The effect of aligned liquid crystal in the electrolyte for efficiency improvement on dye-sensitized solar cell

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ABSTRACT

We report a new strategy for efficiency improvement of electron transfer which is used aligned the liquid crystal by applying voltage in polymer electrolyte on a quasi solid-state dye-sensitized solar cell.

1. INTRODUCTION

Dye-sensitized solar cell (DSSC) [1] researched in the past 10years because it has high power conversion efficiency (PCE) [2], low manufacture cost than amorphous silicon [3], and easily assemble method. The structure of DSSC [4] consists of TiO2 nanoparticles coated with dye sandwiched between a transparent conducting oxide and a platinum counter electrode. Inside of electrodes is filled with electrolyte with iodide/tri-iodide redox mediator [5].

Diverse electrolytes are reported such as liquid electrolytes, polymer electrolytes, solid electrolytes, and so on because electrolytes are an important role in DSSC. Among them, polymer electrolytes have high stability which is possible to solve a problem of electrolytes leakage. However, it is lower performance than liquid electrolytes. So researchers have studied various ideas for enhanced performance using polymer electrolyte. S. Kim et al. [6] were reported polymer electrolytes mixing the liquid crystal (LC) which supported electrolytes to transfer electrons in order to efficiency was increased in DSSC. The LC concentration in electrolytes was tried to optimize in our previous paper. We have optimized the LC concentration about 10 wt% in polymer electrolyte which is used to make experiment in this paper on DSSC [7].

The LC molecules are controlled by applying voltage to cell. This characteristic was used in this paper. We propose alignment of the LC molecules in polymer electrolyte for enhancing performance on a quasi solid-state DSSC.

2. PRINCIPLE of the aligned LC on DSSC

We were used the LC about 10 wt % in polymer electrolyte [7] and the LC is aligned for performance enhancement by applying voltage on DSSC. The LC molecules are able to control using voltage and its direction is decided according to characteristic specific of LC. In case of the E7, it is the nematic LC of positive birefringence and its molecules are aligned along with applying voltage direction [8].

We were applied DC voltage to assembled cell which is filled with electrolyte and LC molecule was aligned. During the applying voltage, solvent in polymer electrolyte was evaporated and the LC molecules were fixed in the DSSC.

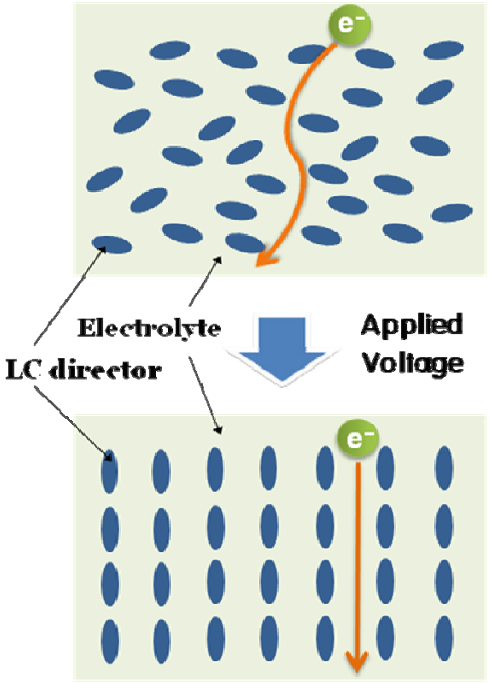


Fig. 1. Before and after of electron transportation according to LC alignment

Figure 1[9] shows before and after of LC alignment and electron transport according to applying voltage. According to LC alignment, the LC molecules play a role in pathway and electrons are easy to transfer in the inside of cell, so that photovoltaic performance of DSSC is increased.

3. EXPERIMENTAL

3.1 Fabrication

In this paper we align the LC in polymer electrolyte for enhancement of performance on DSSC. Firstly, a polymer electrolyte was kept in the control. The TiO2 paste (Ti-Nanoxide HT/SP, Solaronix SA) was coated by doctor blade on the FTO conducting glass. And it was dry in an atmospheric with 5 minutes, it sintered in 500 ℃ for 30min. For absorbing the dye layer into the TiO2, the annealed

nc-TiO2 electrodes were immersed in absolute ethanol containing 0.3mM of N 719 dye for 24 h at ambient temperature. Pt counter electrodes can be formed by coating platinum paste (Pt-Catalyst T/SP, Solaronix SA) on the glass at 400 ℃ for 20 minutes. The polymer electrolyte consists of ethylene carbonate, propylene carbonate, acetonitrile, tetrabutylammonium iodide, iodine, 1-propyl-3-methylimidazolium iodide and polycrylonitrile (Mw=86,200, Aldrich Co). The used LC (E7, Merck Co) has been mixed in the polymer electrolyte with 10 wt %. For appropriate mix of the electrolyte and the LC, we applied 65℃ for 24 hours by magnetic stirrer . Secondly, prepared TiO2 electrode coated dye and Pt counter electrode were fabricated using 60 ㎛ -thick surlyn (SX1170-60, DuPont) [6]. Lastly, fabricated cell is applied AC 10V for 1hour using function generator (Tektronix Inc. , model AFG 3022).

3.2 Measurement of performance

Photocurrent-voltage curve was measured using a Keithly model 2400 source measure unit. A class-A solar simulator (Yamashita Denso, model YSS-200A) equipped with a 1600 W Xenon lamp as a light source, where light intensity was adjusted using a Fraunhofer ISE-calibrated mono Si solar cell with KG-3 filter for approximating AM 1.5G 1 sun illumination.

4. RESULTS

We made experiment in DSSC that is applied voltage to the DSSC for alignment of the LC and have measured performance such as the photocurrent-voltage curves, energy conversion efficiency (η) and the fill factor according to type of polymer electrolyte. Figure 2 shows photocurrent-voltage (J-V) curve of the DSSC using without LC, mixed LC, and Aligned LC in polymer electrolyte. The short-circuit photocurrent density (J_{SC}) of the DSSC using aligned LC is the highest value than others.

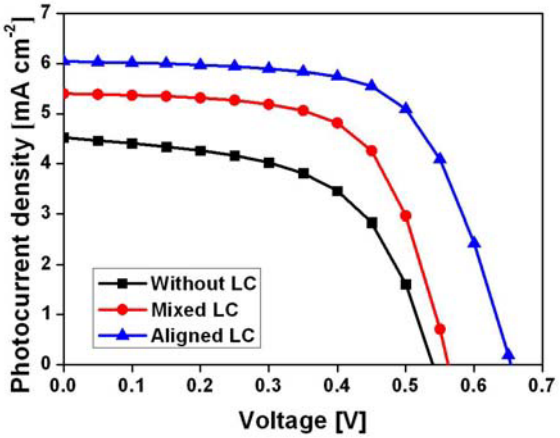
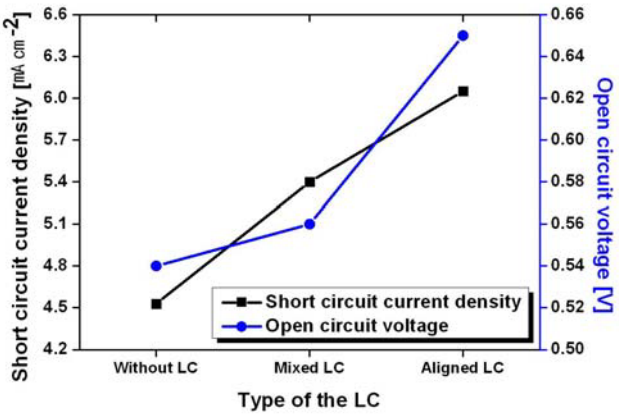


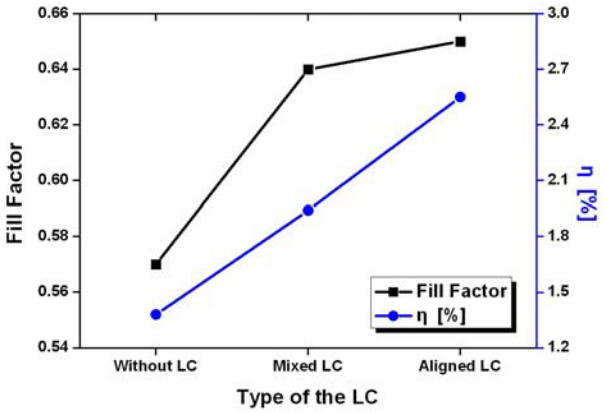
Fig. 2. J-V curve under A.M 1.5G 1 sun illumination (100mW/cm^2)

Figure 3 indicates result of photovoltaic performance in DSSC. The cell using aligned LC in polymer electrolyte shows the best performance in J_{SC} and. J_{SC} using type of aligned LC is about 32%, 12.5% higher than without LC and mixed LC respectively. η of using aligned LC in polymer electrolyte is also higher efficiency than others. Overall, the case of polymer electrolyte using aligned LC tends to have good result.

As a result of experiment, LC alignment is improving photovoltaic performance on DSSC.



(a) Open circuit voltage(V_{OC}) and Short circuit current density(J_{SC}) according to type of the LC



(b) Fill Factor and PCE according to type of the LC

Fig. 3. Comparison of photovoltaic performance according to type of the LC

5. DISCUSSION

We propose a new idea for improvement of problem which is electrolyte leakage in liquid type and low photovoltaic performance in polymer type on DSSC. It is to align the LC in polymer electrolyte mixed LC. DSSC aligned LC was shown the best performance than without LC and mixing LC in polymer electrolyte. This application of LC is enhanced photovoltaic performance in DSSC.

6. REFERENCES

[1] B. O'Regan, M. Grätzel, "A low-cost, high-efficiency solar cell based on dye-sensitized colloidal tio2 films", Nature 353, p. 737-740 (1991)

[2] A. Hagfeldt, M. Grätzel, “Molecular Photovoltaics” Acc. Chem. Rev. 33 (2000)

[3] A. Goetzberger, J. Luther, G. Willeke, “Solar cells: past, present, future” Sol. Energy Mater. Sol. Cells 74 (2002)
[4] C.Barbe, F. Arendse, P. Comte, M. Jirousek, F. Lenzmann, V. Shklover, M. Grätzel, “Nanocrystalline Titanium Oxide Electrodes for Photovoltaic Applications “ J. Am. Ceram. Soc. 80 (1997)
[5] M. Grätzel , “Perspectives for dye-sensitized nanocrystalline solar cells”, Progress in Photovoltaics, vol. 8, num. 1, p. 171-185 (2000).
[6] S. –H. Jin, S. C. Kim, J. S. Park, E. J. Lee, J. W. Lee, Y. -S. Gal, S. -H. Jin, and G. -D. Lee, “High Efficiency Solid-state Dye- Sensitized Solar Cells Using Polymer Electrolytes Containing Liquid Crystals,” submitted to Adv. Mat.
[7] H.K. Kim, M.J. Lee, S.-H. Jin, and G.-D. Lee, “Optimization of Liquid Crystal Concentration in the Dye-Sensitized Solar Cell for High Efficiency”, accepted to Mol. Cryst. Liq. Cryst. (2009)
[8] P. Yeh and C. Gu, Optics of Liquid Crystal Displays, Wiley-Interscience, 1999.
[9] H.K. Kim, S.-H. Jin, and G.-D. Lee, “Enhancement of electro-optic performance in dye-sensitized solar sell using homeotropically aligned liquid crystal molecular”, proceedings International Meetings on Information Display (2009)