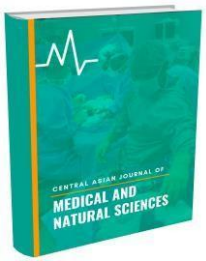

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Article

Studying the Effect of Donor Dyes on the Performance of Dye-Sensitive Solar Cells DSSCs Based on TiO2 Semiconductor

Farah Sadeq Khasrw[1], Hadi J. M Al-Agealy[2] , Methaq A. R. Mohsin[3]

1. Ministry of Education, Rusafa Second Directorate, Al-Takhi Secondary School for Girls,Baghdad,Iraq.
2, 3. Department of Physics College of Education for Pure Science Ibn-ALHaitham, University of Baghdad, Baghdad-Iraq

*Correspondence: Farah.Sadek.1204a@ihcoedu.uobaghdad.edu.iq, hadi.j.m@ihcoedu.uobaghdad.edu.iq, methaq.Abd1204a@ ihcoedu.uobaghdad.edu.iq

Abstract: This study demonstrates the effect of RuN3 and RuN719 donor ruthenium dyes on the performance of dye-sensitive solar cells (DSSCs) by integrating charge transfer theory and quantum transport considerations is subjected to the influences of transition energy, the atomic density, and the charge concentration and bonding coupling. .The mechanism of charge transfer from the excited RuN3 and RuN719 dyes to the conduction band in TiO2 has been elucidated. Transition energy in RuN3/TiO2 and RuN719/TiO2 cells as a function of ethanol solvent polarity, physical force, RuN3, RuN719 and TiO2 material structure, and RuN3, RuN719 and TiO2 pigment spacing. The high transition energy of RuN719/TiO2 increases the probability of charge transfer and reduces the recombination charge, while the low transition energy of RuN3/TiO2 reduces charge transfer and increases the recombination charge. A transition energy reveals that RuN3,RuN719 , TiO2 and ethanol solvent properties play a crucial role improving charge transport in the DSSC from RuN3 and RuN719 dyes and TiO2 surfaces under different bonding coupling at room temperatures. Current density and efficiency increase significantly with increasing transition energy and bonding strength, which improves charge transport and stabilizes the electrolyte system, as a result of the high level of alignment energy of the material system. High current density analyses showed a marked improvement in current density response, mainly due to the strength of the bond between the RuN719 dye and titanium dioxide (TiO2), compared to its decrease in RuN3 with TiO2.This led to an increase in wavefunction interference at the interface, which enhanced charge transport in the RuN719/TiO2 device. The overall performance of the RuN719-TiO2 device has improved thanks to increased charge transfer, reaching 7.2744% compared to 5.3580% for the RuN3/TiO2 device, as a result of increased transition energy and bonding strength.

Keywords: Donor , Performance , RuN3,RuN719,Solar Cells , TiO2.

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Introduction

Recently, due to unprecedented global economic growth, the depletion of fossil fuel resources, and increasing greenhouse gas emissions, energy consumption has become one of the most important environmental challenges that has prompted intensive efforts to promote renewable and clean energy sources [1]. Dye-sensitive organic solar cells DSSCs have garnered increasing attention due to theirlow cost, flexibility and light weight. Thanks to intensive research focusing on integrated material innovation and electronic device architecture, these organic cells have achieved efficiencies exceeding 13% to date [2]. Researchers in the field of renewable energy are turning to low-cost renewable energy sources, such as wind, hydroelectric and solar cells to reduce emissions and achieving

climate goals. In light of current developments, light is considered a major source of energy, providing a clean and convenient source of power, can play a pivotal role in future energy solutions [3].Dye-sensitive solar cells (DSSCs) are the main type of organic solar cell and have gained increasing attention as a practical option due to the high efficiency as well low cost in converting light into electrical energy [4]. Since the pioneering work of Gratzel and Brian O'Regan, dye-sensitized solar cells (DSSCs) have become known for their importance and promise in the field of energy conversion technology, due to their ease of manufacture, low cost, environmental friendliness, and high efficiency [5]. Organic solar cells (DSSCs) comprise several generations. The first generation relies on silicon-based solar cells, which are expensive energy sources. The second generation includes amorphous silicon, thin films, and microcrystalline silicon. The third generation includes technologies such as organic materials, perovskites, DSSCs, and quantum dot cells [6]. DSSC cells are a promising and efficient technology in the field of photovoltaic energy.They are low-cost, energy-clean devices, and are easy to manufacture for solar applications [7].Titanium dioxide (TiO2) is one of the most widely used semiconductors in dye-sensitized solar cells (DSSCs). It has a wide band gap of 3.20 V, is non-toxic, stable, and possesses excellent electrical and optical properties. It is regenerated by an electrolyte solution containing an oxidation-reduction medium [8].The active medium in dye-sensitive organic solar cells (DSSCs) is an integral part of the DSSCs, and is usually composed of donor and acceptor materials [9]. DSSC cells are photovoltaic cells that convert light into electricity when a dye is excited by incident light, and electrons are injected into the conduction band of titanium dioxide. These cells consist of an electrode connected to a titanium dioxide (TiO2)-sensitive dye, a counter electrode, and an electrolyte solution containing an oxidizing-reducing medium. Electrons are transferred to the counter electrode, the oxidizing-reducing medium is reduced to the counter electrode, and the excited dye returns to its ground state [10].In DSSC cells, electron transfer occurs from the light-absorbing dye to a semiconductor across the interfaces between them when the energy levels at these interfaces align [11].Due to the composition and light-sensitive properties of the organic ruthenium dye, it can be used electrochemically and optically in solar cells [12].Electron transport is a fundamental process for understanding solar cells, and many electronic devices depend on it [13].This includes the transfer of photoexcited electrons from the excited dye contact point to semiconductor-based DSSC solar cells [14]. Marcus presents a simplified model of the charge transfer reaction, in which this reaction transitions from the donor excitation state in the dye to the acceptor state in the conduction band of the semiconductor [15]. In DSSC cells, Ruthenium RuN719 and RuN3 are complex dyes and are among the most commonly used photosensitive materials in DSSC solar cells, as they are characterized by stability, exceptional redox properties, high absorption, and superior electron injection ability in titanium dioxide [16]. Ruthenium RuN3, a di(thiocyanate)di(2,2′-dipyridine-4,4′-dicarboxylate)ruthenium(II), exhibits exceptional light absorption and electron transfer capabilities, improving overall device efficiency. This compound demonstrates significant potential for the development of highly efficient solar power systems [17]. Ruthenium RuN719 is a metal-organic dye with broad-spectrum sensitivity, higher absorption, and good stability with interesting electronic and optoelectronic properties, and is the main sensitizer for DSSCs based on its broad absorption [18]. This work highlights the potential impact of ruthenium dyes RuN3 and RuN719 on the performance of third-generation TiO2-based dye-sensitized solar cells (DSSCs), utilizing quantum charge transport theory to enhance sustainable energy solutions. RuN3 and RuN719 dyes were used as contact sensitizers for TiO2 in ethanol solvents within DSSCs.

Theory

The transition of charge transfer is a crucial parameters used to calculate the current density in DSSCs solar cells ,it is given by [19].

$$|T_c| = \frac{2\pi}{\hbar}\int_0^E |\langle \sigma_E \rangle|^2 \, \rho_c(E_D - E_T) dE \qquad (1)$$

Where $\hbar$ is the Dirack constant, $\langle \sigma_E \rangle$ is strength bonding coupling and $\rho_c(E_D - E_T)$ is the density of state and E_D and E_T are energies in RuN3 and RuN719 dye and in conduction band of TiO_2.The density of state $\rho_c(E_D - E_T)$ in dye/semiconductor device is [20].

$$\rho_c(E_D - E_T) = \langle \widehat{\boldsymbol{\rho}}_{\boldsymbol{a}} \rangle \rho_A^{-2/3} \frac{l_T}{(\frac{6}{\pi})^{1/3}} \rho_T(E) \qquad (2)$$

Where $\langle \widehat{\boldsymbol{\rho}}_{\mathbf{a}} \rangle$ is activation density, ρ_A is the atomic density ,l_T is the path length in TiO_2 and $\rho_T(E)$ is the electronic density of the TiO_2 semiconductor. The activation density, $\langle \widehat{\boldsymbol{\rho}}_{\boldsymbol{a}} \rangle$ for charge transport from RuN3 and RuN719 donor dye to conduction band of TiO_2 semiconductor is [21].

$$\langle \widehat{\boldsymbol{\rho}}_{\boldsymbol{a}} \rangle = \frac{e^{-\frac{\left(\Lambda_C^T + \Delta W^0\right)^2}{4\Lambda_C^T k_B T}}}{2\sqrt{\pi \Lambda_C^T k_B T}} \qquad (3)$$

Where Λ_C^T(eV) is transition energy , ΔW^0 is driving electrons energy , k_B is the Boltzmann constant and T is room temperature. The driving energy ΔW^0 is function as band energy E_b of the TiO_2 and chemical potential q^o for RuN3 and RuN719 dye [22].

$$\Delta W^0 = E_b - q^o \qquad (4)$$

By inserting equations (4) and (3) into equation (2), we obtain the results.

$$\rho_c(E_D - E_T) = \frac{e^{-\frac{\left(\Lambda_C^T + \Delta W^0\right)^2}{4\Lambda_C^T k_B T}}}{2\sqrt{\pi \Lambda_C^T k_B T}} \rho_A^{-2/3} \frac{l_T}{(\frac{6}{\pi})^{1/3}} \rho_T(E) \qquad (5)$$

Substituting Eq.(5) in Eq.(1) to give.

$$|T_c| = \frac{2\pi}{\hbar}\int_0^E |\langle \sigma_E \rangle|^2 \frac{e^{-\frac{\left(\Lambda_C^T + \Delta W^0\right)^2}{4\Lambda_C^T k_B T}}}{2\sqrt{\pi \Lambda_C^T k_B T}} \rho_A^{-2/3} \frac{l_T}{(\frac{6}{\pi})^{1/3}} \rho_T(E) dE \qquad (6)$$

The transition energy Λ_C^T(eV) of dye/semiconductor device is [23].

$$\Lambda_C^T(\text{eV}) = \frac{q^2}{8\pi\varepsilon_\circ}\left[\frac{1}{r}\left[\frac{1}{n^2} - \frac{1}{\varepsilon}\right] + \frac{1}{2D_{DT}}\left[\left(\frac{\varepsilon_S^2 - \varepsilon^2}{\varepsilon_S^2 + \varepsilon^2}\frac{1}{\varepsilon^2} - \frac{n_S^2 - n^2}{n_S^2 + n^2}\right)\left(\frac{1}{n^2}\right)\right]\right] \qquad (7)$$

where q , ε_0 , r and D_{DT} are electric charge, permittivity , radius of RuN3 ,RuN719 and TiO_2 distance between RuN3 or ,RuN719 dye and TiO_2 semiconductor, S_S are s, $n_S$and n are the dielectric constant and refractive index of the TiO_2 and solvents. The radius of materials is [24].

$$r(nm) = \left(\frac{3}{4\pi}\frac{M}{N\rho}\right)^{\frac{1}{3}} \qquad (8)$$

Where M is the molecular weight, N_A is Avogadro's number, and ρ is the mass density.The current $J_E(mA)$ in DSSCs produced from moves electrons from dye to semiconductor is [25]:

$$\mathbf{J_E(mA)} = \mathbf{q|T_c|} \qquad (9)$$

Substitute Eq. (6) into Eq. (9) and using Fermi function $\mathbf{f_{(k)}}$ to result:

$$\mathbf{J_E(mA)} = \frac{\pi}{\hbar}\int_0^E |\langle \sigma_E \rangle|^2 \frac{e^{-\frac{\left(\Lambda_C^T + \Delta W^0\right)^2}{4\Lambda_C^T k_B T}}}{\sqrt{\pi \Lambda_C^T k_B T}} \rho_A^{-2/3} \frac{l_T}{(\frac{6}{\pi})^{1/3}} \rho_T(E) f_{(k)} dE \qquad (10)$$

The current density define as current divides on area cell A ,it given by.

$$\mathbf{J_{CD}}\left(\frac{\mathbf{mA}}{\boldsymbol{cm^2}}\right) = \frac{\pi}{\hbar A}\int_0^E |\langle \sigma_E \rangle|^2 \frac{e^{-\frac{\left(\Lambda_C^T + \Delta W^0\right)^2}{4\Lambda_C^T k_B T}}}{\sqrt{\pi \Lambda_C^T k_B T}} \rho_A^{-2/3} \frac{l_T}{(\frac{6}{\pi})^{1/3}} \rho_T(E) f_{(k)} dE \qquad (11)$$

The integral in Eq.(**11**) can solve to results concentration $[C]$ **by**[26].

$$\int_0^E \boldsymbol{\rho_T(E) f_{(k)} dE} = [\mathbf{C}] \quad (12)$$

Insert Eq. (12) in Eq.(11) to results.

$$\mathbf{J_{CD}}\left(\frac{\mathbf{mA}}{\boldsymbol{cm^2}}\right) = \frac{\pi}{\hbar \mathbf{A}} |\langle \boldsymbol{\sigma_E} \rangle|^2 \frac{e^{-\frac{\left(\Lambda_C^T + \Delta W^0\right)^2}{4\Lambda_C^T k_B T}}}{\sqrt{\pi \Lambda_C^T k_B T}} \boldsymbol{\rho_A}^{-2/3} \frac{I_T}{\left(\frac{6}{\pi}\right)^{1/3}} [\mathbf{C}] \quad (13)$$

The efficiency of DSSCs can estimate as function a fill factor FF by [27].

$$\boldsymbol{\eta} = \frac{\mathbf{FF.J_{Sc}.V_{oc}}}{\mathbf{P_i}} \times \mathbf{100}\% \quad (14)$$

where $\mathbf{J_{sc}}$ $(\mathbf{mA/cm^2})$,$\mathbf{V_{oc}}$ (V) and $\mathbf{P_{in}}$ are short-circuit ,current density , voltage and power. The fill factor FF calculates for the DSSCs using [28].

$$\mathbf{FF} = \frac{\mathbf{J_m.V_m}}{\mathbf{J_{sc}.V_{oc}}} \quad (15)$$

Where $\mathbf{J_m}$ and V_m are maximum current density and voltage .

Results

Due to the charge transfer theory, calculating the current density in both RuN3/TiO2 and RuN719/TiO2 cells is an acceptable method for efficiency studies and calculating DSSC characteristics.Transition energy Λ_C^T(eV in Eq. (7) indicates to energy required to start transfer of electrons ,has an crucial influence on current density in Eq. (13).This depends on the polarity of the ethanol solvent and the titanium dioxide semiconductor, by relying on the dielectric constant, refractive index and radius of the three materials used in the manufacture of solar cells. In essence, the expression in Eq. (6), the transition energy was a function of the property of N719 dye, TiO_2 and solvent according to the radius, dielectric and refractive index of three materials. In essence, the radii is a function of the property of RuN3 dye,RuN719 dye and TiO_2 semiconductor , molecular weight and density , it can calculate based on Eq. (8) by inserting the molecular weight M(705.64 $\frac{g}{mol}$ [29],1188.55g/mol[30] and79.866g/mol [30]) and density (1.36 $\frac{g}{cm^3[24]}$ [31], 1.52 $\frac{g}{cm3}$ [30] and 4.23 $\frac{g}{cm3}$ [30])for of RuN3 ,RuN719 dyes and TiO_2 results are5.93 A^0, 6.77 $A°$ and 1.96 $A^0$for RuN3, RuN719 and $Ti0_2$. However , the transition energy of the both RuN3/TiO2 and RuN719 / TiO2 solar cells of charge transfer reaction from RuN3 or RuN719 to TiO_2 evaluates using Eq. (7) and MATLAB software a function of the refractive index and dielectric constant of ethanol solvent and TiO2 semiconductor and radii of RuN3,RuN719 and TiO2 ,respectively . Transition energy $\mathbf{\Lambda_C^T}$ (eV) of RuN3/ TiO_2 and RuN719/ TiO_2 calculates and taken refractive index 2.609 and dielectric constant 55 of TiO2 [32], refractive 1.359 [30] and dielectric constant 24.55 [30] of **Ethanol** solvent using Eq.(7) with MATLAP software to results $\mathbf{\Lambda_C^T}$ (0.363 eV and 0.404)eV for RuN3/ TiO2 or RuN719/ TiO2 solar cells.However, the transition energy is about 0.404 eV indicates that RuN719/ TiO2 solar cell system needs larger energy to reorientation system comparing to RuN3/ TiO2 system has more energy 0.363 eV to reconfiguration energy levels to start charge transition reaction from excited dye RuN3 or RuN719 to the conduction band in the TiO2, therefore the oxide–reduced reaction in N3/TiO2 and N719-TiO2 heterojunction used to understand electron transfer influenced of solar cell systems.The $\mathbf{J_{sc}}$ -V characteristics are essential for investigation, study, and calculation of DSSC efficiency because they depend on the current density and the current that electrons can transfer from the RuN3 and RuN719 dyes excited by light exposure to TiO2.Therefore, the current density $\mathbf{J_{CD}}\left(\frac{\mathbf{mA}}{\boldsymbol{cm^2}}\right)$ for electron transport of the RuN3/ TiO2 or RuN719/ TiO2 solar cell given in Eq. (13) was calculated under the assumption of constant energy levels of the two solar cells system and variety strength bond coupling ,which were a key parameter in the charge transport reaction., the current density is the key parameter that affects the filling factor

and efficiency of DSSCs because it is providing a $\mathbf{J_{CD}} - V$ characteristic for RuN3/ TiO2 or RuN719/ TiO2 solar cells . The current density $\mathbf{J_{CD}}(\frac{\mathbf{mA}}{\boldsymbol{cm^2}})$ given in Eq. (13) for RuN3/ TiO2 and RuN719/ TiO2 solar cells with ethanol solvent calculates taken account $\mathbf{\Lambda_C^T}$ $(0.363\ eV$ and $0.404\ )eV$, the strength bond coupling $\langle \boldsymbol{\sigma_E} \rangle$ [0.035,0.050,0.060,0.067,0.075,0.080,0.085,0.090,0.095,0.105,0.115,0.125,0.135,0.145 and 0.155]eV, the cell area A(0.490cm²)[32],$\boldsymbol{\rho}_A = 4.2 \times 10^{12}\ \frac{1}{cm^3}$[33], , $l_s = 3 \times 10^{-8}\ cm$[33], and carrier concentration (3×10^{18} cm^{-3}) [34], , results list in Table 1.

Table 1. Results of current density $\mathbf{J_{CD}}(\frac{\mathbf{mA}}{\boldsymbol{cm^2}})$ calculation for RuN3/TiO_2 and RuN719/$TiO_2$with Ethanol solvent.

Strength bond coupling $\langle \boldsymbol{\sigma_E} \rangle$ eV	The system solar cells	
	N3/TiO_2	N719/TiO_2
0.035	1.4782	2.60530
0.050	2.9564	4.68224
0.060	4.4346	4.51428
0.067	5.9128	8.4279
0.075	7.3910	10.3008
0.080	8.8692	12.1736
0.085	10.347	14.04673
0.090	11.826	15.91959
0.095	13.304	17.79244
0.105	14.782	19.66530
0.115	16.260	21.53877
0.125	1.7738	23.41020
0.135	19.217	25.28367
0.145	20.695	27.15714
0.155	22.173	29.0306

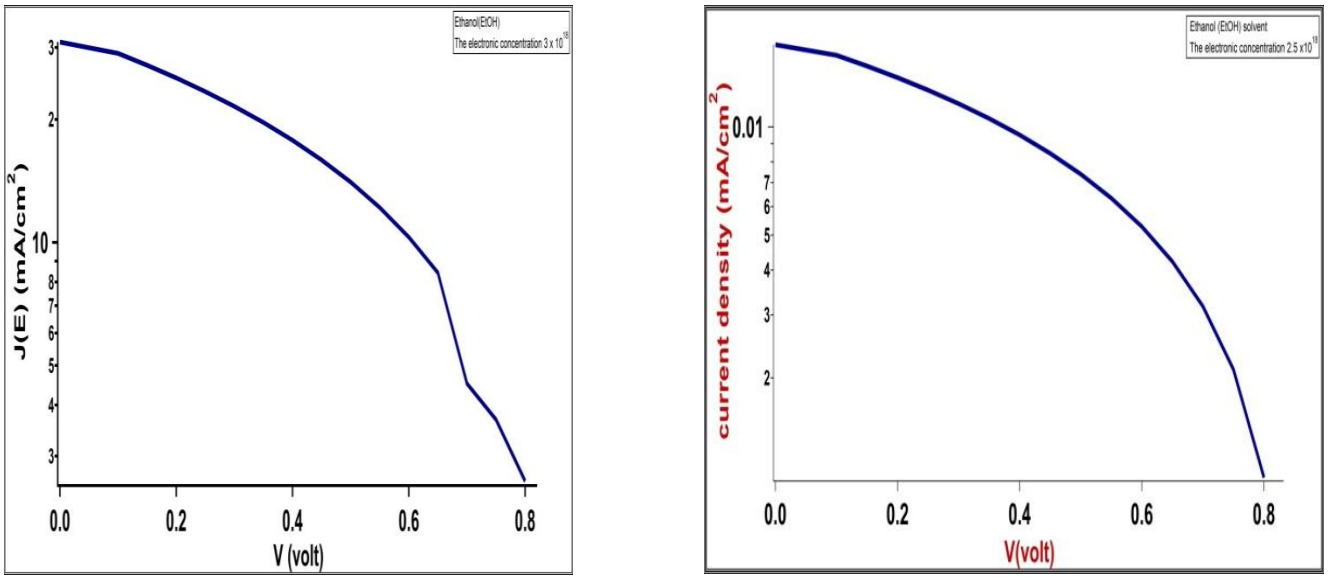
The current density $\mathbf{J_{CD}}(\frac{\mathbf{mA}}{\boldsymbol{cm^2}})$ in Table (1) indicates depending on the transition energy, concentration as well a strength bonding constant in the RuN3/TiO_2 and RuN719/TiO_2 solar cells with Ethanol solvent system. Table (1) shows the $\mathbf{J_{CD}}(\frac{\mathbf{mA}}{\boldsymbol{cm^2}})$ influenced by increasing square bonding $\langle \boldsymbol{\sigma_E} \rangle$ and transition energy of RuN3/TiO_2 and RuN719/TiO_2heterojunction-based solar cell. As mentioned above, the $\mathbf{J_{CD}}(\frac{\mathbf{mA}}{\boldsymbol{cm^2}})$ was increased upon increased $\mathbf{\Lambda_C^T}(eV)$ and strength bonding $\langle \boldsymbol{\sigma_E}(\boldsymbol{eV}) \rangle$ as results increasing in hybridization between the interfacial states . Transition energy plays an important role in enhancing the efficiency of RuN3/TiO_2 and RuN719/$TiO_2$by increasing the transfer of electrons between the ruthenium RuN3 and RuN719 and TiO_2 metal oxides.The comparing between transition energy for RuN3/TiO_2 is about 0.363 eV and RuN719/TiO_2 is about 0.404 eV indicated the system RuN3/ TiO_2 cell needs less energy to reorientation system to start charge transport process from excited energy levels of RuN3 comparing to RuN719 need more energy to reorientation system .Therefore , the oxide–reduced reaction in RuN3/TiO_2 and RuN719/TiO_2 cells used to understand charge transfer affected of solar cell systems. Tables (1) indicated $\mathbf{J_{CD}}(\frac{\mathbf{mA}}{\boldsymbol{cm^2}})$ increasing upon increase bonding coupling from 0.035 eV/ state to 0.155 eV/ state by immobilizing RuN3 and RuN719 dye cross the interaction between the ligand of RuN3 and RuN719 dye and oxygen on TiO_2 for system .To calculate and study the efficiency of solar cells dyed with RuN3 and RuN719 dyes and contact on a TiO2 photoelectrode with ethanol solvent, taking into account the bonding strength $\langle \boldsymbol{\sigma_E} \rangle$ and transfer energy $\mathbf{\Lambda_C^T}$ in the system, with the expectation that these

factors will have a greater impact on efficiency with the same solvent.In essence, the $\mathbf{J_{Sc}}$-V characteristics investigate to estimate the efficiency of both DSSCs , it depends on the current density $\mathbf{J_{CD}}(\frac{\mathbf{mA}}{cm^2})$. The characteristic of $\mathbf{J_{CD}}$-V for RuN3/TiO2 and RuN719/TiO2 solar cells using the simulation MAT:LAB software using theoretical approach of current density $\mathbf{J_{CD}}(\frac{\mathbf{mA}}{cm^2})$ and voltage in Volt as can be shown in Table(2).

Table 2. Results of voltage V(Volt) verse current density $\mathbf{J_{CD}}\left(\frac{\mathbf{mA}}{\mathbf{cm^2}}\right)$for RuN3/TiO2 and RuN719/Ti0_2 with Ethanol solvent.

The solar cells systems			
RuN3/TiO2		RuN719-TiO2	
V(Volt)	$J(\frac{mA}{cm^2})$	V(Volt)	$J(\frac{mA}{cm^2})$
0.805	0	0.811	0
0.8	1.4812	0.8	2.6573
0.75	2.9634	0.75	4.7274
0.7	4.5364	0.7	4.5729
0.65	5.9768	0.65	8.4389
0.6	7.4191	0.6	10.3878
0.55	8.8789	0.55	12.2776
0.5	10.3687	0.5	14.1679
0.45	11.8736	0.45	15.9979
0.4	13.3494	0.4	17.7978
0.35	14.8282	0.35	19.6754
0.3	16.2950	0.3	21.5489
0.25	17.9485	0.25	23.4287
0.2	19.3419	0.2	25.2969
0.15	20.7493	0.15	27.7786
0.1	22.2373	0.1	29.2463
0	24.1682	0	32.1678

In fact, the $\mathbf{J_{CD}}$-V characteristics of RuN3/TiO2 and RuN719/TiO2 are limited by current density $\mathbf{J_{CD}}(\frac{\mathbf{mA}}{cm^2})$, bonding coupling $\langle \boldsymbol{\sigma_E} \rangle$, transition energy $\mathbf{\Lambda_C^T}(\boldsymbol{eV})$ and Voltage (V), and increase with increased bonding coupling constant for both RuN3/TiO2 and RuN719/TiO2 solar cells. In contrast, the fill factor and efficiency can be calculated when ploted the curve between current denxity and voltage $\mathbf{J_{CD}}$-V for RuN3/TiO2 and RuN719/TiO2 .cells,it can be shown in Figure 1.



(A) (B)

Figure 1. The characteristic $\mathbf{J_{CD}}$-V of A)the RuN3/$Ti0_2$devices and B) RuN719/$Ti0_2$ with ethanol solvents.

Furthermore, the fill factor and efficiency calculate using Eq. (15) and Eq. (14) respectively using the results in Table (2) and two curves in Figure 1 to determining the average open circuit current $J_{Sc}$and voltage V_{oc}, the results are shown in Table 3 under simulated AM 1.5 global sunlight (1 Sun, 100 mWcm−2) .

Table 3. The fill factor and efficiency of RuN3/TiO2 and RuN719/$Ti0_2$ DSSCs with ethanol solvent.

Variables	The solar cells systems	
	RuN3/TiO2	RuN719-TiO2
$J_{Sc}(mA/cm^2)$	24.1682	32.1678
V_{oc} Volt	0.8053	0.8117
$J_m(mA/cm^2)$	11.8476	15.9379
V_m Volt	0.4523	0.4565
FF	0.2753	0.2786
Efficiency **η**	5.3580%	7.2744%

The efficiency **η** in Eq. (15) can also indicate directly proportional to current density $J_{Sc}(\frac{mA}{cm^2})$, and it can be noted that efficiency **η** increases with increasing current density and vice versa. Table(3) indicated to current density J_{Sc} is 24.1682($\frac{mA}{cm^2}$), open-circuit V_{oc} (0.8053)Volt, maximum current density $J_m$is 11.8476 (mA/cm^2) and voltage V_m is 0.4523V for RuN3/TiO2comparing to current density J_{Sc} is 32.1678($\frac{mA}{cm^2}$), open-circuit V_{oc} (0.8117)Volt, maximum current density $J_m$is 15.9379 (mA/cm^2) and voltage V_m is 0.4565V for RuN719/TiO2.This indicated that RuN719/TiO2 cell has fast charge transfer than RuN3/TiO2.The RuN719/TiO2 cell achieved a FF = 0.2753 and efficiency 5.3580% ,while the RuN719/TiO2 cell achieved a FF = 0.2786 and efficiency 7.2744%. However, efficiency 7.2744%. for RuN719/TiO2 cell is highest than 5.3580% for RuN3/TiO2. This indicated to produces decreased current density and efficiency with low transition energy of charge in device. The conversion efficiency of RuN719/TiO_2 DSSC increased by 1.9164% when the transition energy increased from 0.363 eV to 0.404eV . The results of efficiency 5.105% for RuN3/TiO2 cell in good agreement with 6.02% [35] and increases efficiency to reach 7.2744% for RuN719/TiO_2 is agreement with 6.97% [36].

Conclusion

In conclusion, based on the results of quantum framework charge transport theory, the highest current density and efficiency are achieved when operating the RuN719/TiO2 device in an ethylene solvent environment, which is characterized by high transfer energy and strong bonds. Two RuN3/ TiO2 and RuN719/ TiO2 solar cells were used to explore the the current density, fill factor as well as efficiency to understand the performance of RuN3/ TiO2 or RuN719/ TiO2 devices using different bonding coupling constants with ethylene solvent at limited transition energy.The results clearly show that the current density in both the RuN3/TiO2 and RuN719/TiO2 devices is strongly affected by the transfer energy and bond strength, as well as the concentration, in both RuN3/TiO2 and RuN719/TiO2 solar cells when using ethyl alcohol as a solvent. The transfer energy refers to the physical correspondence between the excited state energy levels of the RuN3 or RuN719 dyes and the acceptor state in the conduction band of TiO2. A decrease in transition energy means an increase in charge transfer rate, resulting from a better energy match between the excited state of RuN3 or RuN719 and TiO2. Current density increases with increasing transition energy and bond coupling strength. The fill factor and efficiency of the RuN719/TiO2 device larger than RuN3/ TiO2 ,it significantly affected by the transition energy and bonding coupling. Increasing the bonding strength in both RuN3/TiO2 and RuN719/TiO2 solar cells leads to increased charge transfer across the interface between the two materials in the device, ultimately affecting the current-voltage density characteristics, fill factor, and efficiency of the DSSC cell. The photovoltaic conversion efficiency of RuN719/TiO2 solar cells gradually increases compared to RuN3/TiO2, rising from 5.3580% to 7.2744%. This increase is due to the increased charge transfer in dye-sensitive RuN719/TiO2 cells.

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