Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 148 (2016) 100 – 105

Procedia Engineering

www.elsevier.com/locate/procedia

4th International Conference on Process Engineering and Advanced Materials

Binary Ionic Liquid Electrolyte for Dye-Sensitized Solar Cells

Siti Munirah Mhd Yusof[a], Wan Zaireen Nisa Yahya[a, *]

[a] *Chemical Engineering Department, Universiti Teknologi PETRONAS, Bandar Seri Iskandar, 32610, Perak, Malaysia*

Abstract

Binary ionic liquid composed of 1-propyl-3-methylimidazolium iodide (PMII) and 1-butyl-3-methylimidazolium thiocyanate (BMISCN) were mixed at four different ratios to study its effect on the dye-sensitized solar cells' (DSSCs) efficiency. The addition of low viscosity ionic liquid which is BMISCN is to overcome the low mass transportation of iodide/triiodide faced by pure PMII. Therefore, the effect of mixing different ratios of these ionic liquids on the viscosity and triiodide diffusion coefficient were studied and the best ratio was identified. Based on the experimental work, the mixture of BMISCN with PMII of higher viscosity has allowed reducing the mass transport limitation of tri-iodide in the electrolyte as the effect of lowering the overall ionic liquid's viscosity. The binary electrolyte PMII: BMISCN (1:0.75) give the highest power conversion efficiency of 1.89 %, with a fill factor of 0.47, open circuit voltage of 0.62, and short circuit current density of 6.52 mA/cm^2 and triiodide diffusion coefficient of 8.47×10^{-7} cm^2 s^{-1}. This work has provided valuable insight for further development of binary ionic liquid electrolyte for DSSCs.

Peer-review under responsibility of the organizing committee of ICPEAM 2016

Keywords: ionic liquid electrolyte; dye-sensitized solar cells; viscosity; triiodide diffusion coefficient

1. Introduction

Dye-sensitized solar cells (DSSCs) are becoming appealing option to researchers and industry for potential energy production. It is due to its potential low-cost with reasonably high efficiency compared to the conventional Si

Peer-review under responsibility of the organizing committee of ICPEAM 2016
doi:10.1016/j.proeng.2016.06.453

and thin film cell [1]. There are three major components of DSSCs which are the semiconductor, the dye and the electrolyte. According to Yu [2], the electrolyte is responsible for the inner charge carrier transport between electrodes. It consists of a redox couple such as iodide/triiodide and/or additives dissolved in a solvent. The iodide/triiodide ions continuously regenerate the dye and itself during DSSCs operation. After the iodide ion in the electrolyte reduce the excited dye, it dissociates when a second iodide comes in forming di-iodide radicals. Then, the diiodide radicals react to from triiodide and iodide. The regeneration cycle of electrolyte is completed by the conversion of triiodide to iodide ions at the counter electrode.

Incipiently, the organic solvents were commonly used in the electrolyte for DSSCs due to its high efficiency in producing energy. The highest DSSCs efficiency by using organic solvents recorded is about 12% [2]. However, as stated by Kawano et al. [3] and supported by Yu[2], the high volatility of the solvents caused them to evaporate under thermal stress and causes deterioration of the cell over prolonged use. Therefore, ionic liquid solvents have been pursued as promising electrolyte as they possess good chemical and thermal stability, high ionic conductivity, tuneable viscosity and also low volatility [4].

Imidazolium-based ionic liquids have almost dominated the research of ionic liquid-based electrolyte due to high photovoltaic performance of the solar cells. However, the high viscosity of this ionic liquid limits the transportation of triiodide in the electrolyte. As a consequence, binary ionic liquid electrolyte has been introduced to overcome the problem. Low-viscosity ionic liquid is mixed with imidazolium iodide to achieve higher efficiency of DSSCs. In most study, thiocyanate (SCN)-based ionic liquid is mixed with imidazolium based ionic liquid in ratio of 13:7 [5] and 12:8 [6]. Until now, there is no study which indicate the best ratio of these ionic liquids that could give high DSSCs efficiency.

For that reason, the ratio of binary ionic liquid composed of PMII and BMISCN were examined over four different ratios and its effect on the viscosity and the triiodide diffusion coefficient were studied. By analysing the photovoltaic performance of the DSSCs, the best ratio of the binary ionic liquid that optimize the efficiency was identified.

2. Experimental

2.1 Materials

1-butyl-3-methylimidazolium thiocyanate (purity of ≥95%), lithium iodide, LiI (purity of 99.99%) and iodine, I_2 (purity of 99.8%) were purchased from Sigma Aldrich. The ionic liquid PMII was synthesized similar to the procedure proposed by Kim et al. [7]. 0.1 mol (8 ml) of 1-methylimidazole was dissolved in 80 ml of THF and 0.106 mol (10.4 ml) of 1-iodopropane was added to the solution. The mixture was refluxed with vigorous stirring at 50 °C for 20 hours and cooled down to room temperature. Then, the mixture was extracted with THF then with ethyl acetate. The solvents are removed and dried in rotary evaporator under reduced pressure. A yellow colour liquid was isolated. with a yield of 85.3%. NMR Spectroscopy analysis was performed to confirm the chemical structure of the ionic liquid. ^{1}H NMR (500 MHz, D_2O, 25 °C): δ (ppm) = 8.8 [s, 1H], 7.5 [s, 1H], 7.4 [s, 1H], 4.1[t, 2H], 3.9[s, 3H], 1.8[m, 2H], 0.8[t, 3H].

2.2 Mixture preparation

PMII and BMICSN were mixed at four different volume ratios which are 1:0.25, 1:0.5, 1:0.75 and 1:1. 2.0 M I_2 and 2.0 M LiI were added into these binary ionic liquids.

2.3 Viscosity Measurement

Viscosity of the ionic liquids were measured by using Brookfield Viscometer. The measurement was carried out at room temperature and speed of the rotating spindles were maintained at 250 rpm for all ionic liquids.

2.4 Determination of triiodide diffusion coefficients

Electrochemical Impedance Spectroscopy (EIS) was used to measure the triiodide diffusion coefficient. The