

Impact of K⁺ cation with tetramethyl ammonium iodide salt in PVA based gel polymer electrolytes for DSSCs efficiency

Mohd Fareezuan Abdul Aziz^{1,2,3*}, Mohd Asyadi², Azam², Mohd Hamdi Ali@Buraidah³, Abdul Kariem Arof³

¹Centre for Research and Management, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

²Fakulti Kejuruteraan Pembuatan, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

³Centre for Ionics University Malaya, Department of Physics, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia

*Corresponding e-mail: fareezuan@utem.edu.my

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ABSTRACT – Polyvinyl alcohol (PVA)-based gel polymer electrolytes (GPEs) with the incorporation of tetramethyl ammonium iodide (TMAI) - potassium iodide (KI) salts have produced. The main idea is to investigate the combination of two iodide salts affect the ionic conductivity and DSSCs efficiency. The GPE consists of TMAI salt only shows the conductivity of 1.72 mS cm⁻¹. However, the addition of 70 wt. % KI in GPEs improve the conductivity of 7.87 mS cm⁻¹. DSSCs with GPE contains 30 wt. % of TMAI – 70 wt. % of KI show efficiency of 5.02 % compare with GPE consist of 100 wt. % TMAI show efficiency of 2.92 %.

1. INTRODUCTION

Generally, solar cell devices proposed into three generations: first, second, and third. The first-generation solar cells as the silicon-based type (efficiency of 25%) [1]. Thin-film solar cells known as second-generation solar cells [2]. Dye-sensitized solar cells (DSSCs) are in third-generation solar cells, promising a high converting the light to electric power efficiency [3].

A typical DSSCs structure consists of three essential parts: platinum counter electrode, electrolyte as a redox mediator, and TiO₂-Dyed working electrode [4]. Some research used the GPEs with single iodide salt as redox mediator. However, GPEs with single iodide salt shows low ionic conductivity and low efficiency in DSSCs fabrication. The main highlight in this work is to investigate the combination of two iodide salt system instead of using only one iodide salt system shows better conductivity and DSSCs efficiency [5-7].

2. METHODOLOGY

2.1 Materials and GPEs designation

Polyvinyl alcohol (PVA), tetramethyl ammonium iodide (TMAI), potassium iodide (KI), ethylene carbonate (EC) and propylene carbonate (PC) have bought from Sigma Aldrich company. Dimethyl sulfoxide (DMSO) solvent has purchased from Friendemann Schmidt Chemicals. Titanium dioxide (TiO₂) powder (P90 and P25) have acquired from Aerioxide company. Ruthenium N3 dye and Platinum (Pt) solution have bought from Solaronix. Table 1 shows that the designation of the GPEs with various

combinations of TMAI:KI salts used in this work.

| Sample | TMAI:KI (wt. %) |
|--------|-----------------|
| G1 | 100:0 |
| G2 | 70:30 |
| G3 | 50:50 |
| G4 | 30:70 |
| G5 | 0:100 |

2.2 Electrical Impedance Spectroscopy

Impedance measurement for each gel polymer electrolyte was measured by using an AC impedance bridge, HIOKI LCR Hi-Tester, in the frequency range between 1 Hz and 100 kHz. Conductivity was calculated using the following equation:

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

where, t is the thickness of GPE, R_b is the bulk resistance which can be observed from the x-axis intersection of the Nyquist plot, and A is the contact surface area of gel polymer electrolyte.

2.3 DSSCs fabrication and parameters

The DSSCs were fabricated by configure the GPEs in between of working electrode and platinum electrode. DSSCs was tested under light with intensity power of 1000 W m⁻² and J-V characteristics were obtained using Keithley 2400 source meter. The conversion efficiency of DSSCs can be derived from this equation:

$$\eta (\%) = \frac{V_{oc} J_{sc} ff}{P_{in}} \times 100\% \quad (2)$$

where V_{oc} is the open-circuit voltage, J_{sc} is short-circuit current density, ff is fill factor and P_{in} is the incident light power.

3. RESULTS AND DISCUSSION

3.1 Ionic conductivity measurement

Ionic conductivity is determined from the Nyquist plot which is obtained from electrical impedance spectroscopy measurement. Figure 1 shows the graph of ionic conductivity versus weight percentage amount of TMAI-KI salt at 25 °C. From the graph, the ionic conductivity is 1.72 mS cm⁻¹ for GPE contain 100 wt. %

of TMAI. The graph trend shows an increasing trend due to the influence of K^+ cation from the KI salt in the GPEs system.

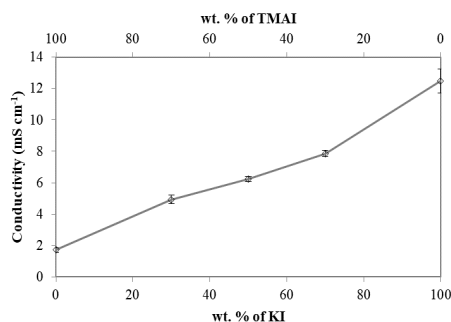


Figure 1: Conductivity versus wt. % of KI and TMAI

From the graph also show that the GPE with 100 wt. % KI has the highest conductivity at 12.48 mS cm⁻¹, as reported previously [8]. However, GPE with 30 wt. % TMAI – 70 wt. % KI show conductivity of 7.87 mS cm⁻¹ higher than GPE with 70 wt. % TMAI – 30 wt. % KI which is show conductivity of 4.94 mS cm⁻¹. The high conductivity in GPEs has probability of high DSSCs efficiency [7].

3.2 DSSCs fabrication and parameters

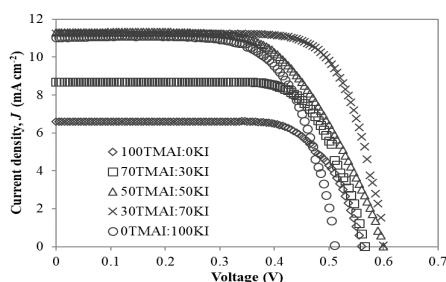


Figure 2: J - V curves for DSSCs fabrication

The current density-voltage, J - V curves for DSSCs utilize all GPEs are presented in Figure 2. Table 2 tabulated the DSSC parameters using GPE with varying amounts of TMAI-KI salts. Short-circuit current density, J_{sc} was obtained in the range of 6 to ~11.30 mA cm⁻². The short-circuit current density, J_{sc} proved an increase from 6.60 mA cm⁻² for DSSC using G1 sample to 11.30 mA cm⁻² for DSSC using G4 sample. The open-circuit voltage, V_{oc} which is measured the gap between redox potential of GPE with the Fermi level of TiO₂ layer, has shown that the range is between 0.50 to 0.60 V. Fill factor, ff show by all DSSCs is exhibit nearly of 60-80 %. G4's DSSCs show that the efficiency of 5.02 % is the highest compared to the other DSSCs samples. It indicates that the existence of KI salt improves conductivity and DSSCs performance [7].

Table 2 DSSCs parameter

| Sample | J_{sc} , mA cm ⁻² | V_{oc} , V | ff | η , % |
|--------|--------------------------------|--------------|------|------------|
| G1 | 6.60 | 0.56 | 0.79 | 2.92 |
| G2 | 8.70 | 0.57 | 0.74 | 3.67 |
| G3 | 11.20 | 0.60 | 0.61 | 4.10 |
| G4 | 11.30 | 0.60 | 0.74 | 5.02 |
| G5 | 11.03 | 0.51 | 0.68 | 3.83 |

4. CONCLUSIONS

Gel polymer electrolytes containing different amounts of TMAI-KI salt were prepared. The GPEs have been characterized by using electrical impedance spectroscopy analysis. G1 (100 wt. % of TMAI) salt has a conductivity of 1.72 mS cm⁻¹. The presence of KI salt effect the GPEs conductivity. G4 (30 wt. % TMAI – 70 wt. % KI) show conductivity of 7.87 mS cm⁻¹ higher than G1 sample. The DSSC employing G4 exhibited the highest efficiency of 5.02 %. Thus it is inferred that the combination of KI and TMAI salt had improvement in the ionic conductivity of GPEs thus enhanced the DSSC efficiency.

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