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상대전극을 스퍼터링 증착한 염료 감응형 태양전지의 새로운 디자인

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The New Design of Dye-Sensitized Solar Cell Adopted by Sputter Deposition of Counter Electrode

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Key words : counter electrode(상대전극), Dye-sensitzed solar cell(염료 감응형 태양전지), RF sputtering(RF 스퍼터링)

Abstract : The counter electrode widely used in DSCs (Dye-sensitized Solar Cells) is constructed of conducting glass substrates coated with Pt films, where the platinum acts as a catalyst. Pt counter electrodes in DSCs are one important component. It is expected that characteristics of Pt electrodes strongly depend on fabrication process and its surface condition. In this study, Pt counter electrode surface of DSC is deposited by reactive RF magnetron sputtering under the conditions of Ar 5mtorr, RF power of 120W and substrate temperature of 100°C. Surface morphology of Pt electrodes was investigated by FE-SEM and AFM. And this paper shows our recent results and technology to fabricate the new designed cell with Pt electrodes deposited by sputtering method. We have achieved fill factor 68% and photoelectric conversion efficiency around 2.6% as the best results of new designed DSCs structure.

1. INTRODUCTION

The low cost of manufacturing and high conversion efficiencies up to around 11% dye-sensitized solar cell (DSC) is alternative for existing solar cell technologies based on silicon[1,2]. In dye-sensitized nanocrystalline solar cells, light is absorbed in a single layer of dye molecules that is chemically bonded to a sponge-like film of interconnected titanium oxide particles. The titanium oxide film is attached to a conductive transparent glass. After light excitation, the dye molecule injects an electron into the TiO_2film. The electron is transported to the conductive glass where it is collected and transferred through a load. The positive charge, formed in the light induced charge separation, is transferred from the dye to an electron donor mediator present in the cell electrolyte. Opposite of the TiO_2 film is the counter electrode, where the mediator is reduced into its original state by the electron collected at TiO_2 side of the cell[3,4].

Here, transparent conductive oxide (TCO) coated glass substrates are presently used as cathodes in solar cell. However, it shows extremely poorcatalytic property for iodine reduction[5,6]. In this reason, they have to be modified by the deposition of high catalytic materials on it. Material used for the count electrode of DSC should satisfy the requirements of superior catalytic reactivity, high conductivity, and low potential of electrode reaction. Pt is well known as a counter electrode material of DSC[7]. Pt can be deposited on TCO by electro-deposition, thermal decomposition and sputtering processes. In this paper, we preparednew design of DSC with Pt counter electrodes prepared by sputtering

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method.

In the series interconnect design, we can obtain identicaloutput when illuminated from either side in each separate single cell, and this design still requires separation of the cells by an effective seal. The interconnect module is recognized as an alternative design that has significant advantages for volume production and for relatively smallcells. It effectively eliminates one substrate by connecting both electrodes to one conductor substrate, affects the cell by electrical isolation on that substrate. The problem of low efficiency and stability will limitthe use of this design in big modules. This paper shows our research and design from the Ag grid single cell and the novel series interconnect design, to the panels. We have achieved photoelectric conversion efficiency around 2.6% with a size of 10cm x 7cm module and fill factor of 68%.

2. EXPERIMENTAL PROCEDURE

2.1. Fabrication of platinized counter electrodes

The counter electrodes were coated on FTO (fluorine doped SnO_2) glass bysputtering methods. Platinized counter electrode was deposited on FTO glass by using RF-magnetron reactive sputtering system under the condition of a base pressure of 1×10^{-5}, 5×10^{-3} torr working pressure, RF sputter power of 120 Watts, substrate temperature of 100°C, and Ar 5mtorr.

2.2. Cell preparation

FTO (9.3 ohm/square) was used both as the working and counter transparent electrodes. Ruthenium 535 bis-TBA (N719, *cis*-bis (isothiocyanato) bis (2,2'-bipyridyl-4,4'-dicarboxylato)-ruthenium(II) bis-tetrabuty -lammonium) was the sensitizer. Electrolyte composition was iodolyte AN-50 (iodide based low viscosity electrolyte with 50mA of tri-iodide). Nanoporous TiO_2 film was prepared as Ti-Nanoxide HT/SP (Colloidal anatase particles size: ~9nm, ~165m^2/g (BET)). Hot-melt sealing sheet (SX 1170-60, 60 microns thick foil) have been used as primary sealing materials. Electrode finger was printed using silver paste.

Mesoporous TiO_2 film was fabricated by screen printing method. Nanocrystalline TiO_2 paste was coated on FTO glass substrate having the electric conductivity of 10 ohm/square, optical transmittance of 80% in the visible region. The TiO_2 paste used in this process has been developed for sintering at 450°Cfor 2hr in air. After sintering photoelectrodes have been immersed in a solution of red dye (N719) in ethanol for 24hr at room temperature. The working and counter electrode are sealed by the Hot-melt sealing sheetin a sandwich. The gap between two electrodes is filled with the electrolyte. Finally, the filling holes in the counter electrodes are closed with the adhesive.

Field emission scanning electron microscopy (FE-SEM), atomic force microscopy (AFM) and α-step (Tencor Alpha-step 200 profilo meter) were employed for the characterization of microstructureand thickness of the films coated by sputtering methods. The sheet resistance was measured using 4-point probe method. A short-circuit photocurrent (Isc), an open-circuit voltage (Voc), and fill factor(FF) of the DSCs were measure using a Keithley 2400 source meter under a Xenon lamp(1000W/m^2, uniform illumination is less than 3% in an active area of 10cm×10cm).

2.3. The novel series interconnected design

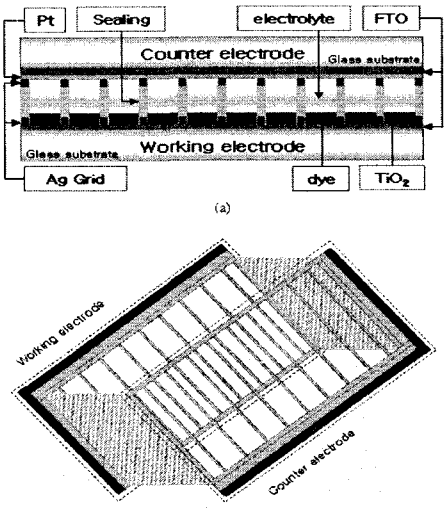

Fig.1. The cross sectionscheme and cross section of the Ag grids of DSC

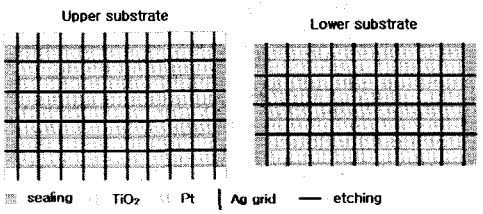

Fig. 2. The design scheme of the novel series interconnect of substrates in DSCs

Strip cells were normally used to test the performance of DSC material, such as TiO_2, dye, and electrolyte, before assembling DSC module and panel in our laboratory. A circulation pump was used to inject the electrolyte through a pinhole. The small holes were sealed by a hot melting sheet after injecting electrolyte. It is an easy way to assemble strip cell by using the same process as that of DSC module. The cross section scheme

and cross section of the Ag grids DSC is shown in Fig. 1. It is a critical step for DSCs to achieve an optimum and long-running module in the laboratory before its entry to the commercial market

Fig. 2 shows the design scheme of the novel series interconnect of substrates in DSCs. Both a working electrode and a counter electrode formed on glass substrates. For interconnection in series, two electrodes are alternately coupled. The novel series interconnect DSC is equal to series interconnected design of 8 single unit cellsas shown in Fig. 3.

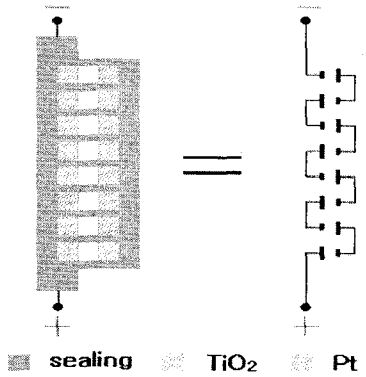

Fig. 3. The cross section design and electric circuit of the novel series interconnect DSC

3. RESULT AND DISCUSSION

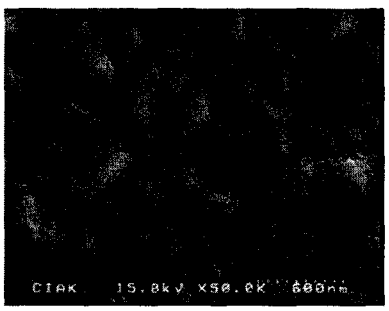

Fig. 4. The FE-SEM images of Pt films prepared by sputtering

The FE-SEM image of Pt electrode surface coated by using the sputtering method is shown in Fig. 4. Pt was deposited as a thick film on rough FTO surface, and its thickness was approximately 0.5㎛. The sheet resistance of Pt sputtered film was measured as 4~5 ohm/square.

Fig. 5 shows the surface morphologies of Pt electrode deposited by sputtering measured by AFM. Fig. 6 shows the surface morphologies of Pt electrode deposited by sputtering, measured by AFM.

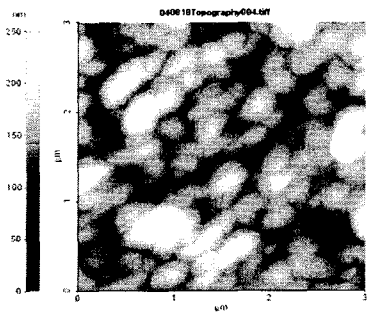

Fig. 5. The surface morphologies of Pt electrode deposited by sputtering measured by AFM

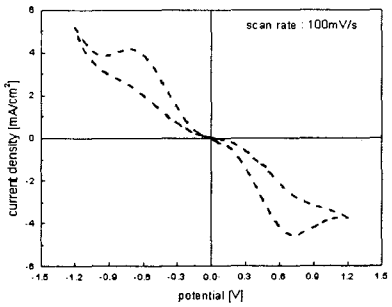

Fig. 6. The cyclic-voltammogram of Pt electrode prepared by sputtering method. Sweep rate is 100mV/s.

A cyclic-voltammetry measurement is helpful to understand the microscopic electrochemical surface reactions at the electrode. Fig. 6 presents the cyclic boltammetric behaviors of the Pt electrodes coated by sputtering at a scan rate of 100mV/s. Here, a peak in negative potential is corresponding to reduction of I_3^- ion. In cyclic voltammogram, peak area and current density for reaction usually increases with the increase of reaction rate. The absolute value of peakpotential is related to the reaction limit of potential. The more the peak potential is big, the better reaction potential range the electrode has.

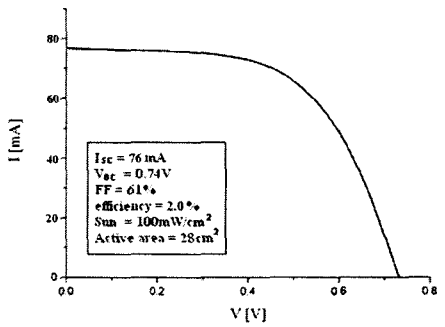

Fig. 7. I-V characteristics curve of Ag grid single cell

Fig. 7 illustrates the design scheme of strip cell and I-V characteristic performance of Ag grid single cell with this strip cell. It is very important that the module performance is very sensitive to the resistance of silver grid. The Ag grid single cell achieved fill factor of 61% and conversion efficiency of 2.0%.

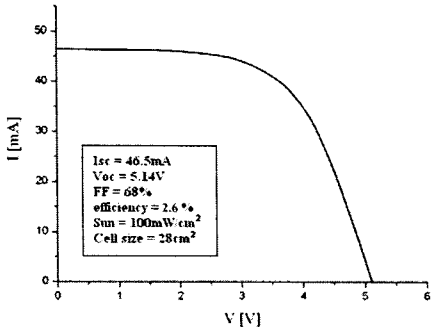

Fig. 8. I-V characteristics of the novel series interconnect DSC

Photoelectric efficiency of 2.6% under 1 Sun have been achieved, the I-V characteristic performance is shown in Fig. 8. The short current density and fill factor increased with the novel series interconnect design, so as the efficiency. This is obviously from the fact that the fill factor increases, which is also the reason why the efficiency increases with the novel series interconnect DSC. From this result, compared to Ag grid single cell, the fill factor as well as efficiency is improved. It is very clear that the module performance is very sensitive to width of electrodes. Fig. 9 shows the designed new DSC cell of voltage rising type with series interconnecting.

Fig. 9 shows the designed new DSC cell of voltage rising type with series interconnecting.

4. CONCLUSION

In this study, the Pt counter electrode was deposited by RF magnetron sputtering method. We investigated surface morphology of Pt electrode using investigated by FE-SEM and AFM and electrochemical behavior of that using cyclicvoltammetry. With the DSC prepared by the Pt electrode, we introduced our test results in designing high efficiency modules. High photoelectric conversion efficiency under 100mW/cm^2 incidence light intensity by using both TCO glass for working electrode and counter electrode with active area of 28 cm^{2}was achieved. In novel series interconnected DSC, the fill factor increase from 61% to 68% and photoelectric conversion efficiency increases from 2.0% to 2.6%. From our test results, it is possible to obtain more high photoelectric conversion efficiency in the near future if we could get more optimum design.

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