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염료감응형 태양전지에서의 고분자 전해질 종류에 따른 이온전도도와의 상호관계

차 시영[1], 김 수진[2], 이 용건[3], 강 용수[4]

The correlation between ionic conductivity and cell performance with various compositions of polymer electrolyte in dye-sensitized solar cells

SiYoung Cha[1], SuJin Kim[2], YongGun Lee[3], YongSoo Kang[4]

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Abstract : Poly(ethylene glycol) dimethyl ether (PEGDME)/fumed silica/ 1-methyl -3-propylimidazolium iodide (MPII)/I_2 mixtures were used as polymer electrolytes in solid state dye-sensitized solar cells (DSSCs). The contents of MPII were changed and the concentration of I_2 was fixed at 0.1 mole% with respect to the MPII. The maximum ionic conductivity was obtained at [EG]:[MPII]:[I_2]=10:1.5:0.15. It was supposed that the maximum of ionic conductivities would match with that of cell efficiencies, if the ionic conductivity is a rate determining step in the solid state DSSCs. However, the maximum composition did not show the maximum solar cell performance, indicating the mismatch between ionic conductivity and cell performance. This suggests that the ionic conductivity may not be the rate controlling step in determining the cell efficiency in these experimental conditions, whereas other parameters such as the electron recombination might play an important role. Thus, we tried to modify the surface of the TiO_2 particles by coating a thin metal oxide such as Al_2O_3 or Nb_2O_5 layer to prevent electron recombination. As a result, the maximum of the cell efficiency was shifted to that of the ionic conductivity. The peak shifts were also attempted to be explained by the diffusion coefficient and the lifetime of electrons in the TiO_2 layer.

1. Introduction

Dye-sensitized solar cells (DSSCs) have attracted over the past decade due to a low production cost and high energy conversion efficiency (~11%) employing liquid lectrolyte. However, the leakage, evaporation of solvent and high temperature instability of the liquid electrolyte causes a drawback for long-term practical applications. To resolve theses problems, many efforts has been made to replace the liquid electrolytes with solid media. Especially, polymer electrolytes have some advantages such as good mechanical strength, long term stability, but have low photovoltaic

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1) 한양대학교
E-mail : wpf12@nate.com
Tel : (02)2296-2968 Fax : (02)2296-2969
2) 한양대학교
E-mail : sjvita@nate.com
Tel : (02)2296-2968 Fax : (02)2296-2969
3) 서울대학교
E-mail : egyg23@dreamwiz.com
Tel : (02)2296-2968 Fax : (02)2296-2969
4) 한양대학교
E-mail : kangys@hanyang.ac.kr
Tel : (02)2296-2968 Fax : (02)2296-2969

performance because of poor contact between electrolyte and electrode and low ionic conductivity. In this paper, it is investigated the correlation between ionic conductivity and cell performance with various compositions of polymer electrolyte in solid state DSSCs.

2. Experimental section

2-1 Cell fabrication

Dye sensitized solar cells were fabricated with the published method. Nanoporous TiO_2 films were prepared on tranparent conductive oxide(TCO) from TiO_2 nanoparticles (P25, STI TiO_2 paste)by annealing at 450℃ in air for 30 minutes. Dyes were adsorbed by dipping the film into a solution containing 0.3mM Ru dye$(Bu_4N)_2[Ru(Hdcbpy)_2(NCS)_2]$ (known as N 719, solaronix). Solar cells were made by placing a Pt-sputtered TCO on the TiO_2 film, and the electrolyte was introduced as casting on TiO_2 film. Typical cell area was approximately 0.16cm^2. The standard electrolyte consisted of PEGDME, fumed silica, 1-methyl-3-propylimidazolium iodide (MPII) and I_2 in acetonitrile.

2-2 I-V measurement

The I-*V* curves were measured at AM 1.5 illumination using a Keithley Model 2400source measure unit. A 500 W xenon lamp (Oriel, 91193) served as the light source.

2-3 Electrochemical impedance spectroscopy.

The symmetric cell was constructed with two platinum coated glasses faced with two conducting sides and polymer electrolyte was employed between two electrodes . The space in between the electrodes was divided imide tape with thickness of 50 µm . The area of the symmetric cells was 0.25cm^2.

Electrochemical impedance spectroscopy was measured using IM6.

3. Results

3-1 Correlation between ionic conductivity and charge trnasfer resistance

The maximum ionic conductivity was obtained at [EG]:[MPII]:[I2]=10:1.5:0.15 through poly(ethylene glycol) dimethyl ether (PEGDME)/fumed silica/ 1-methyl-3- propyl imidazolium iodide (MPII) / I_2 polymer electrolytes. When these electrolytes were employed in dye-sensitized solar cells, the peak positions of both the ionic conductivity and the cell performance were not matched each other, suggesting that parameters other than the ionic conductivity such as electron recombination would also play an important role in determining the efficiency. By modifying the surface of the TiO_2 particles with thin metal oxide to prevent electron recombination, the peak of the ionic conductivities was shifted, to some extent, to that of the cell efficiency.

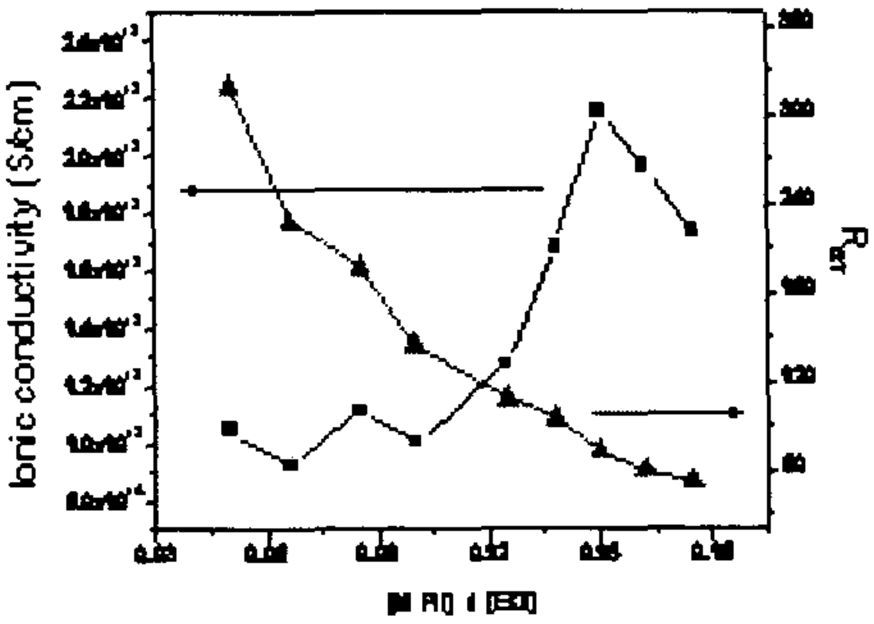

Fig. 1 Influence of MPII concentration on the ionic conductivity (at 30℃) and charge transfer resistance of the polymer electrolyte, the content of I_2 was 10wt% of MPII. Fig. 1 shows the dependence of the ionic conductivity and charge transfer resistance on the MPII

concentration in the polymer electrolyte. The ionic conductivity increased and reached the maximum value. At 30℃, the highest ionic conductivity about 2.2×10^{-3} S cm^{-1} was obtained when the polymer electrolyte contained 3.58M MPII. Then the ionic conductivity decreased with the increase in the concentration of MPII. The initial increase in the ionic conductivity is attributed to the build up of charge carriers[10]. A further increase in the MPII concentration produces a decrease in the ionic conductivity due to the formation of ion pairing that reduced the mobility of the ions[11]. However, charge transfer resistance (R_{CT}) decreased steadly with increasing the concentration of MPII due to increasing amount of ions with increasing MPII concentration and fast ion transfer at interface between electrolyte and Pt electrode.

4. Conclusion

In conclusion, we have demonstrated correlation between ionic conductivity and charge transfer resistance with various compositions of polymer electrolyte in DSSCs. Charge transfer resistance has a resonable correlation with ionic conductivity according the concentration of MPII in this experimental condition. However, further investigation was performed in a mean time, the behaviour of cell efficiency was hardly related with ionic conductivity.

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