Enhancement of electro-optic performance in dye-sensitized solar sell using homeotropically aligned liquid crystal molecular

Hyeonkyung Kim[1], Sung-Ho Jin[2] and Gi-Dong Lee[1]
[1]Dept. of Electronics Engineering, Dong-A University, Busan 604-714, Korea
Tel.:82-51-200-6959, E-mail: gdlee@dau.ac.kr
[2]Dept. Chemistry Education & Interdisciplinary Program of Advanced Information and Display Materials, Pusan National University, Busan 609-735, Korea
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Abstract

We propose a novel way for enhancement of efficiency on a quasi solid-state dye-sensitized solar cell (DSSC). It contained gel type electrolyte mixing the liquid crystal (LC) of specific concentration and applied voltage for alignment of the LC. Aligned LC is supported charge transfer inside electrolyte and efficiency is increased in DSSC. We made a quasi solid-state DSSC which applied DC voltage or not and have measured the power conversion efficiency (PCE) and the fill factor. From measurement, we obtain high performances in case of cell applied voltage compare to reference cell.

1. Introduction

Dye-sensitized solar cell (DSSC) which was published by O'Regan and Gratzel [1] comes into the spotlight according to high energy conversion efficiency, low manufacture cost and use of environmentally harmless material.

A DSSC has arrangement of sandwich that consists of TiO2 nanoparticles coated with dye and counter electrode. Inside of electrodes is filled with electrolyte with iodide/tri-iodide redox mediator [2].

Because electrolytes are an important role in DSSC diverse electrolytes are reported such as liquid electrolytes, polymer electrolytes, solid electrolytes, and so on. Among them, polymer electrolytes have high stability which is possible to solve a problem of electrolytes leakage in DSSC. However, it is lower performance than liquid electrolytes. So many researchers have reported various ideas for enhanced performance. S. Kim et al. [3] were reported polymer electrolytes mixing the liquid crystal (LC) which helped electrolytes to transfer electrons in order to efficiency was increased in DSSC. The concentration of LC in electrolytes was tried to optimize in our previous paper. We were optimized the LC concentration about 10 wt% in polymer electrolyte which is used to make experiment in this paper on DSSC [4].

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

2. Experimental

2.1 Application of LC on DSSC

As previously stated, we were used the LC about 10 wt % in polymer electrolyte 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 LC of positive birefringence and its molecules are aligned along with applying voltage direction [5].

We were applied DC voltage to completed 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.

Figure 1 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.

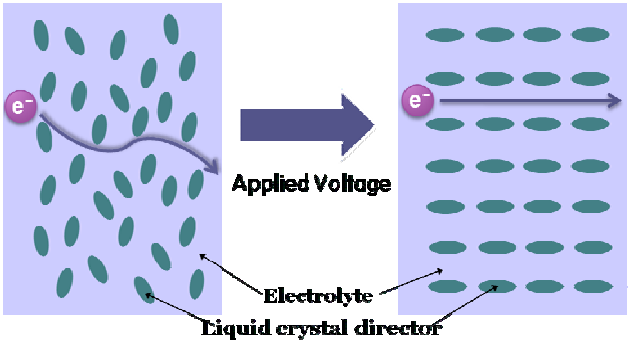

Fig. 1. Comparison of electron transportation according to LC alignment

2.2 Device fabrication

In this work 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 450 ℃ for 30min. For absorbing the dye layer into the TiO_2, the annealed nc-TiO_2 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 [3]. Secondly, prepared TiO_2 electrode coated dye and Pt counter electrode were fabricated using 60 ㎛-thick surlyn (SX1170-60, DuPont). Finally, fabricated cell is applied AC 10V for 1hour using function generator (Tektronix Inc. , model AFG 3022).

2.3 Measuring performance

Photocurrent-voltage curves were 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.

3. Results and discussion

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.

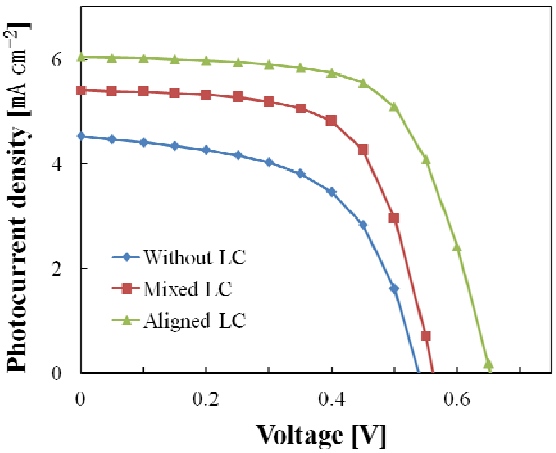

Fig. 2. J-V curve under A.M 1.5G 1 sun illumination (100mW/cm^2)

Table 1 indicates detailed data of photovoltaic performance in DSSC. The cell using aligned LC in polymer electrolyte shows good performance in J_{SC} and. J_{SC} using type of aligned LC is about 33%, 12% higher than without LC and mixed LC respectively. η which is used aligned LC in polymer electrolyte is also higher efficiency than others.

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

TABLE 1. Photovoltaic performance of without LC, mixed LC, and aligned LC in polymer electrolyte

	J_{SC}[mA cm^{-2}]	V_{OC}[V]	FF	η[%]
Without LC	4.53	0.54	0.57	1.38
Mixed LC	5.40	0.56	0.64	1.94
Aligned LC	6.05	0.65	0.65	2.55

4. Summary

We propose a new idea for solving problem of leakage in liquid electrolyte and low performance in polymer electrolyte on DSSC. It is aligned 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.

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5. References

1. B. O'Regan, M. Grätzel, *Nature*, 353, p.737-740 (1991).
2. M. Grätzel, Prog. Photovolt. Res. Appl. 8, p.171-185 (2000).
3. 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, submitted to Adv. Mat..
4. H.K. Kim, M.J. Lee, S.-H. Jin, and G.-D. Lee, accepted to Mol. Cryst. Liq. Cryst., (2009)
5. P. Yeh and C. Gu, Optics of Liquid Crystal Displays, Wiley-Interscience, 1999.