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CNT와 Pt 상대전극을 가지는 염료감응형 태양전지의 직렬·병렬 연결에 따른 특성비교

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Comparative properties for serial-parallel connection of DSC with CNT and Pt counter electrodes

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Key words : Dye-sensitized solar cell(염료감응형 태양전지), Carbon nanotube(탄소나노튜브), Counter electrode(상대전극), A serial-parallel connection(직병렬연결)

Abstract : Cost effectiveness is an important parameter for producing DSSCs as compared to the widely used conventional silicon based solar cells. A fluorine-doped tin oxide (FTO) substrate coated with a catalytic amount of platinum is used as counter electrode in dye-sensitized solar cell. Carbonaceous materials are quite attractive to replace platinum due to their high electronic conductivity, corrosion resistance towards I_2, good catalytic effect and low cost. In this paper, the unit DSSCs with Pt and CNT as a counter electrode were connected in series-parallel externally, then the current-voltage curves were investigated to find out the connection characteristics of the DSSC with CNT counter electrode. The connection characteristics of the DSSC with CNT counter electrode is superior to that of the DSSC with Pt counter electrode. And a parallel connection of the DSSC with CNT counter electrode has higher efficiency than a series connection of that.

Nomenclature

V_{oc} : open circuit voltage, V
I_{sc} : short circuit current, I
P_{max} : maximum power of DSSC, W
ff : fill factor, ($P_{max}/V_{oc} \times I_{sc}$)

subscrip

DSSC : dye-sensitized solar cell
DSSC-CNT: dye-sensitized solar cell with CNT counter electrode
DSSC-PT: dye-sensitized solar cell with Pt counter electrode

1. Introduction

Nanocrystalline dye-sensitized solar cells (DSSCs) are the attractive alternative to existing silicon based solar cell because of the low cost, high conversion efficiency, and simple manufacturing process. The DSSCs consist of a sandwich of dye-absorbed TiO2, electrolyte and catalyst between two transparent conductive oxide substrates[1,2].

Currently, a layer of platinum coated on a transparent conducting oxide (TCO) substrate is widely used as a catalyst of the counter electrode in DSSCs because of its high catalyst property [1]. That is not economic way for production on a large scale. It is needed to investigate new counter electrode materials with catalyst property and low cost. Carbonaceous materials have merits as attractive alternatives of platinum such as their high electronic conductivity, superior electrochemical properties and low cost due to development of mass production technique[3].

In this study, carbon nanotubes (CNT) were used as a counter electrode of DSSCs. First, the photoelectrical properties of the DSSCs with CNT counter electrode were investigated as compared with that of the DSSCs with Pt counter electrode.

The scaling up of DSSCs is important on commercial scale[4,5]. The comparative property experiment for a serial-parallel connection of DSSCs with the CNT and Pt counter electrodes was performed as part of an effort for the commercialization of DSSCs.

2. Experimental procedure

2.1 Preparation of counter electrode

Pt counter electrodes were coated on the F-doped SnO2 glass (FTO) by sputtering system under the condition of a base pressure of 1×10-5 torr, 5×10-3 torr working pressure, 150 Watts sputter power, and 50 sccm Ar gas flow.

CNT powder, CMC, de-ionized water together with a cylinder type of balls (height: 1cm, diameter: 1cm) in a container were mixed by ball miller for 24h ~ 72h and then CNT paste was completed (see Fig. 4-1). The prepared CNT paste was coated by using doctor blade method on FTO glass (10×10mm) and then dried at 230℃ for 30min in air. CNT film thickness is approximately 20~25μm.

2.2 DSSCs assembly and characterization

Fluorine-doped tin oxide glass (FTO, SnO_2:F) substrates were used to make both the working and the counter electrodes. The TiO_2 films (active area: 10mm × 10mm) were printed 50μm thickness TiO_2 pastes on the 20mm × 20mm FTO glass. After printing, the working electrode was sintered at 450℃ for 30 minutes and then they were immersed in a 0.3mM dye sensitizer (N719) ethanol solution for 24h at room temperature.

The prepared working and the counter electrode were assembled in a sandwich type. The electrodes were insulated by Hot-melt sealing sheet (thickness: 60μm) and sealed by heating and pressing at 110℃ for a few seconds. And then the assembled cell was filled with the redox electrolyte containing I^-/I_3^- redox couple in acetonitrile solvent. The filling holes in the counter electrode were sealed with Hot-melt sealing sheet and a glass cover.

A short-circuit photocurrent (Isc), an open-circuit voltage (Voc), and fill factor (FF) of the DSSCs were measured by using a Keithley 2400 source meter under a Xenon lamp (100 mW/cm^2, uniform illumination is less than 3% in an active area of 5cm×5cm).

2.3 A serial-parallel connection of DSSCs with Pt and CNT counter electrodes

The samples used in this experiment were divided into three groups (Type Ⅰ, Type Ⅱ, and Type Ⅲ) depending on their connections (see Table 4-1). Each group was composed of 4 unit DSSCs. The unit DSSCs was prepared by 4 DSSCs with Pt counter electrode (DSSCs-Pt) and 4 DSSCs with CNT counter electrode (DSSCs-CNT). The experiment for a serial-parallel connection was performed into two types of DSSCs-Pt and DSSCs-CNT, respectively. Figure 4-1 shows the equivalent circuit of three different groups connected externally. Figure 1(a), (b), and (c) represent the equivalent circuits of Type Ⅰ connected in series, Type Ⅱ connected in parallel, and Type Ⅲ connected in serial-parallel, respectively.

Figure 2 represents setting appearance for measurement. The unit cells were put together to set under 5cm×5cm active area of a Xenon lamp and externally connected by conductive lines according to the connection method.

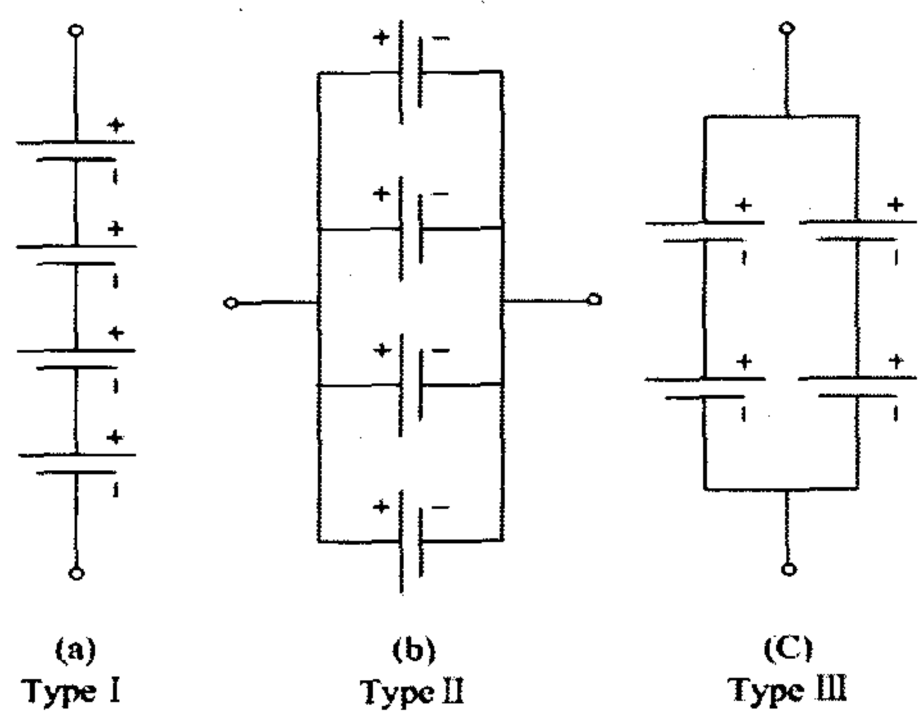


Fig. 1 Equivalent circuit of 3 groups (a) Ⅰ-series connection (b) Ⅱ-parallel connection (c) Ⅲ-series-parallel connection

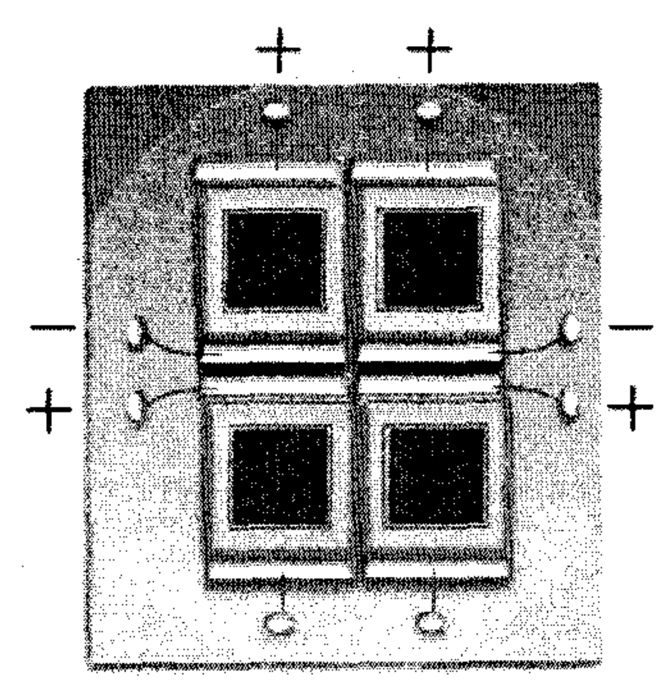


Fig. 2 Setting for measurement

3. Results and discussion

3.1 The current-voltage characteristics of DSSCs-Pt and DSSCs-CNT

Figure 4-6 shows the current-voltage characteristics of the DSSC-Pt and DSSC-CNT. almost 3.92% energy conversion efficiency for the DSSC-CNT was achieved and the energy conversion efficiency of the DSSC-Pt was 3.62% under AM1.5 and the same active area of 10mm

× 10mm. Also, the open circuit voltage and the short circuit current density (8.32V, 7.29mA) of DSSC-CNT was higher than these (8.10V, 6.44mA) of DSSC-Pt. (see Table 1)

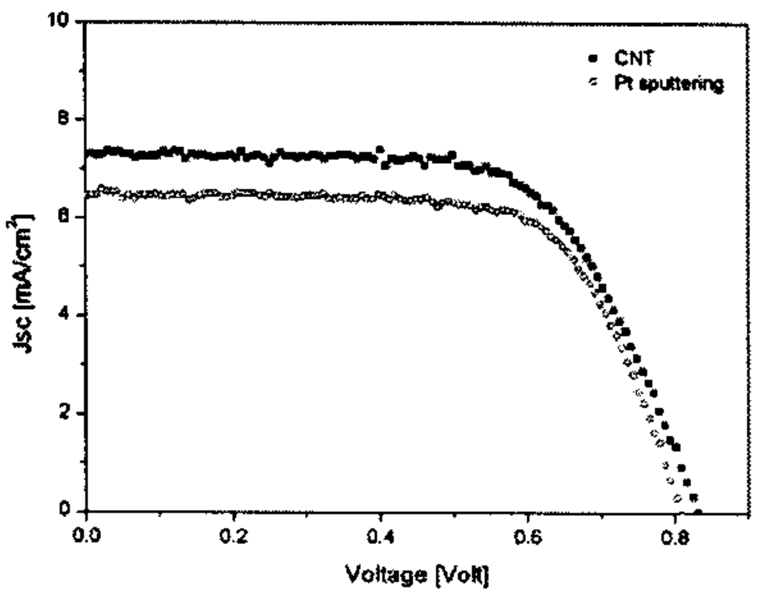
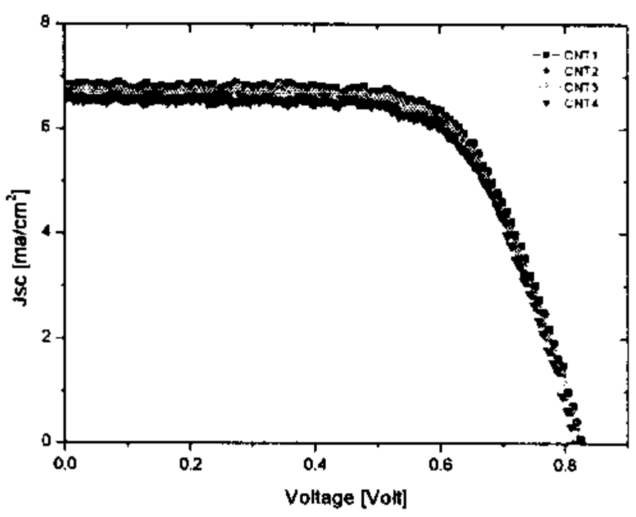


Fig. 3 I-V characteristics of DSSC-Pt and DSSC-CNT.

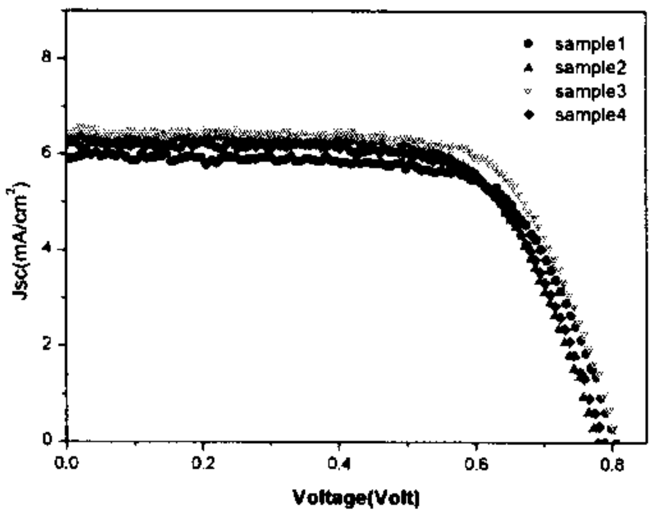
Table 1. I-V parameters of the DSSCs with Pt and CNT counter electrodes

	CNT counter electrode	Pt counter electrode
Voc[V]	8.32	8.10
Jsc [mA/cm^2]	7.29	6.44
Fill factor [%]	66.2	68.4
Efficiency [%]	3.96	3.62
Active are [cm^2]	1	1

3.2. I-V characteristics of the DSSCs-Pt and DSSCs-CNT connected in series-parallel



(a)

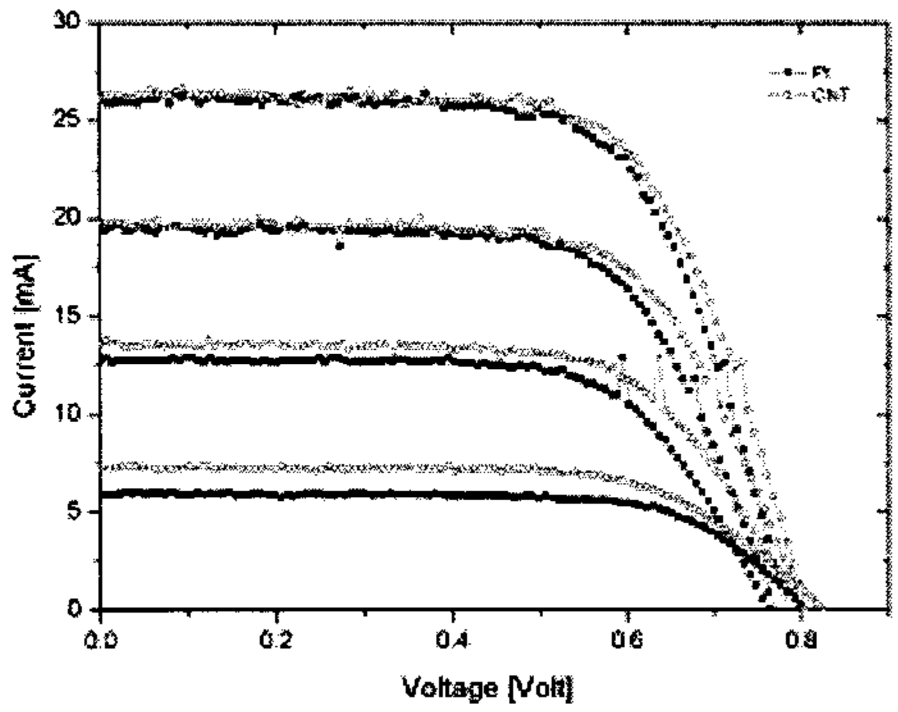


(b)

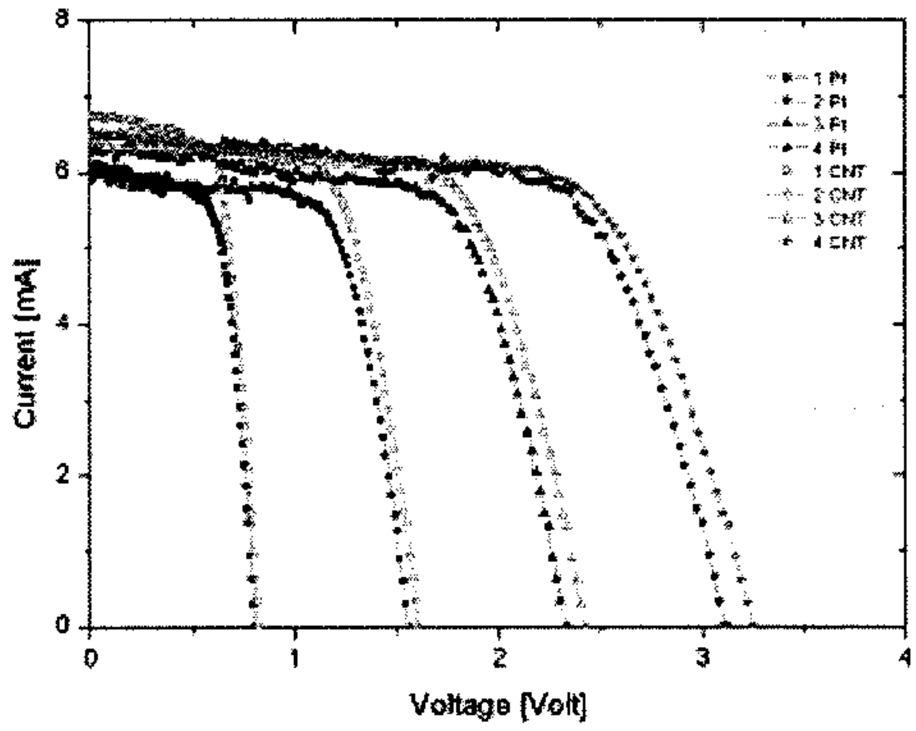
Fig. 4 I-V characteristics of (a) 4 DSSCs-CNT and (b) 4 DSSCs-Pt

Figure 4 shows the current-voltage characteristics of 4 DSSCs-Pt and 4 DSSCs-CNT prepared to form the DSSC module which was externally connected in series, parallel, or series-parallel. To reduce a loss that can be brought on by a connection between cells with the different performance characteristics, each cell was prepared to be similar cell characteristics.

Figure 5 represents the current-voltage characteristics according to increasing the number of connecting DSSCs in parallel or series. The photoelectrical properties of DSSC-CNT have generally higher than that of DSSC-Pt.



(a)



(b)

Fig. 5 I-V characteristics comparison of DSSCs-Pt and DSSCs-CNT according to increasing the number of cell connected in parallel(a) and in series(b)

The current-voltage-power characteristics of the serial-parallel connected DSSCs was shown in Fig. 6. Also, the photoelectrical properties of DSSC-CNT have higher than that of DSSC-Pt. The DSSC-CNT show higher photoelectrical properties than DSSC-Pt not only in unit cell but in the connection module. Table 2 shows current density-voltage characteristics (Voc, Isc, Fill factor, energy conversion efficiency) of the serial, parallel, and serial-parallel connected DSSCs-CNT and DSSC-Pt. A parallel connection of the DSSC with CNT and Pt counter electrode has higher efficiency than a series connection of that.

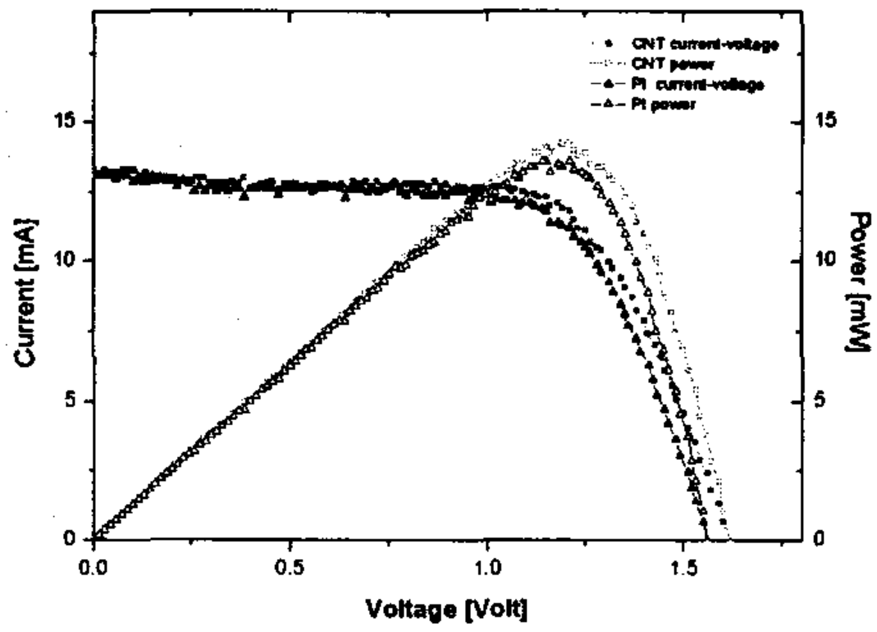


Fig. 6 I-V-P comparison of the serial-parallel connected DSSC-CNT and DSSC-Pt

Table 2. I-V parameters of serial-parallel connected DSSCs with CNT and Pt counter electrodes

Connection types	Type I		Type II		Type III	
Counter electrode	CNT	PT	CNT	PT	CNT	PT
Voc[V]	3.25	3.11	0.81	0.78	1.62	1.56
Jsc [mA]	6.47	6.54	26.1	26.3	13.3	13.1
Power[W]	13.9	13.4	14.1	13.8	16.9	16.2
Fill factor[%]	66.1	65.9	67.1	67.0	66.3	66.4
Efficiency[%]	3.48	3.35	3.52	3.45	3.55	3.45

4. Conclusion

In this paper, two types of DSSCs with Pt and CNT as a counter electrode were fabricated, then 4 DSSCs-Pt and 4 DSSCs-CNT were connected externally in series-parallel. The current-voltage characteristics were investigated to confirm connection characteristics of DSSC-CNT compared with DSSC-Pt. The improved energy conversion efficiency of about 9.4% has been shown in the fabricated DSSCs with CNT as a counter electrode compared with those of Pt. The energy conversion efficiency characteristics of CNT-DSSC module connected externally series and parallel is superior to that of DSSC-Pt.

후 기

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