

## Study and Invistagation of Electric Properties of Dye Sensitized Solar Cell

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### Abstract:

The aim of this paper is on the studies and investigation of the electric properties of dye sensitized solar cell according on estimation of the charge transfer current .Quantum theory have been used to evaluation the probability of current of charge transfer at N3/GeAs and N3/SnO<sub>2</sub> interface system .Theoretical calculation used to explain the behavior of the electric properties in N3/GeAs and N3/SnO<sub>2</sub>interface system depending on the evaluation flow of the current of electron through system. Data results of the current of electron at system show that current of charge is depending on the transfer energy  $\Delta(eV)$  , driving energy  $\Delta V^*(eV)$ , strength coupling coefficient  $(|T^2|)$ , concentration of electron  $n_{in}$ , volume of unit cell for semiconductor  $V$ , penetration factor  $\beta$ , and temperature T(K) for N3/GeAs and N3/SnO<sub>2</sub> system structures. A MATLAB designed program to predict the current of electron.

**Keywords:** Electric Properties, Dye Sensitized Solar Cell.

### Introduction

Global environmental problems have attracted increasing attention in recent years. Fossil fuel such as petroleum is a result of processes that used solar energy at an energy conversion efficiency of about 0.02 % for a period of about 200 million years [1]. The increase of the world's population combined with the growth per capita of energy consumption is expected to bring an explosive rise in energy consumption. To solve these problems, we need to save energy, increase the efficiency of equipment transforming energy and develop the use of new sources of energy. Solar energy is attracting a great deal of attention because it is a clean energy source and will not be depleted. Among the devices available for utilizing the sun's energy, the most prominent one is the solar cell, which uses the photovoltaic effect of semiconductor to convert solar light energy to electric energy [2]. Solar energy is a decentralized and unlimited natural resource, where the

amount of energy reaching the surface of the earth in one hour (4.3 x 10<sup>20</sup> J) is more than all energy consumed by humans in an entire year (4.1 x 10<sup>20</sup> J) [3]. However, in 2010 the contribution of solar electricity to the final energy consumption in leading countries in solar energy, such as Germany was merely 2%, whereas the global share was even smaller [4]. Photovoltaic devices are based on the concept of charge separation at an interface of two materials of different conduction mechanism. To date this field has been dominated by solid-state junction devices, usually made of silicon, and profiting from the experience and material availability resulting from the semiconductor industry. The dominance of the photovoltaic field by inorganic solid-state junction devices is now being [5]. A solid-state composite electrolyte, comprising two ionic liquids and a material, was sandwiched between a dye-sensitized porous TiO<sub>2</sub> working electrode and its counter electrode to fabricate a solid-state dye-sensitized solar cell (DSSC) [6].

Introduction Dye-Sensitized Solar Cells (DSC) have proven to be a promising new concept. In contrast to conventionally used Si-based solar cells, the main advantages of DSC are the low-cost manufacturing process (non-purified starting material as compared to Si-cells), the use of titanium dioxide as a non-toxic supporting material, and the efficient generation of electricity even at diffuse light conditions.

However, so far these solid-state electrolytes limited the capabilities of kinetic charge separation and proved to be unstable as well [7]. A compromise with new prospects to optimization exists in the use of an electrolyte film on the nanoparticles for charge collection. With this alternative cell concept, the liquid electrolyte is replaced by a surface electrolyte film which at the same time avoids the use of toxic organic solvents (Nano Surface Conductivity Solar Cell (NSCSC) [8]. Dye sensitized solar cells (DSSCs) offer the potential of being low-cost, high-efficiency photovoltaic devices. However, the power conversion efficiency is limited as they cannot utilize all photons of the visible solar spectrum. The proposed strategy provides an alternative method for enhancing the performance of DSSCs for low-cost renewable energy in the future [9].

**Material and Methods**

**Theory**

For quantum mechanical description of the electronic and vibrational dynamics involved in the electron transfer, we suppose two localized quantum states, donor state  $|D\rangle$  and acceptor state  $|A\rangle$  system are given in Hilbert space at quantum system by [10]

$$|\alpha, \tau\rangle = e^{-\frac{i}{\hbar} E \tau} |\alpha_i\rangle \dots \dots \dots (1)$$

For the Dye sensitized solar cell system we can introduce the Hamiltonian of the transition that can be written as [11].

$$\tilde{T}_{Dye/sem} = \tilde{T}_{CT} + \tilde{T}_{Dye} + \tilde{T}_{sem} \dots \dots \dots (2)$$

This operator obeys the Schrodinger equation [12].

$$i\hbar \frac{\partial}{\partial \tau} |\alpha, \tau\rangle = \tilde{T}_{Dye/sem} |\alpha, \tau\rangle \dots \dots \dots (3)$$

Inserting Eqs. (1) and (2) in Eq.(3) and integrate to results of the probability of particles at the time  $\tau$  and given by [13].

$$P_n(t) = \frac{2\pi\tau}{\hbar} |T_{Dye/Sem}|^2 \int_{-\infty}^{\infty} \rho(E_f) \delta(E_f - E_i) dE_f \dots\dots\dots(4)$$

Where the probability is

$$\rho(E) = \frac{e^{-\frac{(\Lambda+\Delta V^*)^2}{4\Lambda k_B T}}}{\sqrt{4\pi\Lambda k_B T}} \dots\dots\dots(5)$$

Substituting Eq.(5) in Eq.(4) to results.

$$\Gamma_{CT} = \frac{2\pi}{\hbar} \int_{-\infty}^{\infty} \left[ \frac{1}{4\pi\Lambda k_B T} \right]^{\frac{1}{2}} \exp \frac{-(\Lambda+\Delta V^*)^2}{4\Lambda k_B T} \rho(E_f) |T_{Dye/Sem}|^2 f(\epsilon_K) d\epsilon \dots (6)$$

Here  $f(\epsilon)$  is the Fermi-Dirac distribution of state [14]

$$f(\epsilon) = [1 + e^{(\epsilon-\epsilon_f)/k_B T}]^{-1} \dots\dots\dots (7)$$

Where  $(\epsilon_f)$  is the Fermi-energy levels and depends linearly on the applied potential  $E_{app}$  [15].

$$\epsilon_f = qE_{app} + \epsilon_f^0 = qE_{app} + V_{bi}^0 + \epsilon_f^b \dots\dots\dots (8)$$

Inserting Eqs. (8)and(7) in eq (6) results .

$$\Gamma_{CT} = \frac{4\pi^2}{\hbar} \int_{-\infty}^{\infty} \frac{1}{\sqrt{4\pi\Lambda k_B T}} e^{-\frac{(\Lambda+\Delta V^*)^2}{4\Lambda k_B T}} |T_{Dye/Sem}|^2 [1 + e^{\frac{(\epsilon-q E_{app}-\epsilon_f^0)}{k_B T}}]^{-1} d\epsilon \dots (9)$$

Where  $\Delta V^*_o = \Delta V^* - \epsilon$  then Eq.(9) is write as .

$$\Gamma_{CT} = \frac{4\pi^2}{\hbar} \int_{\epsilon} \frac{1}{\sqrt{4\pi\Lambda k_B T}} e^{-\frac{(\Lambda+\Delta V^*-\epsilon)^2}{4\Lambda k_B T}} |T_{Dye/Sem}|^2 \rho(\epsilon) [1 + e^{\frac{(\epsilon-q E_{app}-\epsilon_f^0)}{k_B T}}]^{-1} d\epsilon \dots(10)$$

When the Fermi energy  $f(\epsilon) = e^{\frac{(\epsilon-q E_{app}-\epsilon_f^0)}{k_B T}}$  is occupation of the surface states [15]

,then Eq. (10) can then be written as

$$\Gamma_{CT} = \frac{4\pi^2}{\hbar} e^{\frac{q E_{app}}{k_B T}} \int e^{-\frac{(\Lambda+\Delta V^*-\epsilon)^2}{4\Lambda k_B T}} e^{-\frac{(\epsilon-\epsilon_f^0)}{k_B T}} |T_{Dye/Sem}|^2 \rho(\epsilon) d\epsilon \dots\dots\dots (11)$$

Here  $(\epsilon_f^0)$  a constant for system. The term  $(e^{-\frac{-(\epsilon-\epsilon_f^0)}{k_B T}})$  refers to the occupancy of the conduction band at when the applied potential is zero  $E_{app}=0$  [15]. Introduce the factor  $(n_0 e^{\frac{qv_{bi}^0}{k_B T}})$  in both sides of Eq. (11) results.

$$\Gamma_{CT} = \frac{4\pi^2}{h} \frac{e^{\frac{q E_{app}}{k_B T}} n_0 e^{\frac{qv_{bi}^0}{k_B T}}}{n_0 e^{\frac{qv_{bi}^0}{k_B T}}} \frac{1}{\sqrt{4\pi\lambda k_B T}} \int e^{-\frac{(\Lambda+\Delta V^*-\epsilon)^2}{4\lambda k_B T}} e^{-\frac{-(\epsilon-\epsilon_f^0)}{k_B T}} |T_{Dye/Sem}|^2 \rho(\epsilon) d\epsilon \dots (12)$$

Where  $n_0$  is the number density of conduction band electrons and  $(v_{bi}^0)$  is the potential drop. Then Eq. (12) is .became

$$\Gamma_{CT} = \frac{4\pi^2}{h} \frac{n_0 e^{\frac{(qv_{bi}^0 - q E_{app})}{k_B T}}}{n_0 e^{\frac{qv_{bi}^0}{k_B T}}} \frac{1}{\sqrt{4\pi\lambda k_B T}} \int e^{-\frac{(\Lambda+\Delta V^*-\epsilon)^2}{4\lambda k_B T}} e^{-\frac{-(\epsilon-\epsilon_f^0)}{k_B T}} |T_{Dye/Sem}|^2 \rho(\epsilon) d\epsilon \dots (13)$$

But the number density of electrons  $n = e^{\frac{(qv_{bi}^0 - q E_{app})}{k_B T}}$  is function of the applied potential [16]. Then eq (13) must be written as.

$$\Gamma_{CT} = \frac{4\pi^2}{h} \frac{n_s}{n_0 e^{\frac{qv_{bi}^0}{k_B T}}} \int \frac{1}{\sqrt{4\pi\lambda k_B T}} e^{-\frac{(\Lambda+\Delta V^*-\epsilon)^2}{4\lambda k_B T}} e^{-\frac{-(\epsilon-\epsilon_f^0)}{k_B T}} |T_{Dye/Sem}|^2 \rho(\epsilon) d\epsilon \dots (14)$$

The quantity  $n_0 e^{\frac{qv_{bi}^0}{k_B T}} = \int_0^\infty \frac{\rho(\epsilon) f^0(\epsilon) d\epsilon}{v}$  in Eq. (14) [17], then the Eq. (14) become

$$\Gamma_{CT} = \frac{4\pi^2}{h} v n_s \int \frac{1}{\sqrt{4\pi\lambda k_B T}} \frac{e^{-\frac{(\Lambda+\Delta V^*-\epsilon)^2}{4\lambda k_B T}} e^{-\frac{-(\epsilon-\epsilon_f^0)}{k_B T}}}{\rho(\epsilon) f^0(\epsilon) d\epsilon} |T_{Dye/Sem}|^2 \rho(\epsilon) d\epsilon \dots (15)$$

The coupling by coefficient matrix element is estimated by using [17].

$$|T_{Dye/Sem}|^2 = \sqrt{\frac{\pi}{\beta a}} \frac{4}{3\pi^2} \epsilon_k \mu_e^k \dots \dots \dots (16)$$

Where  $\beta$  is the decay constant,  $a$  is the lattice constant,  $\mu_e^k$  is the factor multiplying and  $\epsilon_k$  is the energy of state k.

$$\Gamma_{CT} = \frac{64V}{9\hbar\pi^2\beta a} |\mu_e^k|^2 [\sqrt{\pi}(\lambda k_B T) + \sqrt{4\lambda k_B T} (\Delta V^* - \Lambda) + \frac{(\Delta V^* - \Lambda)^2}{2} \sqrt{\pi}] \dots (17)$$

When dye sensitized absorption photon light to excited according with potential barrier height .

$$\Delta V^* = hv - \Lambda \dots \dots (18)$$

The  $\Lambda$  is called solvent transition energy and arises from differences between the orientation and polarization of solvent molecules around system[18]. It represents the energy necessary to reorient the solvent molecules around the new equilibrium geometry of the product and represented by [19].

$$\Lambda = \frac{1}{24\pi\epsilon^0} \left[ \frac{1}{D} \left( \frac{1}{n^2} - \frac{1}{\epsilon_{SD}} \right) - \frac{1}{2R} \left( \frac{n_{Sc}^2 - n^2}{n^2} \frac{1}{\epsilon_{Sc}^2 - \epsilon_{SD}^2} - \frac{\epsilon_{Sc}^2 - \epsilon_{SD}^2}{\epsilon_{Sc}^2 + \epsilon_{SD}^2} \frac{1}{\epsilon_{SD}^2} \right) \right] \dots\dots\dots(19)$$

Where  $\epsilon^0$  is the vacuum permittivity ,  $\epsilon$  is the static dielectric constant of solvent,  $n$  is the refractive index of the solvent,  $n_{Sc}$  is the refractive index of the semiconductor,  $\epsilon_{Sc}$  dielectric constant of the semiconductor,  $D$  is the rudies of the molecular dye, and R is the distance between the complex and the semiconductor , and  $e$  is the charge of electron. The radius of the dye molecule can be evaluated using [20].

$$D = \left( \frac{3}{4\pi} \frac{M}{N\rho} \right)^{\frac{1}{3}} \dots\dots\dots (20)$$

Where M is the molecular weight, N is Avogadro number, and  $\rho$  is the density.

### Results and Discussion

A theoretical study have been applied to investigation the electric properties of dye sensitized solar cell system according to evaluate the current of electron transfer for N3 sensitized dye, to conduction band of Ga As, and SnO2 by Eq. (17). Many important parameter thats controlling on the current of electrons in dye/semiconductor interface is the transition energy  $\Lambda$  (eV). The estimation of the transition energy for both systems GaAs/N3, and SnO2/N3, we can using Eq. (19). Table (1) and (2) present some of physical constant for solvent and semiconductor which are used in the present calculation.

Table (1): A common properties of solvent.

Solvent	Chemical Formula[21]	Dielectric constant $\epsilon_{SD}$ [21]	Optical Dielectric Constant $n$	Viscosity $\eta$ (cp)[21]
1-Butanol	C <sub>4</sub> H <sub>10</sub> O	17.84	1.397[21]	2.57
Acetone	C <sub>3</sub> H <sub>6</sub> O	21.01	1.3563[21]	0.30
Ethanol	C <sub>2</sub> H <sub>2</sub> O	25.3	1.359[21]	1.94
Methanol	CH <sub>4</sub> O	33.0	1.329[21]	0.55
Formamide	CH <sub>2</sub> NO <sub>2</sub>	109	1.445[21]	3.3

Transition energy of the current electrons for semiconductor/dye system has been estimation using Eq. (19), with five solvents. The radius of N3 dye has been taken as ( $R_{N3} = 6.5A^0$ ) [22],. The value of D is chosen as the value

corresponding to the direct contact is a bout (7.5 Å) for N3. Inserting in Eq. (20), the values of radii , contact distance  $D=R_{Dye}+1A^{\circ}$ ,  $n_{sc}$ , and  $\epsilon_{sc}$  for GaAs, and SnO2 from Table (2), and the values  $\epsilon_{so}$  and n for nine solvent from Table (1), with  $e^2/8\epsilon_0\pi\approx 7.2$  eV. Results are listed in Table (3) for GaAs/N3, and SnO2/N3 system.

Table (2): Properties data of semiconductors

Semiconduct or	Dielectric constant $\epsilon_{sc}$	Optical Dielectric Constant $n_{sc}$	Energy gab (eV)	Lattice constant (nm)	Crystal structure
GaAs	13[22]	3.41917[22]	1.5177[22]	a= 5.6533 [22]	cubic[22]
SnO2	14[22]	3.785[22]	3.8[22]	a=4.737,c=3.186[22]	Zinc blend[22]

Table (3) :the transition energies values for donor N3 Dye and acceptor semiconductor GaAs, and SnO2.

Solvent	$\Delta$ (eV). forGaAS	$\Delta$ (eV). for SnO2
1-Butanol	0.32944492522	0.31815507085461
Aceton	0.35896520132120	0.34746453314474
Ethanol	0.36656078701199	0.35504332390785
Methanol	0.39283290678492	0.38116566083581
Formamide	0.36008625041689	0.34889968487816

However, the other important parameter for current electrons is driving force energy  $\Delta V^*$ (eV). It is provided by the absorption of light by molecule dye in system of solar cells. Driving force energy is the energy can be broken into the work; it takes to bring dye molecule state and semiconductor state together. The driving force energy can be calculated theoretically using Eq. (18), where  $h\nu=(hc/\text{wave length})$ , h is Planck constant ( $6.6 \times 10^{-34}$ J.sec), c is the light velocity ( $3 \times 10^8$ m/sec), and the wave length in nano meter for absorption spectra of N3 sensitized dye (500-1000)nm [3], and the transition energy taken from Table (3).

These calculated results of  $\Delta V^*$  (eV) for GaAs/N3, and SnO2/N3 are summarized in Tables (4), and (5) respectively.

The current of electron is proportional to the volume of the unit cell for semiconductor that is shown in Eq.(19). For GaAs the lattice parameters  $a=b=c=5.6533\text{\AA}$ [22], and have been a unit cell volume  $V_{\text{GaAs}}=1.806783 \times 10^{-28} \text{m}^3$  and the volume of unit cell for SnO2 is  $V_{\text{SnO2}}=7.1491192 \times 10^{-29} \text{m}^3$ , with  $a=b=4.737 \text{\AA}$ , and  $c=3.186 \text{\AA}$  [23].

Table (4): Driving force energy  $\Delta V^*$  (eV) of the electron transfer in N3/ GaAs

system with nine solvents in solar cell.

Wave length	Effective Free Energy $\Delta G^\circ$ (eV)										
	500nm	550nm	600nm	650nm	700nm	750nm	800nm	850nm	900nm	950nm	1000nm
Solvent											
1-Butanol	2.1526	1.9265	1.735	1.5795	1.4431	1.3249	1.2215	1.1303	1.0492	0.9766	0.9113
Acetone	2.1226	1.8970	1.7090	1.5499	1.4136	1.2954	1,1920	1.1008	1.0197	0.9471	0.8818
Ethanol	2.1150	1.8894	1.7014	1.5423	1.4060	1.2878	1.1844	1.0932	1.0121	0.9395	0.8742
Methanol	2.0888	1.8632	1.6752	1.5161	1.3797	1.2615	1.1581	1.0669	0.9858	0.9132	0.8479
Formamid	2.121	1.8959	1.7079	1.5488	1.4125	1.2943	1.1909	1.0997	1.0186	0.9460	0.8807

**Table (5):** Driving force energy  $\Delta V^*$  (eV) of the electron transfer in  $\text{SnO}_2/\text{N}_3$  system with nine solvents in solar cell.

Wave length	Effective free energy $\Delta G^\circ$ (eV)										
	500nm	550nm	600nm	650nm	700nm	750nm	800nm	850nm	900nm	950nm	1000nm
Solvent											
<b>1-Butanol</b>	<b>2.1634</b>	<b>1.9378</b>	<b>1.7498</b>	<b>1.5908</b>	<b>1.4544</b>	<b>1.3362</b>	<b>1.2328</b>	<b>1.1416</b>	<b>1.0605</b>	<b>0.9879</b>	<b>0.9226</b>
<b>Acetone</b>	<b>2.1341</b>	<b>1.9085</b>	<b>1.7205</b>	<b>1.5614</b>	<b>1.4251</b>	<b>1.3069</b>	<b>1.2035</b>	<b>1.1123</b>	<b>1.0312</b>	<b>0.9586</b>	<b>0.8933</b>
<b>Ethanol</b>	<b>2.1266</b>	<b>1.9010</b>	<b>1.7129</b>	<b>1.5539</b>	<b>1.4175</b>	<b>1.2993</b>	<b>1.1959</b>	<b>1.1047</b>	<b>1.0236</b>	<b>0.9510</b>	<b>0.8857</b>
<b>Methanol</b>	<b>2.1004</b>	<b>1.8748</b>	<b>1.6868</b>	<b>1.5277</b>	<b>1.3914</b>	<b>1.2732</b>	<b>1.1698</b>	<b>1.0786</b>	<b>0.9975</b>	<b>0.9249</b>	<b>0.8596</b>
<b>Formamid</b>	<b>2.1327</b>	<b>1.9071</b>	<b>1.7191</b>	<b>1.5600</b>	<b>1.4237</b>	<b>1.3055</b>	<b>1.2021</b>	<b>1.1108</b>	<b>1.0297</b>	<b>0.9672</b>	<b>0.8919</b>

The current of electrons can be evaluated by using Eq. (19) for  $\text{GaAs}/\text{N}_3$ , and  $\text{SnO}_2/\text{N}_3$ , with five variety solvents. It can be evaluated by inserting transition energy  $\Delta$ , driving force energy  $\Delta V^*$  (eV), volume of unit cell  $V(\text{m}^3)$ , attenuation parameter  $\beta(\text{m}^{-1})$ , and lattice parameter  $a(\text{m})$ . A MATLAB program is used to compute the parameters leading to the computation of the current electrons. The results are listed in Tables (7), and (8),  $\text{GaAs}/\text{N}_3$ , and  $\text{SnO}_2/\text{N}_3$  respectively.



Table (7) : Rate constant of electron transfer  $\Gamma_{CT}$  in N3/Ga AS with nine solvents in dye sensitized solar cell system.

Wave leng	Rate Constant of Electron Transfer $\Gamma_{CT}$										
	500nm	550nm	600nm	650nm	700nm	750nm	800nm	850nm	900nm	950nm	1000nm
	X10 <sup>-48</sup>	X10 <sup>-44</sup>	X10 <sup>-41</sup>	X10 <sup>-38</sup>	X10 <sup>-36</sup>	X10 <sup>-34</sup>	X10 <sup>-32</sup>	X10 <sup>-31</sup>	X10 <sup>-29</sup>	X10 <sup>-28</sup>	X10 <sup>-27</sup>
Solvent											
1-Butanol	0.061 5	0.039 8	0.058 2	0.027 0	0.051 1	0.047 1	0.024 2	0.076 9	0.016 3	0.024 8	0.0282
Acetone	0.189 4	0.121 6	0.176 2	0.081 1	0.152 1	0.138 8	0.070 5	0.221 6	0.046 5	0.069 7	0.0782
Ethanol	0.252 8	0.162 0	0.234 2	0.107 6	0.201 2	0.183 1	0.092 8	0.290 5	0.060 8	0.090 7	0.1014
Methanol	0.685 9	0.436 4	0.625 7	0.285 1	0.528 1	0.475 8	0.238 6	0.738 3	0.152 6	0.224 5	0.2471 0.2471
Formamid	0.197 6	0.126 9	0.183 7	0.084	0.158 5	0.144 5	0.073 4	0.230 6	0.048 4	0.072 5	0.0813

Table (8): Rate constant of electron transfer  $\Gamma_{CT}$  in N3/ SnO2 with nine solvents in dye sensitized solar cell system.

Wave leng	Rate Constant of Electron Transfer $\Gamma_{CT}$										
	500nm	550nm	600nm	650nm	700nm	750nm	800nm	850nm	900nm	950nm	1000nm

	$X10^{-48}$	$X10^{-44}$	$X10^{-41}$	$X10^{-39}$	$X10^{-36}$	$X10^{-34}$	$X10^{-33}$	$X10^{-31}$	$X10^{-30}$	$X10^{-29}$	$X10^{-28}$
Solvent											
1-Butanol	<b>0.015</b> 8	<b>0.010</b> 2	<b>0.010</b> 0	<b>0.070</b> 2	<b>0.013</b> 3	<b>0.012</b> 3	<b>0.063</b> 5	<b>0.020</b> 2	<b>0.043</b> 3	<b>0.066</b> 0	<b>0.0755</b>
Acetone	<b>0.048</b> 8	<b>0.031</b> 1	<b>0.045</b> 3	<b>0.209</b> 4	<b>0.039</b> 3	<b>0.036</b> 0	<b>0.184</b> 2	<b>0.058</b> 1	<b>0.122</b> 7	<b>0.184</b> 7	<b>0.208</b>
Ethanol	<b>0.064</b> 5	<b>0.041</b> 5	<b>0.060</b> 1	<b>0.277</b> 6	<b>0.052</b> 0	<b>0.047</b> 5	<b>0.242</b> 3	<b>0.076</b> 2	<b>0.160</b> 4	<b>0.240</b> 7	<b>0.2706</b>
Methanol	<b>0.174</b> 2	<b>0.111</b> 2	<b>0.160</b> 0	<b>0.732</b> 3	<b>0.136</b> 2	<b>0.123</b> 2	<b>0.621</b> 2	<b>0.193</b> 2	<b>0.401</b> 9	<b>0.595</b> 1	<b>0.6596</b>
Formamid	<b>0.051</b> 1	<b>0.032</b> 9	<b>0.047</b> 8	<b>0.220</b> 9	<b>0.041</b> 5	<b>0.038</b> 0	<b>0.194</b> 0	<b>0.061</b> 1	<b>0.129</b> 1	<b>0.194</b> 2	<b>0.2191</b>

**Discussion**

A theory have been used to study and investigation the electric properties according to evaluated the current of electron at N3/ GaAS and N3/ SnO2 system according on the quantum consideration transport theory. We assume the wave function for transmission of electron from dye to semiconductor are adabted in Hilbert space, and transmission of electrons flow happened due to the potential barrier at interface, when the electron at dye bring to interface with semiconductor state, the Fermi level for tow material much be coincident at equilibrium state according of the Fermi distribution function. Current of electrons  $\Gamma_{CT}(\text{Sec}^{-1})$  due to the interface of N3/ GaAS and N3/ SnO2 system in Eq. (17) describe the behaviour

of electron transport at interface. Due to Eq. (17) the flow of electrons has been occurring due to potential barrier at the overlap of the wave functions for the dye electrons state and electrons at semiconductor state. At the interface of the dye / semiconductor interface, the wave functions for donor and acceptor overlap. However, the potential of electrons between molecule of dye and semiconductor occurs, the electronic states at interface should have alignment energies.

For this reason, one can assumes the two material energy levels state are continuum levels for system because, the two material dye and semiconductor are different structures and electron state in dye different for semiconductor, and the density of electron on various dye surfaces has difrent than in conduction band of semiconductor. The current of electron  $\Gamma_{CT}(\text{Sec}^{-1})$  in Eq. (17) refers to the transition of electron depending on the transition energy, potential barrier, coupling coefficient matrix element ( $T_{Dye/Sem}$ ), concentration of electron, volume of unit cell for semiconductor  $V$ , penetration factor  $\beta$ , and temperature T(K) .

On the other hand, the physical natures for dye, and semiconductor are different thats shown to predict correctly the typical order of the magnitude of the values observed for the transition energies  $\Lambda(\text{eV})$  and current of electron  $\Gamma_{CT}(\text{Sec}^{-1})$

The coupling coefficient  $T_{Dye/Sem}$  (eV), have controlled the kinetics of charge transfer between the dye and semiconductor system and effected on the current density of electrons at systems. Also the electronic properties of semiconductor are markedly affected by the proximity of molecule dye surfaces, depending on the strength of the dye–semiconductor interaction .

Electronic strength was reflected that the capability to current density of electron is determined by the alignment of the levels state of semiconductor with respect to the dye Fermi energy. Data resultant of the currentt of electron  $\Gamma_{CT}(\text{Sec}^{-1})$  That is evaluated theoretically using Eq. (17) are listed in tables (7-8) for N3 /GeAs, and Ag/ SnO2 system. Current of electron become increasing when the coupling transition energy between dye and semiconductor system will be increasing that's shown from data in tables (3 to 4) and (7-8) for two system.

The present data for the current of electron that accrue in a dye/semiconductor system with more transition energies for both N3/semiconductor system for example  $\Gamma_{CT}(\text{Sec}^{-1}) = 0.0615$

$\times 10^{-48}$  when  $\Lambda$  (eV) = **0.32944492522** and  $\Gamma_{CT}(\text{Sec}^{-1}) = 0.6859 \times 10^{-48}$  when  $\Lambda$  (eV) = **0.39283290678492** for N3/ GaAs. The transition energy  $\Lambda$  (eV) is depending on the polarity function, this indicates that the transfer of electron is more probable in dye / semiconductor system have more polarity parameter. Not ably the system have large dielectric constant are stronger than system have small dielectric constant and vice versa.

In summary, the current electron at interface of dye/semiconductor depending on the transition energy and energy has to drive to cross from dye to semiconductor state.

## Conclusions

The dye-sensitized solar cell system has good conversion of solar energy into electricity if the current of electrons is large and vice versa. It is important to expanding search of energy technology devices exploiting the specific characteristics of this material structure for dye and semiconductor films. The improvement in the area of sensitizers for

dye sensitized solar cell devices have lead to dyes which absorb across the visible spectrum leading to higher current of electrons in system and resulting to higher efficiencies. The current of electrons at dye/semiconductor system results have been enabled us to elaborated and tested the system have its advantage to use or not in many applied . The development of dye sensitized solar cell holds additional to decreasing the potential barrier height at interface. In order to achieve a system with a high degree of current of electrons, and further cost reduction and simplification of the manufacturing of dye solar cells. It was important to choose systems have small potential barrier to enable to good electric properties behavior between dye and semiconductors.

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