Electron Transport Kinetics in Solid State Dye-sensitized Solar Cells Utilizing Polymer Electrolyte

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Dye-sensitized solar cells (DSCs) based on meso-porous TiO_2 photoanode and solid-state polymer electrolytes (SPE) are emerging as low cost alternatives to conventional inorganic photovoltaic devices. Therefore, there have been several attempts to improve the power conversion efficiencies of DSCs utilizing SPE because solid state DSCs have many advantages over liquid state ones such as solvent problems and long-term stability except the power conversion efficiency. In solid state DSCs utilizing polymer electrolyte, poor contact between dyes and electrolyte could be one of the most serious problems lowering the power conversion efficiency mostly due to the shallow penetration of polymer electrolyte through meso-pores of TiO_2 layer.

Table 1. Photovoltaic parameter of the DSCs based on liquid electrolyte and SPE with TiO_2 layer, as determined from J-V curves

Electrolyte	TiO_2 layer/4μm	V_{OC}/V	J_{SC}/mAcm$^{-}_{2}$	FF	Eff./%
Liquid	1	0.77	9.1	0.73	5.1
	2	0.74	12.7	0.73	6.8
	3	0.68	14.2	0.71	6.9
	4	0.67	13.1	0.71	6.3
Polymer	1	0.76	7.8	0.73	4.3
	2	0.75	10.5	0.73	5.8
	3	0.71	10.9	0.71	5.4
	4	0.70	9.5	0.71	4.7

There have been several different approaches to overcome the poor contact problems with a given thickness of the photoanode TiO_2 layer. For instance, oligomeric electrolyte was used during cell preparation and subsequently polymerized to make the oligomers the solid state polymers.[1] Several different approaches to increase the ionic conductivity of polymer electrolyte have also been widely investigated by utilizing copolymer,[2] the cross-linking,[3] and so on.

In this paper, the photoanode thickness for solid state DSCs utilizing solid polymer electrolyte is optimized to improve the power conversion efficiency by comparing results with the liquid state DSCs. A possible mechanism for different behavior between those electrolytes is also suggested, based on the measurement for the electron diffusion coefficient and lifetime.

The characteristic J-V results illustrate that the liquid electrolyte-based DSCs show higher J_{SC} and efficiency than the SPE-based DSCs. Interestingly, the SPE-based DSCs have the similar electron lifetime with the liquid ones except 4 layered TiO_2 film. As previous reported, the V_{OC} is however decreased with the TiO_2 thickness in the both states of electrolytes. The low J_{SC} in the solid state DSCs seems to be mostly associated with the low ionic diffusion coefficient of SPE. The highest efficiency and J_{SC} in the solid state DSCs are obtained from the thinner thickness than the liquid DSCs. This difference in the efficiency of the DSCs suggests us to use a rather thin layer of photoanode for the solid state DSCs to improve the power conversion efficiency.

[1] (a) Kim, Y. J.; Kim, J. H.; Kang, M. S.; Lee, M. J.; Won, J.; Lee, J. C.; Kang, Y. S., Supramolecular Electrolytes for Use in Highly Efficient Dye-Sensitized Solar Cells. *Adv. Mater.* 2004, *16* (19), 1753-1757; (b) Kang, M.-S.; Kim, J. H.; Kim, Y. J.; Won, J.; Park, N.-G.; Kang, Y. S., Dye-sensitized solar cells based on composite solid polymer electrolytes. *Chem. Commun.* 2005, (7), 889-891; (c) Kang, M.-S.; Kim, J. H.; Won, J.; Kang, Y. S., Oligomer approaches for solid-state dye-sensitized solar cells employing polymer electrolytes. *J. Phys. Chem. C* 2007, *111* (13), 5222-5228.

[2] Nogueira, A. F.; Durrant, J. R.; De Paoli, M. A., Dye-Sensitized Nanocrystalline Solar Cells Employing a Polymer Electrolyte. *Adv. Mater.* 2001, *13* (11), 826-830.

[3] Kang, M.-S.; Kim, J. H.; Won, J.; Kang, Y. S., Dye-sensitized solar cells based on crosslinked poly (ethylene glycol) electrolytes. *J. Photochem. Photobio. A: Chem.* 2006, *183* (1), 15-21.