Surface Treatment of Dye-Sensitized Solar cells by Atmospheric Pressure Plasma

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INTRODUCTION

The dye-sensitized solid-state solar cells (DSSSCs) could have the potential to be alternatives to the existent DSSCs. However, solar conversion efficiency of DSSSCs is lower than that of conventional DSSCs efficiency [1, 2].
Surface treatment of dye-sensitized solid-state solar cells by atmospheric pressure plasma jet was studied to improve its efficiency.

METHODS

(1)Experimental setup

Figure. 1 shows an experimental setup for surface modification. Atmospheric pressure plasma jet was generated between two electrodes. The plasma jet electrode was powered by an AC high voltage power supply. The process gas was fed through the glass tube from gas cylinders. DSSSCs sample and the plasma jet electrode were placed into a chamber. An Ar/O_2 mixture (5.00 + 0.25 L/min.) was used as the process gas. Additionally, the process gas can be humidified (relative humidity 65%). The frequency of AC high voltage was set at 16.1 KHz. Discharge voltage was 5.0 kV (Figure. 2 (a)). Distance between cathode and TiO_2sample was 13 mm. Figure. 2 (b) shows an image of light emission of Ar + O_2 plasma discharge.

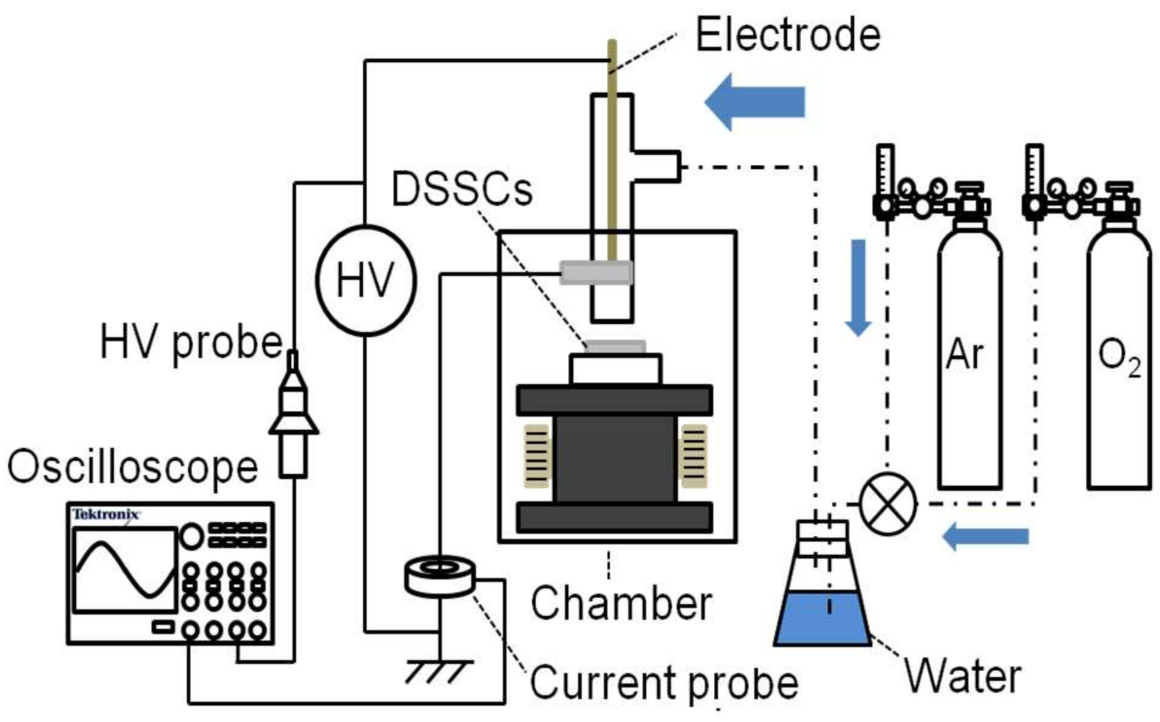


Fig. 1 An experimental setup for TiO_2 sample surface modification.

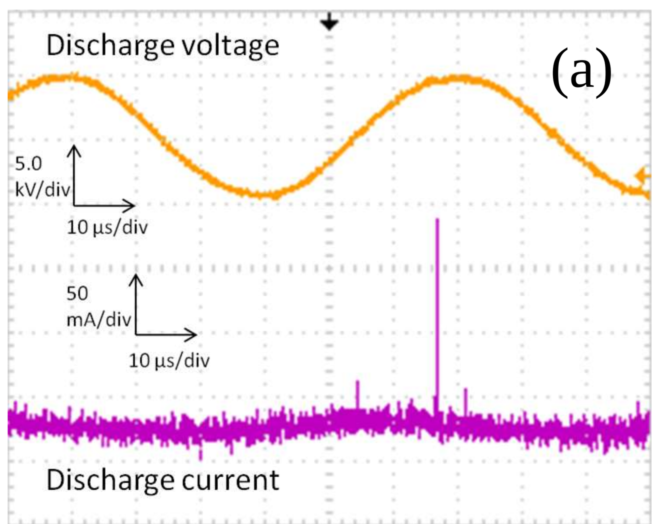


Fig. 2 (a) current-voltage wave form.

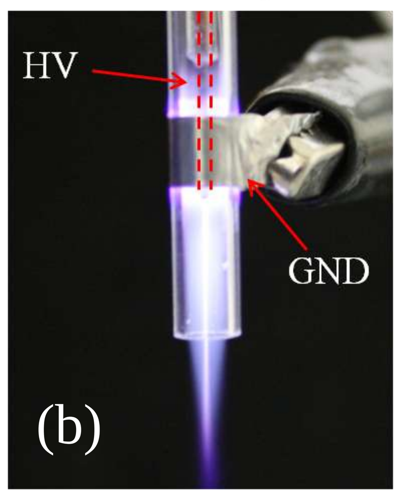


Fig. 2 (b) image of Ar + O_2 plasma discharge.

RESULTS

(1)Photovoltaic measurements

The size of the TiO_2 sample was 0.5 cm^2. After the plasma exposure treatment, The TiO_2 sample was soaked to dye again for about 18 hours. N719 Ruthenium-based dye was used. I-V characteristics were measured under simulated solar light (AM 1.5, 100mW/cm^2) using a solar cell evaluation system (JASCO, CEP-25BX). Treatment time of sample surface was 5, 10 and 15 min. The target sample was attached in the chamber and relative humidity in chamber was 0%. 3 samples were treated each time. Figure. 3 and Table. 1 show the result of photovoltaic measurements. Efficiency was improved with increasing treatment time because the short circuit photocurrent density was increased by plasma treatment.

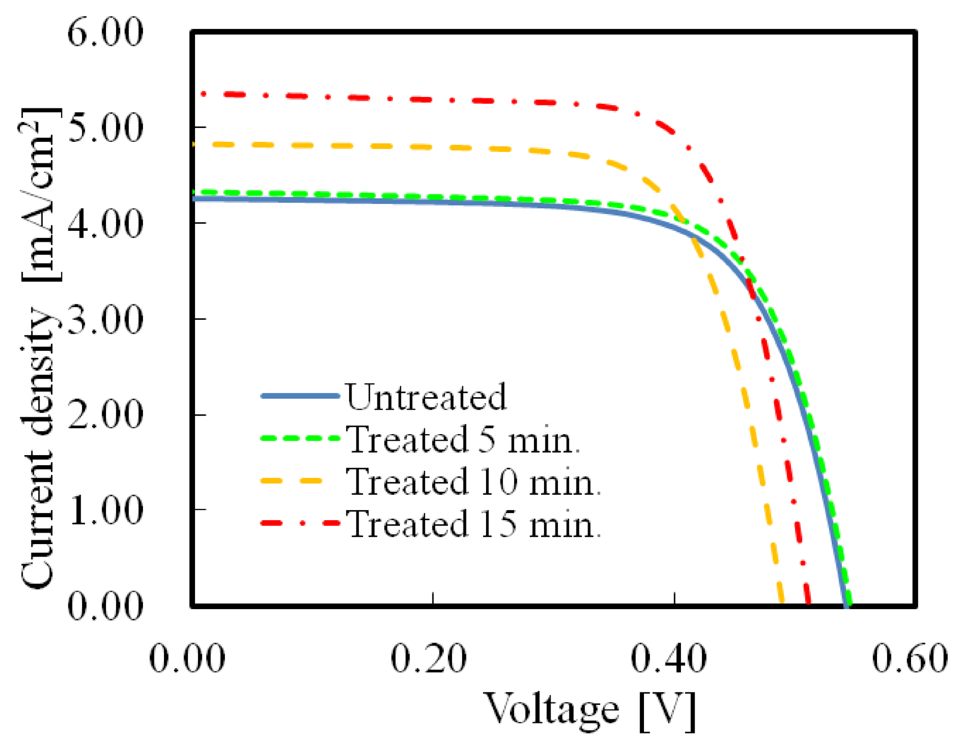


Fig. 3 I-V characteristics before and after various treatment times (5, 10 and 15 min.).

Table 1 Characteristics of no treated and treated DSSCs.

Treatment time [min.]	J_{sc} [mA/cm2]	V_{oc} [V]	FF	h [%]
Untreated	4.25	0.54	0.69	1.60
5	4.32	0.55	0.70	1.65
10	4.82	0.49	0.71	1.67
15	5.35	0.51	0.72	1.96

(2) XPS analysis

The surface stoichiometry was determined by calculating the relative peaks area as ratio of the total Ti 2p and O 1s in XPS spectra (Figure 4). Table. 2 shows chemical composition of TiO_2 surface before and after treatment. Ti^{3+} peaks and Ti_2O_3 peaks were increased after plasma treatment.

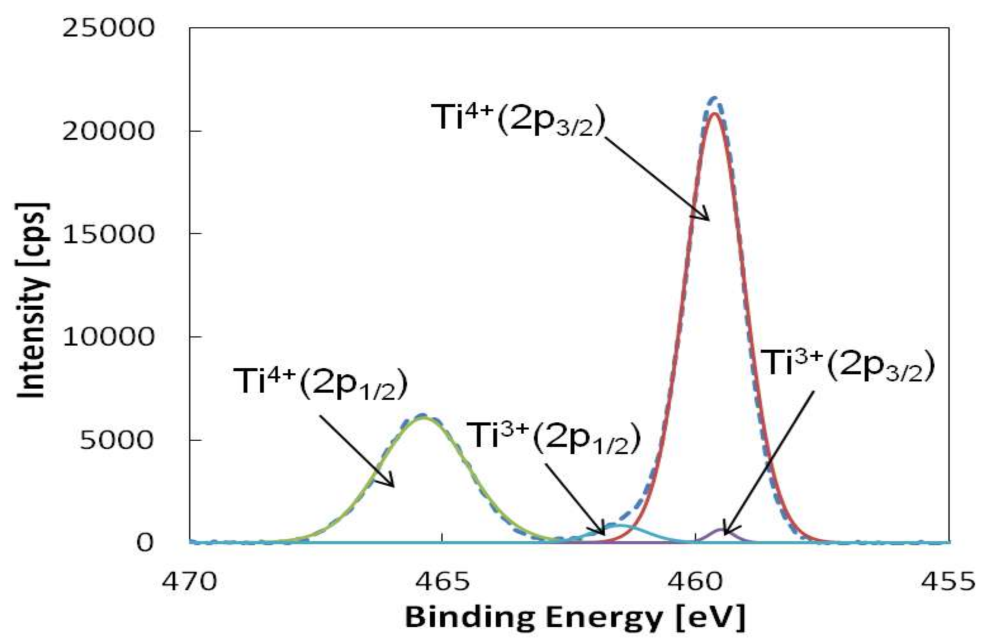


Fig.4 (a) XPS spectra of Ti 2p on the TiO_2 surface (treated 15 min.).

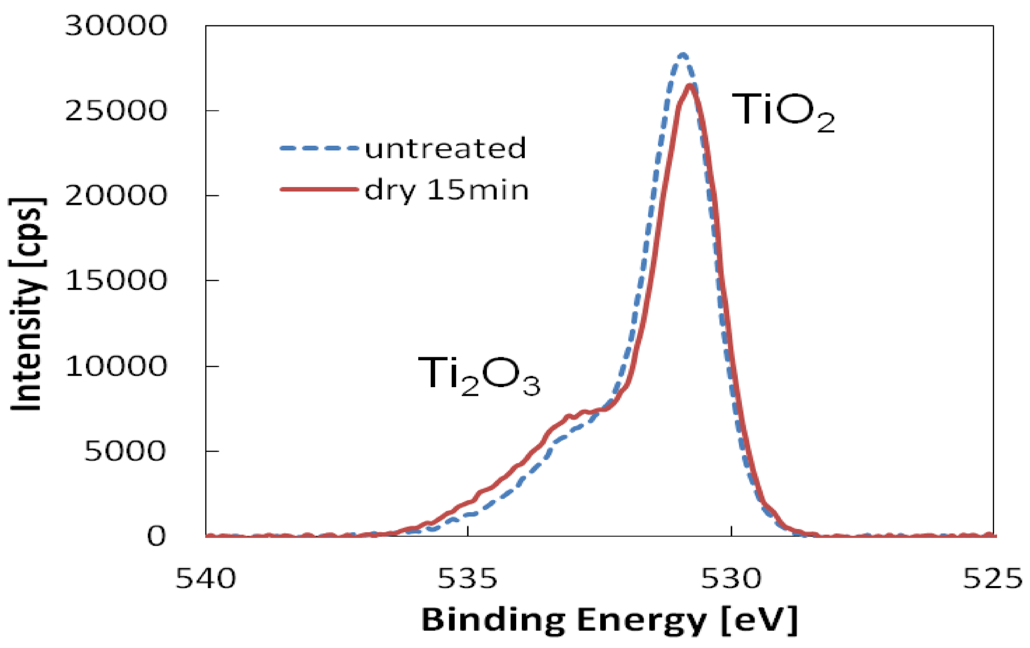


Fig.4 (b) XPS spectra of O 1s on the TiO_2 surface (treated 15 min.).

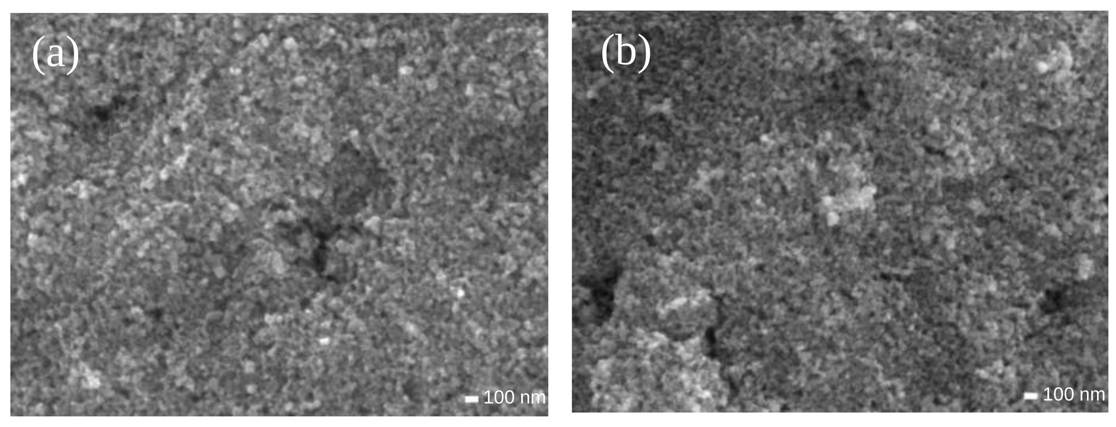
Table 2. Chemical composition of TiO_2 surface.

Ti 2p	Ti^{4+} $2p_{1/2}$	Ti^{4+} $2p_{3/2}$	Ti^{3+} $2p_{1/2}$	Ti^{3+} $2p_{3/2}$
No treated	29.52	67.21	2.39	0.88
15 min	29.61	66.48	2.93	0.97

O 1s	TiO_2	Ti_2O_3
No treated	72.99	27.01
15 min	67.81	32.19

(3) SEM image

As shown in Figure. 5, The photo of TiO_2 surface before and after treatment were taken by a SEM. No significant change on the TiO_2 surface was observed.



(a) Before treatment (b) 15 min. treatment

Fig. 5 FE-SEM images of TiO_2 surface

(4) Effect of humidity

Dry treatment (dry process gas with relative humidity 0%), and wet treatment (humid process gas with relative humidity 65%) were carried out (Figure 6).Dry treatment improved the conversion efficiency. Improvement rate increased with about 20% after 15 min. Wet treatment worsened the conversion efficiency. After 15 min of wet treatment, improvement rate decreased with about 45%.

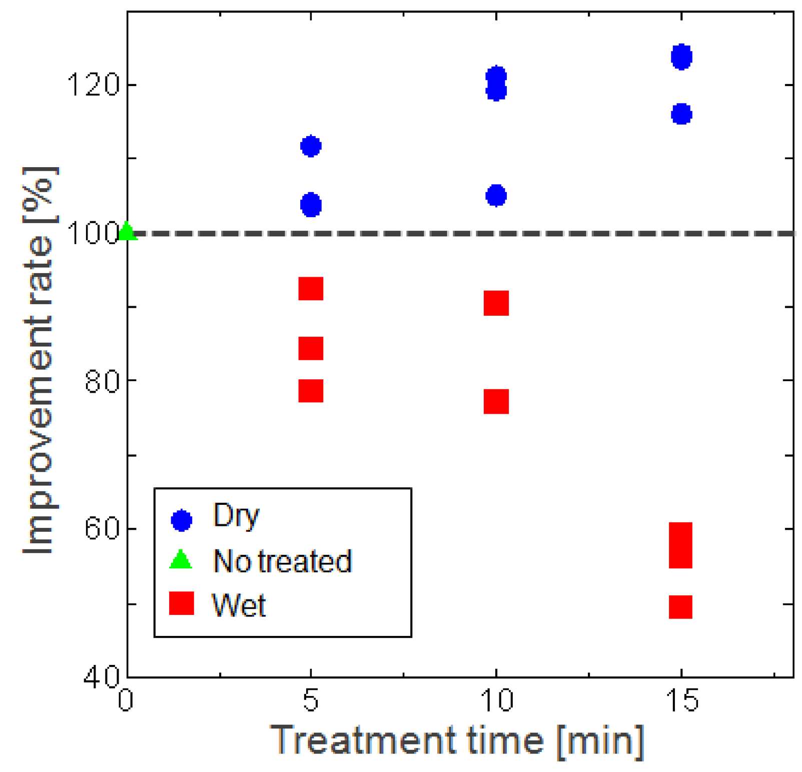


Fig. 6 Effect of humidity in the carrier gas.

(5) Dye adsorption quantity

Figure. 7 shows dye adsorption quantity of TiO_2 surface after plasma treatment. After Dry treatment, dye adsorption quantity increased with about 5%. On the other hand, after Wet treatment, dye adsorption amount decreased with about 20%. Hydrophilic group modification could have been occurred during both types of treatment. However, humidity in process gas inhibited the dye adsorption and decreased the conversion efficiency.

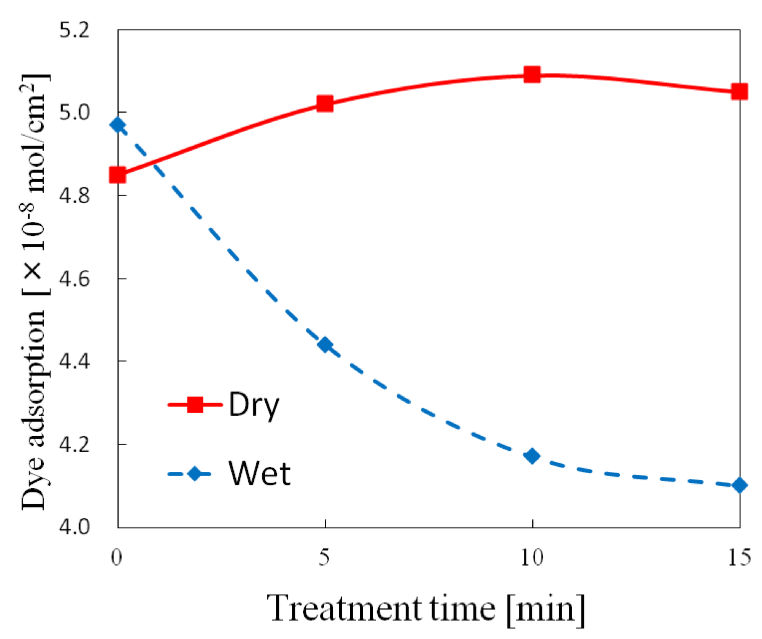


Fig. 7 Dye adsorption quantity of TiO_2 surface versus treatment time

CONCLUSIONS

In this study, the following conclusions were obtained.

1. The DSSSCs surface modification using atmospheric pressure plasma jet improved the conversion efficiency of DSSSCs.
2. The electric conductivity of the DSSSC sample surface was increased after 15min of plasma treatment.
3. Humidity in the carrier gas decreased the conversion efficiency of DSSSCs because humidity in process gas inhibited the dye adsorption.

REFERENCE

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