

## EFFECT OF SALT CONCENTRATION ON THE PERFORMANCE OF QUASI SOLID STATE DYE SENSITIZED SOLAR CELLS

G.S. Samarakkody\*, Y.M.C.D. Jayathilake, C.M. Bandaranayake, W.A.D.S.S. Weerasinghe  
and G.A.K.S. Perera

*Department of Electronics, Wayamba University of Sri Lanka, Kuliypitiya, Sri Lanka*  
*gresh.maya112180@gmail.com\**

### ABSTRACT

Gel polymer electrolytes have been developed to overcome some problems evolved with liquid and solid electrolytes. Their electrochemical properties can be considered as major factors which affect the performance of applications. This study was conducted to identify the dependence of salt concentration in a gel polymer electrolyte on the performance of dye sensitized solar cells. The concentration of 1-methyl-3-propylimidazolium iodide (1M3PII) was varied with the fixed amounts of poly(vinylidene fluoride)(PVdF), ethylene carbonate(EC) and propylene carbonate(PC) in the electrolyte composition. The performances of dye sensitized solar cells with those electrolytes were investigated. The electrolyte with the composition of 14.5 wt.% PVdF, 36.3 wt.% EC, 36.3 wt.% PC, 11.8 wt.% 1M3PII and 1.2 wt.% iodine shows the highest room temperature conductivity of  $3.55 \times 10^{-3} \text{ Scm}^{-1}$ . Salt concentrations which are lower and higher than this value result in lesser conductivities. The dye sensitized solar cells fabricated with this electrolyte exhibits the highest performances with an efficiency of 3.31 %, short circuit current density of  $9.42 \text{ mAcm}^{-2}$ , open circuit voltage of 602.2 mV and fill factor of 0.58. This confirms that salt concentration of the electrolyte has a great effect on the performance of DSSCs.

**Keywords :** Gel polymer electrolytes, Dye sensitized solar cells, Current-voltage characteristics, 1-methyl-3-propylimidazolium iodide.

### 1. INTRODUCTION

Basically, a gel polymer electrolyte (GPE) is consisting with a polymer, a salt and a solvent or a mixture of solvents. While polymer provides mechanical strength, salt and solvents directly accounts for the conduction of the electrolyte.<sup>1</sup> Low vapor pressure, good long term

stability and the high ionic conductivity are some advantages of GPEs which lead for several electrochemical applications like super capacitors, batteries and solar cells.<sup>2,3</sup>

Dye sensitized solar cells (DSSCs) belong to one class of solar cells. They employ a dye as a sensitizer for the process of converting solar energy into electricity. At present, a great deal of research activities is being done on DSSCs having a GPE as the electrolyte. The configuration of a DSSC is fluorine doped conductive tin oxide (FTO) glass/TiO<sub>2</sub>/dye/electrolyte/Pt/glass.<sup>3</sup> In this study, it was attempted to study the effect of salt concentration on the performance of DSSCs.

## 2. EXPERIMENTAL

### 2.1 Preparation and characterization of GPEs

Poly(vinylidene fluoride) (PVdF, 534 000MW), 1-methyl-3-propylimidazolium iodide (1M3PII, 98%), ethylene carbonate (EC, 98%), propylene carbonate (PC, 99%) and I<sub>2</sub> purchased from Aldrich were used without purification. Required amount of starting materials were weighed and stirred magnetically for some time. GPE films were prepared by heating the mixture of PVdF, EC, PC and 1M3PII at 100 °C for 20 min. The resulting homogeneous, viscous solution was poured and pressed in between two well cleaned glass plates. It was kept in a desiccator for about 24 h. Different electrolyte samples were prepared by varying the salt concentrations with the fixed amounts of PVdF, EC and PC. A circular shaped GPE film was loaded inside a sample holder and the impedance measurements were taken in the frequency range from 0.01 Hz to 400 KHz by using the Metrohm Autolab M101 impedance analyzer from 28 °C to 55 °C.

### 2.2 DC polarization test

The dc polarization tests were carried out at the room temperature for the sample which showed the highest room temperature conductivity, in order to find the nature of the conductivity of the GPE. Sample was loaded between two stainless steel (SS) blocking electrodes first and then, between two non-blocking iodine electrodes. The measurements of current drop with time were taken by applying a dc bias voltage of 1V.

### 2.3 Fabrication and characterization of DSSCs

Titaniumdioxide (TiO<sub>2</sub>), Triton X, acetic acid and ethanol were ground well and the resultant was spread on a pre-cleaned, fluorine doped tin oxide (FTO) glass plate using the doctor blade technique. It was sintered at 450 °C for 45 minutes. Then, the films were allowed to

cool down and were dipped in Ruthenium dye for a period of 24 h. The DSSCs were fabricated by sandwiching the GPEs in between the dye sensitized TiO<sub>2</sub> electrode and Pt coated glass by using the configuration of glass/FTO/TiO<sub>2</sub>/dye/GPE/Pt/glass for the samples of GPEs which had different salt concentrations. The photocurrent-voltage characterization was done under the illumination of 100 mWcm<sup>-2</sup>.

### 3. RESULTS AND DISCUSSION

#### 3.1 Influence of salt concentration on conductivity of GPE

Conductivity ( $\sigma$ ) was calculated using the equation,

$$\sigma = \frac{t}{R_b \cdot A} \quad (1)$$

where  $t$  is the thickness of the polymer electrolyte,  $R_b$  is the bulk electrolyte resistance which is obtained from the Nyquist plot and  $A$  is the area of the GPE.

Figure 1 shows the variation of the ionic conductivity at 28 °C with the salt concentration. The ionic conductivity increases and attains a maximum value of  $3.55 \times 10^{-3} \text{ Scm}^{-1}$  at the salt concentration of 11.8 wt. %. Then the ionic conductivity decreases with further increment of salt concentration.

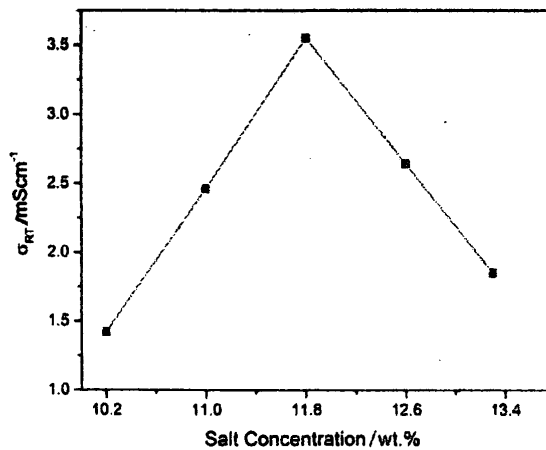


Figure 1: Room temperature conductivity variation of GPEs.

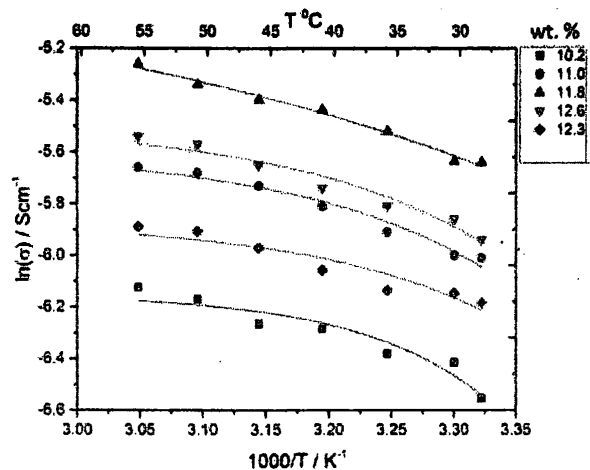


Figure 2: Temperature dependence of the conductivity.

Increasing salt concentration may enhance charge carrier concentration resulting higher conductivity. However, higher amount of salt may lead to the enhancement of the viscosity of GPE. This retards the mobility of charge carriers reducing conductivity.<sup>4</sup>

The conductivity-temperature correlation of GPEs with different salt concentrations is exhibited in Figure 2. This behavior evidences the fact that conducting mechanism takes place via the free volume theory explained by Vogel-Tamman-Fulcher (VTF) equation.<sup>5</sup>

$$\sigma = AT^{1/2} \exp\left[\frac{E_a}{(T-T_0)}\right] \quad (2)$$

where,  $T_0$  is the glass transition temperature of the polymer electrolyte,  $T$  is the absolute temperature,  $A$  is the n pre-exponential factor and  $E_a$  is the activation energy.

### 3.2 DC polarization test

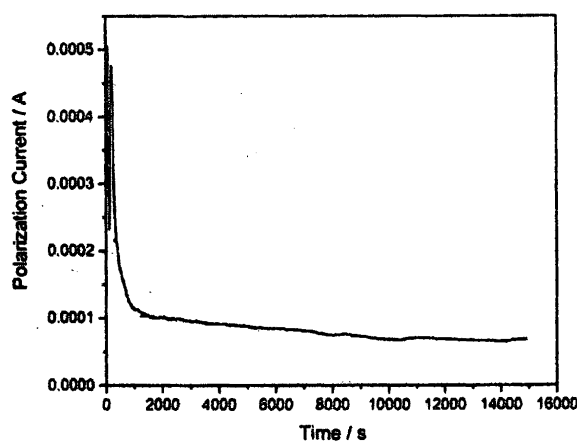


Figure 3: DC polarization results with blocking electrodes.

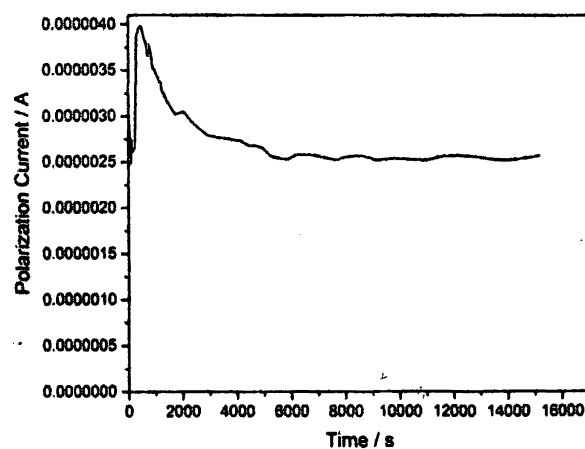


Figure 4: DC polarization results with non-blocking electrodes.

DC polarization test curves with blocking and non-blocking electrodes are shown in Figure 3 and Figure 4 respectively. The value of ionic transference number was found to be 0.87. High ionic transference number hints that ion contribution for the conductivity is higher than electron contribution. The calculated anionic transference number was 0.65. This high value, confirms that anionic contribution is higher than the cationic contribution. This can be expected due to the bulky size of the cation in the salt which is less mobile.<sup>3</sup>

### 3.4 Performances of the DSSC

Fill factor (FF) and energy conversion efficiency ( $\eta$ ) were calculated using the following equations.

$$FF = \frac{V_{MPP} \cdot J_{MPP}}{V_{OC} \cdot J_{sc}} \quad (3)$$

$$\eta = J_{sc} \cdot V_{OC} \cdot FF \quad (4)$$

where  $V_{MPP}$  is the voltage at maximum power point,  $J_{MPP}$  is the current density at maximum power point,  $J_{SC}$  is the short circuit current density and  $V_{OC}$  is the open circuit voltage.

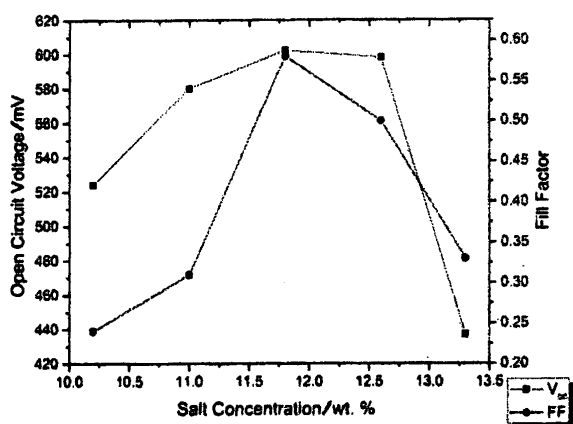


Figure 5: Variation of  $V_{OC}$  and FF with the salt concentration of the GPEs.

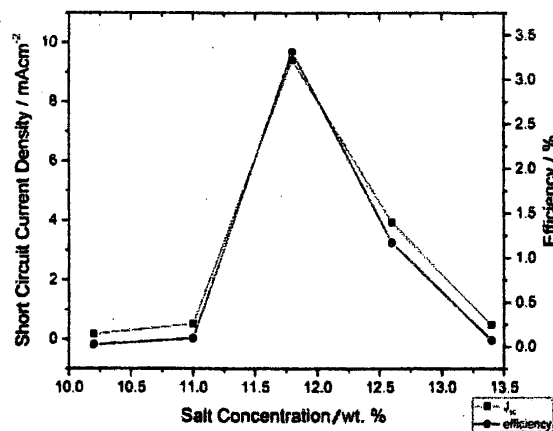


Figure 6: Variation of  $J_{SC}$  and  $\eta$  with the salt concentration of GPEs.

Figures 5 and 6 exhibit the variations of  $V_{OC}$ ,  $J_{SC}$ , FF and  $\eta$  with salt concentration. The highest solar cell performance is shown by the DSSC with the electrolyte containing a salt concentration of 11.8 wt. %. This GPE is corresponding for showing the highest conductivity at 28 °C. That means, all the DSSC parameters are strongly depending on the conductivity of the GPE.

The ionic conductivity is assumed to be governing the short circuit current density.<sup>5</sup> As iodide ions are the main contributors to the ionic conductivity in GPE, they play a major role in determining the  $J_{SC}$ . It can be seen that the variation of the efficiency is in parallel with short circuit current density. These results show that the efficiency variation is strongly depending on the variation of  $J_{SC}$ .<sup>2</sup>  $V_{OC}$  values are nearly equal to each other and all are of high values. This may be due to the high anionic contribution with the salt having the bulky cation as observed from DC polarization test.

#### 4. CONCLUSION

The GPE of which the composition is 14.5 wt.% PVdF, 36.3 wt.% EC, 36.3 wt.% PC, 11.8 wt.% 1M3PII showed the highest the conductivity of  $3.55 \times 10^{-3} \text{ Scm}^{-1}$  at 28 °C. It is purely an ionic conductor having appreciable anionic conductivity. This is an essential requirement to serve as an electrolyte in DSSC having a  $I^- / I_3^-$  redox couple. And DSSC fabricated with it exhibited the highest performances, where efficiency is 3.31 % with  $J_{SC}$  of  $9.42 \text{ mAcm}^{-2}$ ,  $V_{OC}$

of 602.2 mV and FF of 0.58. This evidences the fact that salt concentration of the GPE is affecting the performance of DSSCs.

### ACKNOWLEDGEMENTS

Authors wish to thank the assistance given by Wayamba University of Sri Lanka under the research grant SRHDC/RP/04/13/01 and National Research Council of Sri Lanka under the research grant NRC 12-109.

### REFERENCES

- [1]. Kumar, M., Sekhon, S.S., *International Journal of Ionics*, 8 (2002) 223.
- [2]. Yusuf, S.N.F., Aziz, M.F., Hassan, H.C., Bandara, T.M.W.J., Mellander, B.E., Careem, M.A., Arof, A.K., *Journal of Chemistry*, 2014 (2014) 1.
- [3]. Agrawal, R.C., *Indian Journal of Pure & Applied Physics*, 37 (1999) 294-301.
- [4]. Radha, K.P., Gurulakshmi, G., *International Journal of Scientific Research*, 4 (2015) 420.
- [5]. Yang, H., Huang, M., Wu, J., Lan, Z., Hao, S., Lin, J., *Material Chemistry and Physics*, 110 (2008) 38.
- [6]. Jawad, M.K., Al-Ajaj, E.A., Suhail, M.H., Majid, S.R., *Advances in Physics Theories and Applications*, 34 (2014) 51.