02.22.11

Study of The Effect of Transition Energy on Efficiency of N749/TiO_2 Solar Cells

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Abstract

In this research, we study the transition energy effect on the efficiency of the N749-TiO_2 hetero junction solar cell based on the donor-acceptor model with electron transfer theory .The photovoltaic characteristics of sensitized N749 black dye contact with wide band gab TiO_2 semiconductor are calculated using the current density .For both DCM and EtOH solvents, the N749 - TiO_2 hetero junction solar cell show that transition energy is the main factor effect on the current density, fill factor and efficiency . The current and current density increase with decreasing in the dielectric constant and increases the refractive index with more polar media. However, the current density and efficiency are more sensitive with decreased transition energy and stepwise increased the strength coupling from $[0.1 \times 10^{-2}|eV|^2$ to $1.5 \times 10^{-2}|eV|^2]$. However, the transition energy changes of the N749 - TiO_2 device affect the performance of a dye solar cell and it has higher efficiency with DCM solvent compared with EtHO solvent.

Keywords: Transition Energy , Efficiency , N749/ TiO_2 ,Solar Cells.

دراسة تأثير الطاقة الانتقالية على كفاءة الخلايا الشمسية N749/

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مستخلص:

في هذا البحث ، قمنا بدراسة تأثير الطاقة الانتقالية على كفاءة الخلية الشمسية غير المتجانسة N749 - TiO_2 بناءً على ا نموذج المانح– المستقبِل مع نظرية انتقال الإلكترون . تم حساب الخصائص الكهروضوئية لخلية الصبغة السوداء N749 الحساسة للضوء والملامسة لشبه الموصل TiO_2 مالك فجوة واسعة النطاق باستخدام كثافة التيار.

لكل من مذيبات DCM و EtOH ، تُظهر الخلية الشمسية غير المتجانسة N749 - TiO_2 أن الطاقة الانتقالية هي العامل الرئيسي الذي يؤثر على كثافة التيار وعامل الملء والكفاءة. تزداد كثافة التيار والتيار مع تناقص ثابت العزل و زيادة معامل الانكسار و تزايد الوسط القطبي. ومع ذلك ، فإن كفاءة و كثافة التيار أكثر حساسية مع انخفاض الطاقة الانتقالية وزيادة تدريجية في ثابت اقتران من إلى . ومع ذلك، فإن تغيرات الطاقة الانتقالية لجهاز N749 - TiO_2 تؤثر على أداء الخلايا الشمسية الصبغية ولها كفاءة أعلى مع مذيب DCM مقارنة بمذيب EtHO. $[0.1 \times 10^{-2}|eV|^2$ to $1.5 \times 10^{-2}|eV|^2]$

الكلمات المفتاحية: الطاقة الانتقالية ، الكفاءة ، N749 / TiO_2 ، الخلايا الشمسية.

Introduction

The dye-sensitized solar cell DSSC was taken more attention of the international research community when O'Regan and Gratzel worked on their devices in 1991 with a conversion efficiency of 7% [1]. The DSSC was a topic of significant interest in research for solar cell technology because of low costs, optical properties and its ease of fabrication [2]. The dye-sensitized solar cell DSSCs have converted the light into electric by a photo electrochemical process[3]. It became an essential variety entirety solve the increased energy crisis that will eventually replace fossil fuels energy sources in increasing resources [4]. The DSSCs promise devices for low cost to produce electricity from converting sunlight. The DSSC is a third-generation photovoltaic device, it contains a photoactive electrode consisting of sensitized molecular dye and metal oxide semiconductors [5] . Finally, nanotechnology is the most assisted search to solve global energy problems by finding new sources of energy [6] . The DSSC is the photo-induced cell, its more attractive to attention in resulting in wide-ranging operative advantages of low-cost materials, printable, accessible manufacturing technology and flexible usage [7]. The ability of charge transfer from donor surface material to acceptor surface required that energy levels states must be closed to each other in both materials [8]. Hadi et al show that reorganization energy with alignment energy levels is key factors in charge transfer processes of different devices [9]. In heterostructure materials, the charge transfer occurs between donor energy level and acceptor energy level in the different solar cell devices [10]. However, the molecule in dye contact with semiconductor interface of devices has been an active field research in many technological devices because the charge transfer process is occurred through an interface [11]. Charge transfer process is the core operation in the photovoltaic devices system; the electron was transferred from the initial energy state in donor to the final energy state in acceptor of the semiconductor [12]. The electrons transferred to TiO2 electrodes were mainly related to their coupling coefficient. Electrons travel a distance through the interface to reach the conduction band

before charge recombination[13]. The N719 Dye is a metal-based organic ruthenium complexes dye, which includes the sensitizers for DSSCs due to the optical absorption spectrum, and chemical and thermal stabilities with an interest in electronic and optoelectronic properties .[14] The N749 dye has formula [(C4H9)4N]3[Ru(Htcterpy)(NCS)3] C69H117N9O6RuS3,-Tris[N,N,N-tributyl-1-butanaminium{[2,2′′6′,2′′-terpyridine]-4,4′,4′′-tricarboxylato(3-)- N1,N1′,N1′′}

tris(thiocyanato-N)hydrogen ruthenum [15] and structure is shown in figure (1) [16]. In this paper ,we study the effect of transition energy on the efficiency of N749 contact with titanium dioxidesemiconductor in heterojunction devices solar cell devices using the quantum theory and transition current.

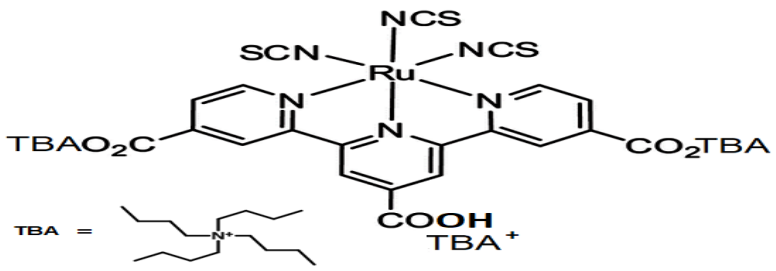


Figure (1): Structure of N749 sensitised dye [16].

Theory

Electronic current $J(E)$ from donor to an acceptor of heterojunction devices is [17].

$$J(E) = e\sum[f(E_D) - f(E_A)]T(E) \ldots\ldots (1)$$

Where $f(E_D)$ and $f(E_A)$ are the distribution of electrons in donor and acceptor state, $T(E)$ is the transmission coefficient probability writes by.

$$T(E) = \frac{2\pi}{\hbar} |\langle C_{SC}\rangle|^2 \rho_f(E) \ldots\ldots\ldots\ldots\ldots (2)$$

Where C_{SC} is strength coupling and $\rho_f(E)$ is the effective density for system and given by [18].

$$\rho_f(E) = \rho_S l_f / (\frac{6}{\pi})^{1/3} \ldots\ldots\ldots\ldots (3)$$

Where ρ_S is electronic density in semiconductor and l_f is effective length .The ρ_S is[19].

$$\rho_S = \rho_B(E)\langle\hat{\rho}\rangle d_s^{-2/3} \ldots\ldots\ldots\ldots\ldots (4)$$

Where density of state in Black dye $\rho_B(E)$, d_S is the atomic density of semiconductor and $\langle\hat{\rho}\rangle$ is expectation of density of state

$$\left(\frac{1}{\sqrt{4\pi\lambda_S^B k_B T}} e^{-\frac{(\lambda_S^B+\Delta u^0)^2}{4\lambda_S^B k_B T}} \right)$$

in system and Eq.(4) reduced to .

$$\rho_S = \frac{\rho_B(E)}{\sqrt{4\pi\lambda_S^B k_B T}} e^{-\frac{(\lambda_S^B+\Delta u^0)^2}{4\lambda_S^B k_B T}} d_S^{-2/3} \ldots\ldots\ldots\ldots\ldots (5)$$

We can insert Eqs.(3) ,(4) and (5) in Eq.(2) to result.

$$T(E) = \frac{2\pi}{\hbar} |\langle C_{CET}\rangle|^2 \frac{\rho_B(E)}{\sqrt{4\pi\lambda_S^B k_B T}}$$

$$|\langle C_{CET}\rangle|^2 e^{-\frac{(\lambda_S^B+\Delta u^0)^2}{4\lambda_S^B k_B T}} \frac{l_{eff}}{(\frac{6}{\pi})^{1/3}} d_S^{-2/3} \ldots\ldots\ldots (6)$$

here Δu^0 and T are the driving free energy and room temperature and λ_S^B (eV) is the transition energy of system, its given by [20].

$$\lambda_S^B(eV) = \frac{e^2}{8\pi\varepsilon_\circ}\left[\frac{1}{D}\left[\frac{1}{n^2}-\frac{1}{\varepsilon}\right] - \frac{1}{2R}\left[\frac{n_{Sem}^2-n^2}{n_{Sem}^2+n^2}\frac{1}{n^2} - \frac{\varepsilon_{Sem}^2-\varepsilon^2}{\varepsilon_{Sem}^2+\varepsilon^2}\frac{1}{\varepsilon^2}\right]\right] \ldots\ldots\ldots (7)$$

where e and $\varepsilon_\circ$ are electronic charge and permittivity. The D and R are the radius of the molecule and the distance between molecule and semiconductor, n and ε are refractive index and dielectric constant of solvent, n_{Se} is the refractive index of semiconductor and ε_{Se} is the dielectric constant of semiconductor. The radius is [21].

$$D = \left(\frac{3}{4\pi}\frac{m}{N\rho}\right)^{\frac{1}{3}} \ldots\ldots\ldots\ldots (8)$$

where molecular weight m, Avogadro number N, and ρ is the density material.

Substituting the Eq. (6) in Eq. (1) and assume $f(E) = [f(E_D) - f(E_A)]$ for continuum system to obtain.

$$J(E) = \frac{2\pi e}{\hbar} \frac{1)}{\sqrt{4\pi\lambda_S^B k_B T}} |\langle C_{CET}\rangle|^2 e^{-\frac{(\lambda_S^B+\Delta u^0)^2}{4\lambda_S^B k_B T}} \frac{l_{eff}}{(\frac{6}{\pi})^{1/3}} d_S^{-2/3} \int_0^E f(E)\rho_B(E)\, dE \ldots (9)$$

The solution integral in Eq. (9) reduce to electronic concentration n_s by form [22].

$$\int_0^E f(E)\rho_B(E)\, dE = n_s \ldots\ldots (10)$$

The Eq. (10) together Eq. (9) to.

$$J(E) = \frac{2\pi e}{\hbar} \frac{1}{\sqrt{4\pi\lambda_S^B k_B T}} |\langle C_{SC}\rangle|^2 e^{-\frac{(\lambda_S^B+\Delta u^0)^2}{4\lambda_S^B k_B T}} \frac{l_f}{(\frac{6}{\pi})^{1/3}} d_S^{-2/3} n_s \ldots\ldots (11)$$

The atomic density d_S is given by relation [23].

$$d_S = \frac{D_S}{D_n} \quad \ldots\ldots\ldots\ldots\ldots(12)$$

Where D_n and D_S are the number of states per atom per eV and density of states for semiconductor that's function of carrier concentration N_e and Fermi energy E_F given by [23] .

$$D_S = \frac{3}{2}\left(\frac{N_e}{E_F}\right)\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

The efficiency of DSSCs is defined as the ratio of output power to its incident light power density and it is [24].

$$\eta = \frac{J_{Sc}V_{oc}.FF}{I_o} \times 100\%\ldots\ldots\ldots\ldots(14)$$

where I_o is incident light intensity and FF is the fill factor and its ratio of J-V curve's maximum and gives ratio [25].

$$FF = \frac{J_mV_m}{J_{Sc}V_{oc}}\ldots\ldots\ldots\ldots\ldots\ldots(15)$$

where J_mV_m is the maximum power and J_{Sc} and V_{oc} are short-circuit current and open circuit voltages.

Results

Indeed, under the donor-acceptor model and quantum transition theory ,the transition energy tends to play an important parameters to point electron transfer from excited N749 to TiO_2 . The investigated and calculated the transition energy depends on some parameters ;radii of N749 and TiO_2 ,refractive index and dielectric of TiO_2 and solvents .The radii of TiO_2 and N749 depending on Eq.(8) with molecular weight M=79.866g/mol[26] and mass density $4.23\frac{g}{cm3}$ [24] of TiO_2 and M= 1364.98 g/mol[27] with density $\rho = 1.28\ \frac{g}{cm3}$ [27] for N749, results are 1.956 A^o for TiO_2 and 7.472 A^o for N749. The transition energy calculates due to Eq. (7) with takes refractive index 2.609 and dielectric constant 55 of TiO_2 semiconductor [28] with solvents refractive index 1.4241 , 1.359 and dielectric constant 8.93 , 24.55 of Dichloromethane(DCM) and Ethanol (EtOH) solvents to results λ_S^B= 0.267 eV and 0.363 eV for **N749** / TiO_2 with DCM and EtOH solvents respectively.

Next, we applied the both relation in Eq.(12) and Eq.(13) to evaluate the atomic density by inserting the carrier concentration $N_e = 1.4 \times 10^{20} m^{-3}$ [29] , effective density of states of TiO_2 $D_n = 8$, (state /eV) [30] and takes the Fermi energy $E_F = 4.52eV$ [31] , results $d_{TiO_2} = 5.81 \times 10^{18}\frac{1}{m^3}$. Hence it can be calculate the current yields in sensitized N749 dye - TiO_2 semiconductor with

DCM solvent calculated using Eq.(11) taken the transition energy 0.268 eV and 0.363 eV for N749 / TiO_2 with Ethanol and DCM solvents ,coupling strength $[1.5 \geq |\langle C_{CET}\rangle|^2 \geq 0.1] \times 10^{-2}\ |\mathrm{eV}|^2$, effective length $l_{eff} = 3A^0$ [32], atomic density $d_{TiO_2} = 5.81 \times 10^{18} \frac{1}{m^3}$ and electronic concentration $n_s = 1.5 \times 10^{24} \frac{1}{m^3}$ [33] with MATLAP program, results list in the Table (1) for N749/ TiO_2 devices .

Table (1): Results of electronic current calculation for N749 / TiO_2 with Ethanol (EtOH) and Dichloromethane(DCM) solvents at electronic concentration 3.5x10^{18}

Strength coupling $\|\langle C_{CET}\rangle\|^2 \times 10^{-2}\|\mathrm{eV}\|^2$	The electronic current $J(Amper)$	
	EtOH	DCM
0.1	2.3356x 10^{-4}	6.0412x 10^{-4}
0.2	4.6711x 10^{-4}	1.2082x 10^{-3}
0.3	7.0067x 10^{-4}	1.8124x 10^{-3}
0.4	9.3422x 10^{-4}	2.4165x 10^{-3}
0.5	1.1678x 10^{-3}	3.0206x 10^{-3}
0.6	1.4013x 10^{-3}	3.6247x 10^{-3}
0.7	1.6349x 10^{-3}	4.2289x 10^{-3}
0.8	1.8684x 10^{-3}	4.8330x 10^{-3}
0.9	2.1020x 10^{-3}	5.4371x 10^{-3}
1	2.3356x 10^{-3}	6.0412x 10^{-3}
1.1	2.5691x 10^{-3}	6.6454x 10^{-3}
1.2	2.8027x 10^{-3}	7.2495x 10^{-3}
1.3	3.0362x 10^{-3}	7.8536x 10^{-3}
1.4	3.2698x 10^{-3}	8.4577x 10^{-3}
1.5	3.5033x 10^{-3}	9.0619x 10^{-3}

The current density corresponding to the current that's generated when the light absorbs by the N749 sensitizer and directed to the wide band gap

TiO_2 semiconductor in cell has area cell (0.158) cm^2 [11] has been estimated by divides the current on area ,results shows in Table (2) for N749/ TiO_2 with Ethanol and DCM solvents .

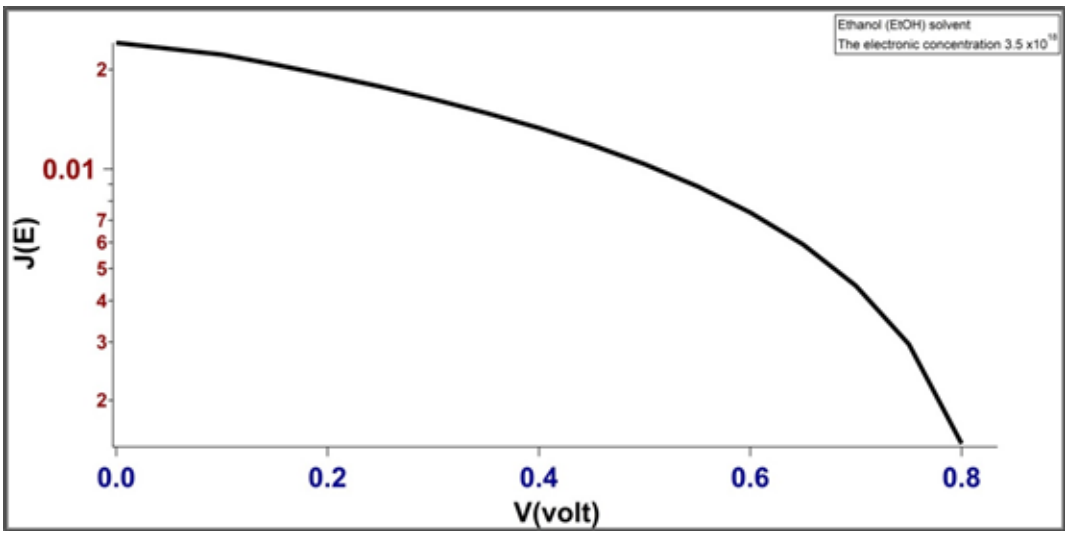
Table (2): Results of current density calculation for N749 / TiO_2 with EtOH and DCM solvents at electronic concentration $3.5 \times 10^{18} \frac{1}{cm^3}$.

Strength coupling $\|\langle C_{CET}\rangle\|^2 \times 10^{-2}\|eV\|^2$	**Current density ($A.cm^{-2}$)**	
	EtOH	DCM
0.1	1.4782×10^{-3}	3.8236×10^{-3}
0.2	2.9564×10^{-3}	7.6471×10^{-3}
0.3	4.4346×10^{-3}	1.1471×10^{-2}
0.4	5.9128×10^{-3}	1.5294×10^{-2}
0.5	7.3910×10^{-3}	1.9118×10^{-2}
0.6	8.8692×10^{-3}	2.2941×10^{-2}
0.7	1.0347×10^{-2}	2.6765×10^{-2}
0.8	1.1826×10^{-2}	3.0589×10^{-2}
0.9	1.3304×10^{-2}	3.4412×10^{-2}
1	1.4782×10^{-2}	3.8236×10^{-2}
1.1	1.6260×10^{-2}	4.2059×10^{-2}
1.2	1.7738×10^{-2}	4.5883×10^{-2}
1.3	1.9217×10^{-2}	4.9706×10^{-2}
1.4	2.0695×10^{-2}	5.3530×10^{-2}
1.5	2.2173×10^{-2}	5.7354×10^{-2}

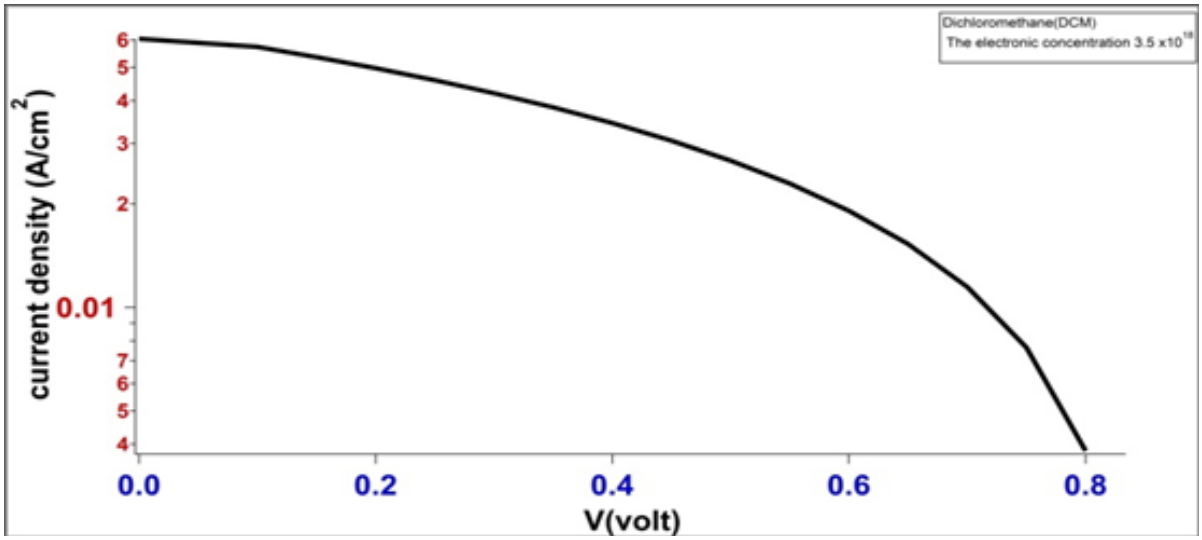
The photovoltaic characteristic of N749/ TiO_2 devices with EtOH and DCM_solvents can be estimation from curves J –V that's plotting between current density J(mA/cm_2) and voltage in Volt of data in table (3) and illustrated in figure (2) .

Table (3): Results of J-V characteristic of N749 / TiO_2 with EtOH and DCM solvents at electronic concentration $3.5 \times 10^{18} \frac{1}{cm^3}$. .

The J-V characteristic			
EtOH		DCM	
V(Volt)	$J(E)(\frac{A}{cm^2})$	V(Volt)	$J(E)(\frac{A}{cm^2})$
0.83406	0	0.834	0
0.8	1.4782x 10^{-3}	0.8	3.8236x 10^{-3}
0.75	2.9564x 10^{-3}	0.75	7.6471x 10^{-3}
0.7	4.4346x 10^{-3}	0.7	1.1471x 10^{-2}
0.65	5.9128x 10^{-3}	0.65	1.5294x 10^{-2}
0.6	7.3910x 10^{-3}	0.6	1.9118x 10^{-2}
0.55	8.8692x 10^{-3}	0.55	2.2941x 10^{-2}
0.5	1.0347x 10^{-2}	0.5	2.6765x 10^{-2}
0.45	1.1826x 10^{-2}	0.45	3.0589x 10^{-2}
0.4	1.3304x 10^{-2}	0.4	3.4412x 10^{-2}
0.35	1.4782x 10^{-2}	0.35	3.8236x 10^{-2}
0.3	1.6260x 10^{-2}	0.3	4.2059x 10^{-2}
0.25	1.7738x 10^{-2}	0.25	4.5883x 10^{-2}
0.2	1.9217x 10^{-2}	0.2	4.9706x 10^{-2}
0.15	2.0695x 10^{-2}	0.15	5.3530x 10^{-2}
0.1	2.2173x 10^{-2}	0.1	5.7354x 10^{-2}
0	2.4079x 10^{-2}	0	6.054x 10^{-2}



A- N749/ TiO_2 DSSCs with EtOH solvent



B- N749/ TiO_2 DSSCs with DCM solvent

Figure(2): Current density $J(mA/cm^2)$vs. Voltage (Volt) characteristics for A- N749/ TiO_2 DSSCs with EtOH and B- N749/ DSSCs with DCM solvents.

From figure (2).we can estimate the short-circuit of the highest current at cell voltage zero and the open-circuit highest voltage V_{OC} of a solar cell at a given light intensity when the current flow through cell is to be equal zero ,results are shown in table(4). The values of V_m and J_m are estimated from curves of $J-V$ in figure (2) and listed in table(4).

Table (4): Results of photovoltaic parameters of the N749/ TiO_2 DSSCs sensitized with Ethanol (EtOH) and Dichloromethane(DCM) solvents.

Variables	The electronic concentration $1/cm^3$	
	EtOH	DCM
Reorganization energy	0.362548 eV	0.268616 eV
$J_{Sc}(mA/cm^2)$	24.079	60.54
V_{oc} (Volt)	0.834	0.864
$J_m(mA/cm^2)$	3.843	9.545
V_m (Volt)	0.732	0.732
F.F	0.140	0.134
efficiency	2.802	6.991

Fill factor F.F is one important factor to specify the overall capability of a solar cell. It calculates by inserting the results of J_m, V_m, J_{Sc} and V_{oc} from table (4) in Eq.(15) to results 0.140 and 0.134 for N749/TiO_2 DSSCs with EtOH and DCM solvents respectively .However , the efficiency calculates by using the ratio of maximum generated power divided on input power from the Eq.(16) to results 2.802 and 6.991 for N749/TiO_2 DSSCs with EtOH and DCM solvents respectively.

Discussion

Transition energy is main factor effected on the current density ,fill factor and efficiency through effected on the current in Eq.(11) . Table(1) shows the current was influence by transition energy in forcedly .The current in N749 contact with TiO_2 with DCM in solar cell higher than with EtOH ,this refers to lower transition 0.268 eV with DCM comparing with 0.363 eV for solar cell with EtOH solvents .In order that ,the transition energy for N749 contact with TiO_2 solar cell with both solvents increases with increases the dielectric constant and increases the refractive index .This indicate the current increases with decreases the dielectric constant with more polar media . However , the current increases with increases refractive index by same ratio with proportional to transition energy and vice versa .Table(1) The currents of the sensitized N749 dye with TiO_2 solar cell with both were

stepwise increased from 2.3356E-04 A to 3.5033E-03 A for EtOH and from 6.0412E-04 A to 9.0619E-03 A with DCM solvents with increased the strength coupling from 0.1 x 10^{-2} $|eV|^2$ to 1.5 x 10^{-2} $|eV|^2$ with decreases transition energy from 0.363 eV with EtOH solvent to 0.268 eV with DCM solvent .The current and current density relate to transition energy that's depends on refractive index and dielectric constant according to polarity of EtOH and DCM solvents . As expected, the current density in the table(2) in the unit (A/cm^2) decreases with increasing transition energy with the same proportion as the current in the table(1). In addition ,the current density results in table(2) of sensitized N749 dye with TiO_2 solar cell with EtOH solvent were lower than current density with DCM solvent due to related to transition energy . The current density increases upon increases strength coupling from 0.1 x 10^{-2} $|eV|^2$ to 1.5 x 10^{-2} $|eV|^2$ and decreasing transition from 0.363 eV to 0.268 eV for EtOH and DCM solvents with carrier concentration 3.5 x 10^{18}. As seen as ,the current density increased alternatively with multiple factor withincreases the strength couploing .More importantly, the higher current density for N749 contact with TiO_2 solar cell with DCM solvents indicates that electrons are transferred in most probable cross interface of heterojunction N749-TiO_2 devices comparing with used the EtOH solvent with same N749-TiO_2 devices. In fact, the transition energy changes of N749 - TiO_2 device affect the performance of a dye solar cell and it limits the electric properties according to the influence on current density and J-V characteristic .Furthermore, the J-V characteristic has been shown in table(3) and graph in figure (2) . The J-V curves calculates of N749 -TiO_2 device at 300 k are investigated to understand the heterojunction properties. Figure 2 (a) demonstrates shows J-V curves at carrier concentration $1.5 \times 10^{18} \frac{1}{cm^3}$ of the N749/TiO_2 device. The current and voltage in the average open-circuit are found to be 1.676 x 10^{-3} mA/cm2 and 0.7287Volt where short-circuit current JSc is10.0507 x 10^{-3}, and open circuit voltages Voc is 0.8301voltrespectively.By using Eq. (14) and Eq.(1), the other fill factor and efficiency parameters of the N749/TiO_2 device are calculated from the curve scale of J-V

characteristics as shown in the inset of Figure 2(a) which are 0.14639 and 1.22125, respectively .In figure 2 (b) we demonstrate shows J-V curve at carrier concentration 2.5 x 10^{18} of the N749/TiO_2 device. The transition energy can be affect the Fill factor as well as the performance of a N749 -TiO_2 of DSSCs solar cell through affected on the current density . However, the open-circuit current density J_{Sc} was shifted to higher values from $J_{Sc} = 24.079(mA/cm^2)$ with transition energy 0.363 eV for solar cell with EtOH solvent to $J_{Sc} = 60.54(mA/cm^2)$ with transition energy 0.268 eV with DCM solvents and open-circuit potential V_{oc} shift increases from 0.834Volt with EtHO to 0.864 Volt with DCM solvent . Hence the power of the N749 dye - solar cell increases with DCM solvent comparing to same solar cell with EtHO solvent . The Fill factor in table () was nearly small changes for solar cell with EtOH at about 0.006 than solar cell with DCM solvent. It is smaller at low transition energy. The efficiency of solar cells is very sensitive to transition energy changes as it incorporates the N749 dye and TiO_2 semiconductor materials. The efficiency in table (4) is increased with decreased transition energy as seen as efficiency is 6.991 for cell with DCM and is 2.802 with EtOH. This indicates on the one hand to rise electron transfer flow for solar cell with less transition energy and vice versa .

Conclusion

A transition energy affected on the photovoltaic characteristic of the N749 contact with TiO_2 heterojunction solar cell has been studied and calculated using donor-acceptor quantum model with using the electron transfer theory. The current ,current density ,fill factor and efficiency of N749-TiO_2 device are showing more sensitive to changes of transition energy under constant carrier concentration. The J-V characteristics of the N749-TiO_2 device with DCM reveal more changes due to changes transition comparing with same solar cell with EtOH solvent. The N749-TiO_2 device with DCM solvent exhibit good efficiency about 6.991 comparing with N749-TiO_2 device with EtOH solvent that has efficiency about 2.802 .The higher efficiency of N749-TiO_2 device with DCM solvent at concentration carrier 3.5 is evident from the higher electron transfer rate .

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