Application of Dye-Sensitized Solar Cell (Dssc) from Polyurethane (Pu)/Diol-Nai Electrolyte with Activated Carbon (Ac) Composite Electrode

Mohd Hamizan Selamat [1], *Azizah Hanom Ahmad[1,2,]

Abstract— **Application of dye-sensitized photoelectrochemical cell (DSSC) was developed using bio-based hybrid polyurethane (PU) polymer and composite electrolyte of Sodium iodide as cation of charge transport. The conducting electron transport material for the regenerative mechanism for Redox couple (I-1/I-3) was due corrosion in contacts of electrode. The polymer as additive has leveraged conductivity level of PU-composite electrolyte prepared by varying amount of Sodium iodide (NaI) via solution casting technique. These properties of composite electrolyte exhibited photoelectrochemical cell that was least corrosive (Block Membrane) for bio-based polymer electrolyte. DSSC design of heterojunction cell requires essential need of functions such as light absorption, charge regeneration -separation and transport to electrodes for a complete cell to work. The addition of polymer composite electrolyte in the redox energy separation of electrical transport was effective for bulk material of the DSSC cell system. The electrical conductivity of electrolyte material was evaluated as fair (x10−5 S.cm-1) using electrical impedance (EIS) with efficiency performance of photo-electro conversion. The hybrid-dye-sensitized solar cell of PU-Cu/TiO2-dye/PU-NaI-I2/B-AC configuration gave a response under light intensity of 100 mW cm−2 with 3.9% conversion efficiency with current density, Jsc of 0.06 mA cm−2 and open circuit voltage, Voc of 0.14 V respectively**

***Index Terms*— Activated carbon, NaI, Polyurethane diol, Composite electrolyte, Electrical Impedance,DSSC, efficiency, electrode**

I. INTRODUCTION

Dye Sensitized Solar Cells (DSSC) technology using inorganic electrolytes post problem in solvent evaporation and iodine sublimation (corroding contacts) causing instability of cells. Application of low molecular oligomers is progressing recently for an improved performance [1-5]. The electrolyte system was aimed for improving electrochemical stability using quasi-solid-state electrolytes from organic capped polymers [11-13]. A photoelectrochemical cell was developed from bio-based polyurethane (PU) polymer electrolyte with Sodium iodide (NaI) as conducting electrolyte transport material.

[1]Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor D.E., Malaysia
[2]Institute of Science, Universiti Teknologi MARA, 40450 Shah Alam, Selangor D.E., Malaysia
(azizahanom@salam.uitm.edu.my)
*corresponding author

1.1 Dye-sensitized Solar Cell

Researchers for alternative flexible thin film solar cells are more recently based on organometal of composite based semiconductor. Solar cells based on monocrystalline silicon have reached efficiencies up to 25% while the highest efficiency of DSSC with metallic grids contacts were reaching 12% efficiency design. DSSC cell functionalities needs spectrum of light absorption, charge separation and transport of electron flow recombinant electrodes. Electrocatalyst of electron production and separation of electrical sources were combined within one bulk material as DSSC photoanode-electrode heterojunction cell. The electrical conductivity of system from composite electrolyte material was placed within band gaps electro-dynamic condition of redox Fermi energy transfer. Functional use of photoelectric performance and its efficiency with long term stability were obtained and suitable for DSSC applications where material properties must be individually optimized in views of performance of high photon to current conversion efficiency. Mesoporous structure of semicrystalline makes the fabrication easier and less expensive and low charge carrier in recombination of indirect band gap with low absorption electron coefficient. Thin film photoactive layers equated to absorb maximum sunlight intensity for the photoelectron generation with the addition of activated carbon. DSSC charge regeneration-separation and transport catalyst where the separation of electrical charges was assembled within one bulk device of DSSC hybrid system.

1.2 Electrolytes

Electrolytes play an essential role for the operation of DSSC for presence of a redox couple in the charge transfer as transient voltage commonly I-/I3- as diffusion mechanisms to restore/regenerate the oxidized dye molecules to ground state of equilibrium. The I3- ions were formed after the dye regeneration is reduced at the electrolyte to counter electrode using ions of I-. Electrolytes in DSSC were divided into three categories mainly based on their physical as liquid or quasi-solid (gel) and solid states. Liquid electrolytes have exhibited high conductivity and contributed high efficiencies of DSSC performance because of the low viscous materials composite with good pore filling in liquid-gel phase. The solvents used in the electrolyte post volatility where quasi-solid state electrolytes contribute to least usage of metals using hybrid composite material of solid electrolytes. [3-9]

II. MATERIALS AND METHOD

(a) Electrolyte preparation

The polyurethane-diol (PuD) was purchased from Sigma-Aldrich with 88% of purity and Sodium Iodide (NaI) was at 99.5% of purity. All the samples was prepared at room temperature (RT) and undergone the sonication and hydrothermal processes. The electrolyte of modified PuD-NaI was prepared at varied wt% for samples as shown in Table 3.0.

Table 3.0: Designation of varied wt% of PuD-NaI

Sample	% PuD	% NaI
A	1	0
B	0.9	0.1
C	0.8	0.2
D	0.7	0.3
E	0.6	0.4
F	0.5	0.5
G	0	1

(b) PU flexible substrate using RT preparation

The flexible DSSC design has the dssc protective functional layers from conventional substrate which was very brittle yet able to be cured in glass pane. Consequently, the high cost on the invention of DSSC hybrid organic systems of photoelectric devices is converging into flexible substrate or hybrid type for outdoor application. PU using applied substrate was peeled-off into flexible thick film with rational hybridization presented in this at RT. The prepared films were ready with self cured (Solvent-activated) transparent substrate to complete with the adhesion of electrodes systems reaction enclosure DSSC active electrode and composite electrolyte layers.

(c) Electrical Impedance Spectroscopy (EIS)

EIS was providing cole-cole plot graphical representation of frequency of complex frequency response determined for the circuit elements. A Zi or imaginary component was plotted on the vertical axis with Zr real components for the conductivity requirement of impedance analysis. The plot was for investigating the material electrical conductivity behaviour that possess one or more well separated electron transfer-relaxation process within comparable magnitudes (mV) perturbation [8-9] yielding semicircle shape of mammographic plot. Response plot of semicircle determines resistance Rb and Rs of the sample and Rc (coating resistance) can be measured by using equation below:

$Rc = Rb - Rs$ (1)

The conductivity, σ is subsequently calculated using the equation below:

$\sigma = 1/Rc$ (2)

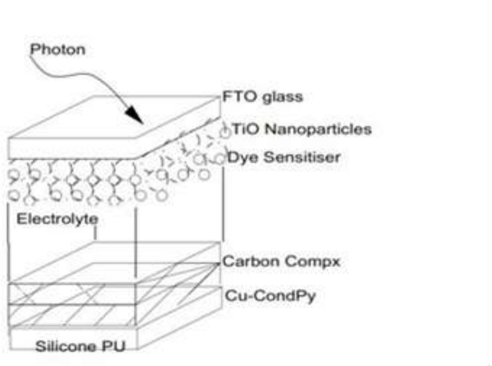

Fig. 1 DSSC cell diagram

(d) DSSC Fabrication

DSSC device was made of a multi-layered electrode structure consisting of a photoanode, electrolyte and counter electrode. The photoanode was formed by a TiO2 mesoporous layer deposited on a conducting glass (FTO glass) with a sensitizer dye (N719) embedded system for regeneration for photoelectron while the regeneration is supporting via redox function in liquid electrolyte for oxidation and reduction of electron towards the counter electrode. The flow of Fermi energy through wide band gap in oxide material contains a redox couple (I-/I3-) as the transient flow energy. The completed electrodes with Platinum catalyst where a layer of thin film on a FTO glass activated carbon coated organic-composite layer. The photoelectron conversion of photo catalytic synthesis process was presented in the heterojunction device. The energy flow in the TiO2, and the subsequent regeneration of the dye from the redox couple contained in the liquid electrolyte created potential for electrical dye molecules that absorb solar energy for photoelectron conversion.

III. RESULTS AND DICUSSION

3.1 Electrochemical Impedance Spectroscopy (EIS)

The samples of modified PuD-NaI was undergone EIS for characterization of conductivity of PuD-NaI gel electrolyte system measured with Hioki electrochemical impedance spectroscopy. Each sample was analyzed for resistance value and was taken placed through a semicircle analysis. The semi-circular evaluation represent the circuit evaluation to obtain the bulk resistance, Rb value in second intercept of total impedance plot as summarized in Table 2.

Table 2 The conductivity of modified PuD-NaI

Sample PuD (wt%)	Rb(Ω)	Rs(Ω)	Rc(Ω)	Σ(Scm-1)
A 1.0	2.33E+05	1.00E+04	2.23E+05	4.49E-06
B 0.9	2.75E+07	5.00E+05	2.70E+07	3.70E-08
C 0.8	1.26E+07	2.00E+05	1.24E+07	8.06E-08
D 0.7	1.35E+07	2.50E+05	1.33E+07	7.55E-08
E 0.6	1.30E+07	2.50E+05	1.28E+07	7.84E-08
F 0.5	1.48E+07	2.50E+05	1.45E+07	6.90E-08
G 0.0	7.05E+05	5.00E+03	7.00E+05	1.43E-06

All samples measured fair conductivity as calculated and summarized in Table 2. It can be seen that sample G showed the highest conductivity of 2.70 x 10-6 Scm-1 compared to the other samples. The electrolyte system was valued as separator of Rc that permited conductivity at a constantan factor of the evaluated gel-electrolyte performance. The conductivity analyses of samples were plotted in figure 2 as a graph of resistance versus wt% of PuD-NaI as shown.

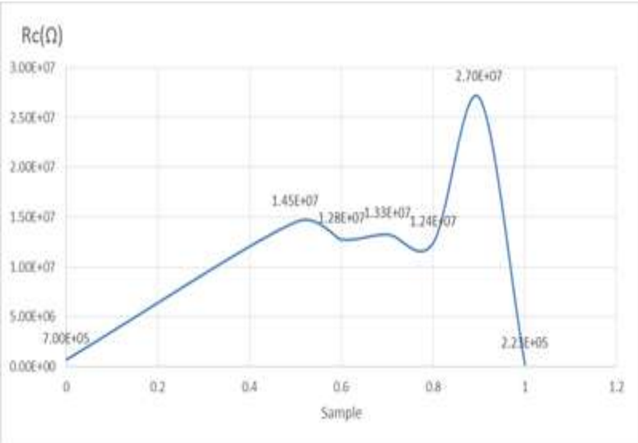

Fig. 2 Rc (ohm) versus wt% of modified PuD-NaI

The IPCE of electrode device material plot was viewed as in Table 3 and found respected conversion parameters values. The conductivity value obtained for CE1 as electrode was a better performance of IPCE with a conversion of 0.2%. The compared composite cells were studied using Pt electrode and Pthalocyanine dyes (ZnPc and CuPc) and has shown a comparable performance and IPCE plot determined performance was as is increasing in conductivity of CE composite system was determined by respected organic electrode composite used as efficient catalytic in electron transport system for DSSCs.

IV. CONCLUSIONS

Modified polyurethane-diol with NaI cations in the hydrothermal chemical reaction formed modified polyurethane-diol electrolyte. Conductivity studies carried out by EIS have proven the occurrence of polymer-salt complexation contributed structural of conductivity analysis as revealed that polyurethane electrolytes with 25 wt.% NaI was a semi-crystalline in characteristics. NaI-plasticized polyurethane and chemical structure of polyurethane-diol and NaI confirm iodide colocation using Fourier Transform Infrared spectroscopy. The highest Electrical Impedance value of conductivity of 8.06x10-5 S.cm-1 was achieved and resulted stable chemical reaction as shown in the Fourier Transform Infra-Red (FTIR). The redox Fermi energy was evaluated with performance of DSSC efficiency with stable cell. DSSC of FTO/TiO2-dye/PU-NaI-I2/Pt give a response under light intensity of 100 mW cm−2 indicated efficiency of 0.27% with photovoltaic effect of current density, Jsc of 0.06 mA cm−2 and open circuit voltage, Voc of 0.14 V respectively. These properties exhibited promising potentials for photoelectrochemical cell giving the focus on bio-based polymer electrolyte.

REFERENCES.

[1] Arof, A.K.; Aziz, M.F.; Noor, M.M.; Careem, M.A.; Bandara, L.R.A.K.; Thotawatthage, C.A.; Rupasinghe, W.N.S. and Dissanayake, M.A.K.L.; 2014; Efficiency enhancement by mixed cation effect in dye-sensitized solar cells with a PVdF based gel polymer electrolyte. International journal of hydrogen energy 39 : 2929 -2935

[2] Asim, N.; Sopian, K.; Ahmadi, S.; Saeedfar, K.; Alghoul, M.A.; Saadatian, O.; and Zaidi, A.; 2012 : A review on the role of material science in solar cells. Renewable and Sustainable Energy Reviews 16 : 5834–5847

[3] Chen, J.; Peng, T.; Shi,W.; Li, R. and Xia, J.; 2013 : An efficient binary ionic liquid based quasi solid state electrolyte for dye-sensitized solar cells. Electrochimica Acta 107 : 231–237

[4] Falco, C.; Sacco, R. and Verri, M.; 2010 : Analytical and numerical study of photocurrent transients in organic polymer solar cells. Computer Methods in Applied Mechanics and Engineering 199 : 1722–1732

[5] Lee J. and Yang M.,; 2013 : Progress in light harvesting and charge injection of dye-sensitized solar cells. Materials Science and Engineering B 176 :1142–1160

[6] Maçaira, J.; Andrade, L. and Mendes, A.; 2013: Review on nanostructured photoelectrodes for next generation dye-sensitized solar cells. Renewable and Sustainable Energy Reviews 27 : 334–349

[7] Pivrikas, A.; Neugebauer, H. and Sariciftci, N.S.; 2011 : Influence of processing additives to nano-morphology and effciency of bulk-heterojunction solar cells: A comparative reviee. Solar Energy 85 :1226–1237

[8] Sadoughi, G.; Mohammadpour, R.; Irajizad, A.; Taghavinia, N.; Dadgostar, S.; Samadpour, M.; Tajabadi, F.; 2013 : Improved charge collection efficiency of hollow sphere/nanoparticle composite TiO2 electrode for solid state electrolyte, Current Applied Physics 13 : 371-376

[9] Sethupathy, M.; Pandey, P. and Manisankar, P.; 2014: Photovoltaic performance of dye-sensitized solar cells fabricated with Polyvinylidene florideepolyacrylonitrile hybrid composite membrane. Materials Chemistry and Physics 143 : 1191-1198

[10] Sharma, G.D.; Balraju, P. and Kumar, M.; Roy, M.S. ; 2009 : Quasi solid state dye sensitized solar cells employing a polymer electrolyte and xanthene dyes. Materials Science and Engineering B 162 : 32–39

[11] Thavasi, V.,; Renugopalakrishnan, V.; Jose, R. and Ramakrishna, S.; 2009. Controlled electron injection and transport material interfaces in dye-sensitized solar cells. Materials Science and Engineering R 63 : 81–99

[12] Wang, Y.; Wei, W.; Liu,X.; Gu,Y.; 2012: Research progress on polymer heterojunction solar cells. Solar Energy Materials & Solar Cells 98 :129–145

[13] Xia, J. and Yanagida, S.; 2011. Strategy ro improve the performance of dye-sensitized solar cells; interface engineering principle. Solar Energy 85 ; 3143–3159