Preparation of spray-coated TiO_2 electrodes and I-V characteristics for Dye-sensitized Solar Cells

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Abstract

Fabrication and characterization of dye-sensitized TiO2 solar cells(DSSC) consisting of spray-coated TiO2 electrode, an electrolyte containing I-/I3- redox couple, and a Pt-coated counter electrode was carried out, using mainly FE-SEM and solar simulator. Also, effect of rapid thermal annealing(RTA) temperature on I-V curves of DSSCs consisting of approximately 10m thickness and 5x5mm2 active area. No significant difference in the apparent size of TiO2 clusters was observed with increasing RTA temperature. Also, an open circuit voltage(Voc) of approximately 0.70V and a short-circuit photocurrent(Jsc) of 8 to 12mA/cm2 were observed in the TiO2solar cell. With increasing RTA temperature upto 550oC, photocurrent density of dye-sensitized solar cells was enhanced, leading to enhancing the efficiency of dye-sensitized solar cells having Pt-electroplated counter electrode.

Keywords: sprayed-coating, TiO2, electrode, DSSC,

1. INTRODUCTION

The dye sensitized solar cell(DSSC) consisting of dy electrode, an electrolyte containing I-/I3- redox couple, and Pt coated counter electrode is a promising alternative to the inorganic solar cell[1]. Due to low cost, permanence, environmental compatibility and relatively simple fabrication process, great interest in DSSC has grown continuously[2]. In spite of the cost-efficiency of DSSC, the improvement of efficiency and long term stability is needed in terms of practical application.

TiO2 electrode is used as a cathode for DSC. TiO2 materials have anatase and rutile crystalline phases, which are well known to be formed as a meta-stable phase at temperatures lower than ~ 400 ℃ and as a thermodynamically stable phase at higher temperatures, respectively. Also, TiO2 polycrystal transforms anatase to rutile phase easily by high temperature treatment with inevitable growth of the particles size [3]. Mainly, anatase phase TiO2 materials, i.e. P25(comerciallized powder) was mainly used for DSC, since good particle size distribution, high purity, good moisture stability, etc. Simultaneously, other attempts into developing Titanium oxides for DSSC have been carried out, using hydrate (TiO (OH)2 , TiO (OH)2), also, TiO2 sol-gel.

Many studies on fabricating TiO2 electrodes for dye sensitized solar cells have been carried out until now. Screen printing, tape casting (Dr Blade method) and spin coating are mainly used. However, spray coating has not much used for dye sensitized solar cells in conjunction with rapid thermal annealing so far. Especially, diluted TiO2 sol can not be used for fabricating TiO2coating layer, also, it is difficult to make an enlarge in the active area of TiO2 electrode, using screen printing and tape casting. Here, spray coating is very useful for applying especially very dilute sol of TiO2 to prepare enlarged TiO2 electrode.

In these respects, it can be very meaningful investigation for understanding characteristics of spray coated TiO2electrode for DSSC. Therefore, we investigated spray coating, its characteristics of TiO2electrode, and dye-sensitized solar cell. Photoelectric property of DSSC having TiO2electrode and Pt electrode was measured, using solar simulator and Keithley 2400 I-V source meter. Microstrucural study of TiO2 electrode and counter electrode were carried out, using FE-SEM(field emission scanning electron microscope), AFM(atomic force microscope). Also, we suggested possibility of using spray coating method for fabricating TiO2 electrode used in DSSC. e-modified wide band semiconducting TiO2

2. EXPERIMENTAL PROCEDURE

2.1 TiO2 ELECTRODE PREPARATION

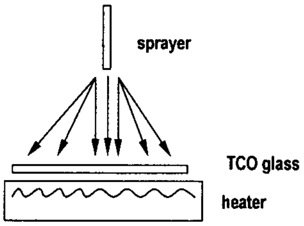


Fig.1 Schematic diagram of spray-coating

Fig.1 shows a schematic diagram of of spray-coating for dye-sensitized solar cell. In order to fabricate TiO2 electrode, nano-crystalline TiO2 (P25, Degussa) powders were used. First, slurry of TiO2 (10w%) powder and alchole, done with ball milling for 24 hr was prepared, second, spray coating was conducted on SnO2:F glass(FTO, 8 ohm/sq, 80% transmittancein the visible, 5mm5mm in active area of TiO2), third, TiO2-coated FTO glass was thermally treated as a function of temperature.

Table 1. Fabrication condition of spray coating for TiO2electrodes at 25oC

Nozzle Dia.	Distance btwn spray and sample	Coating time	Substrate temperature
0.3mm	200mm	<1min	Room temperature

In order to sensitize TiO2 films, TiO2 electrodes were immersed in a solution of 0.02mg/cc red dye (RuL2(NCS)2[L=2,2'-bipyridine-4,4'-dicar boxylic acid] in ethanol for 24h at room temperature. The cleaning process was followed with pure ethanol.

2.2 COUNTER ELECTRODE

Pt counter electrodes were deposited from Pt targets on FTO glass by using a DC-magnetron sputtering system with a base pressure of 3×10-6 torr and a deposition pressure 3x10-3 torr. The input power was 100W. The thickness of Pt is ~300nm.

2.3 CELL CONTRUCTION

In order to assemble solar cell having 5x5 mm2active area, the structure of solar cell were design as shown in Fig.2.

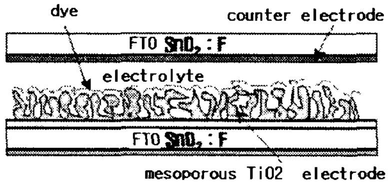


Fig. 2. Schematic diagram of dye sensitized solar cell.

The Pt electrode and the dye-adsorbed TiO2 electrode were sandwiched, using clamps and the redox electrolyte containing I-/I3- redox couple was introduced into the solar cell by capillary effect through spacer(50m thick). The spacer was loaded with clamps. Ag paste was put on the side edge of two electrodes. Therefore, solar cell having an active of approximately 0.25cm2 was fabricated.

2.4 CHARACTERIZATION

Photoelectric property of DSSC having TiO2 electrode and Pt electrode was measured, using solar simulatorand Keithley 2400 I-V source meter in order to measure short-circuit photocurrent (Jsc), open-circuit voltage (Voc), fill-factor (FF) and cell efficiency. Microstrucural investigation of mesoscopic TiO2 electrode and counter electrode were carried out, using FE-SEM(field emission scanning electron microscope) and sheet resistance was measured with 4-point probe. α-step (Tencor Alpha-step 200 profilo meter) was employed for measuring thickness of TiO2 electrode.

3. RESULTS AND DISCUSSION

3.1 SURFACE THICKNESS & ROUGHNESS

The thickness of spray- coated TiO2 electrode was measured by a-step. In the case of as-prepared TiO2 electrode, its thickness is approximately 10m under the above spray coating condition.

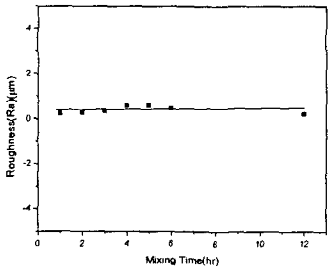


Fig. 2 Surface roughness of spray coated TiO2 electrode (Ra= 0.1um) heat-treated by rapid thermal annealing at 550oC

Fig.2 shows surface roughness of spray coated TiO2 electrode measured by -step. In general, it is considered that the roughness of spray-coated layer is more rougher than that in the case of tape casting. In this reason, spray coating has not applied to fabricate TiO2 electrode. From our observation, Surface roughness of spray coated TiO2electrode is approximately Ra < 0.1m. This means that such roughness does not significantly affect on breaking-down between TiO2 electrode and Pt counter electrode, since the spacers between TiO2 electrode and Pt counter electrode is used to be approximately 20~50m

3.2 MICROSTRUCTURE OF TiO2 ELECTRODE

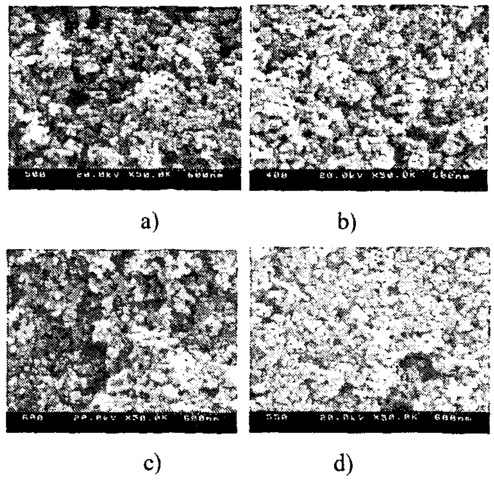
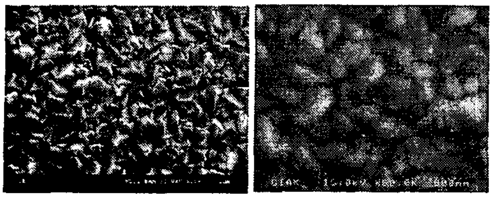


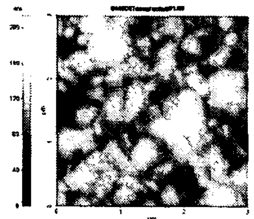
Fig.3 SEM micrographs of nanocrystalline TiO2 deposited by spray coating.

Fig.3 shows FE-SEM micrographs of TiO2 electrode deposited by spraying coating, following rapid thermal annealing as a function of temperature. There is no significant change in the microstructure of spray-deposited TiO2 electrodes with increasing RTA temperature. This means that TiO2 powders(P25) is narrow particle size distribution of 25nm.

The particle size of TiO2 particles experienced with rapid thermal annealing was approximately 60nm. In this case, majority of TiO2 particles were agglomerates (~60nm) consisting of several TiO2 particles, forming grain boundary between TiO2 particles. Although it is difficult to distinguish the increase in number of necking between TiO2 particles, we may consider the increase in number of necking between TiO2 particles with increasing RTA temperature, without any significant change in apparent microstructure of TiO2 electrodes. Such increase in number of the necking allows electron generated during exposed sunlight to enhance its transfer. We expect enhanced photocurrent of dye-sensitized solar cells.



a) (b)



(c)

Fig. 4. FE-SEM and AFM images of FTO glass (a) and Pt films prepared by sputtering methods.

Fig. 4 shows FE-SEM and AFM micrographs of FTO glass (a) and Pt films(b) prepared by sputtering methods. Fig.4a shows FE-SEM photograph of FTO glass consisting of triangular facets. Fig.4b shows full Pt coverage with small Pt cluster on the surface of FTO glass. The sheet resistance of Pt sputtered film on FTO glass is approximately 4~5 ohm/sq, smaller than that in the case of FTO glass itself. Fig.4c shows more precise image of Pt sputtered film. From this observation, we expect the large surface are of Pt sputtered film plays a key role in occurring good catalytic reaction.

3.3 I-V CHARACTERISTICS OF DSSCS

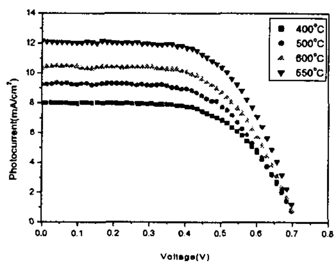


Fig. 5 Photocurrent-voltage curves of DSCs in variation of RTA temperature

Fig.5 shows photocurrent-voltage curves in variation of TRA temperature. Solar cell was exposed to simulated sunlight with AM1.5 spectral distribution. Light intensity was 100mW/cm2 and the active area was approximately 0.25cm2. With increasing RTA temperature, photocurrent density of dye-sensitized solar cells was enhanced.

4. CONCLUSION

Fabrication and characterization of dye-sensitized TiO2 solar cells(DSSC) consisting of TiO2 electrode, an electrolyte containing I-/I3- redox couple, and a Pt-coated counter electrode was carried out. TiO2 electrodes for DSSC were prepared by spray-coating. Also, effect of substrate temperature on I-V curves of solar cell consisting of approximately 10m thickness and 5x5mm2 active area, The heat treatment was carried out at 550oC for 1min, using rapid thermal annealing(RTA) furnace. Solar cells having 5x5 mm2 active area were assembled for measuring I-V characteristics. There was no significant difference in the apparent diameter of TiO2particles, but the increase in number of vertical cracks occurred with increasing substrate temperature. Also, an open circuit voltage(Voc) of approximately 0.70V and a short-circuit photocurrent(Jsc) of 8 to12mA/cm2 were observed in the TiO2 solar cell. With increasing RTA temperature, photocurrent density of dye-sensitized solar cells was enhanced, leading to enhancing the efficiency of dye-sensitized solar cells having Pt-electroplated counter electrode.

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