電気材料技術雑誌　第20巻第２号
J. Soc. Elect. Mat. Eng.　Vol.20,　No.2　２０１１

Development, Characteristics and Durability of Dye-Sensitized Solar Cell

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Abstract

The DSSC 120 x 120 mm square sub-module with high conversion efficiency, excellent high temperature durability was fabricated using the new ruthenium-complex dye J2 which was developed by us, most appropriate TiO_2 nano-particles, suited electrolyte containing iodine, the improved sealant, protective material of collecting grids. By assembling many sub-modules, large size of modules and also see-through type DSSC modules were developed. By the study of characteristics of DSSC on the incident angle of light and temperature, the advantage of DSSC has been discussed comparing with other Si solar cells.

Keywords; Solar cells, DSSC, Dye, Durability, Module, Titania, Catalyst, Screen-print

1. Introduction

Recently organic solar cells have attracted much attention among various solar cells because of potential low cost for the material and for preparation.

There are two types of organic solar cells, one is donor-acceptor type systems such as conducting polymer/C_{60} systems and the other is dye sensitized solar cells(DSSC) utilizing TiO_2 and dyes.

Development of the former type of solar cells was triggered by our discovery of remarkable quenching of photoluminescence and enhancement of photocurrent in conducting polymers upon doping of small amount of C_{60} molecules[1)2)3)4)] and in conducting polymer-C_{60} junction systems photovoltaic characteristics have been confirmed[5)6)7)8)].

On the other hand, the latter type DSSC was initiated by the proposal by M.Graetzel[9)].

It should be mentioned that the researches of both types started at early 1990th. However, because of relatively low conversion efficiency and short life time both types have not been practically used so far.

Recently we have developed large size of highly reliable DSSC modules with durability at 85C[10)].

2. Preparation of devices and experimental

FTO glass (120x120mm) was used for the working electrode substrate. Titania particle layers, collecting grids and protective layers were screen-printed in this order on the substrate. Glass frit layers protect the cell from the corrosion by iodine. The ruthenium dye developed by us was adsorbed on the titania layer. Figure 1 and 2 indicate the molecular structure of J2 and its absorption spectrum, respectively. The titanium plate was used as the counter electrode. The platinum catalytic layer was formed on the plate.

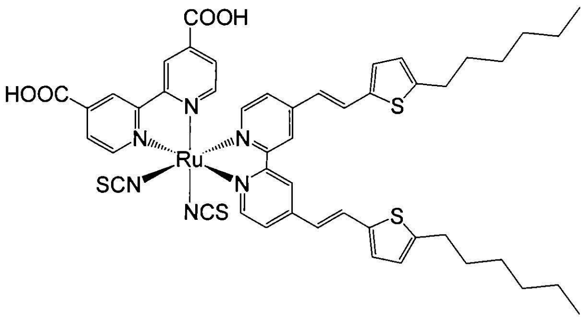

Fig. 1 Molecular structure of J2

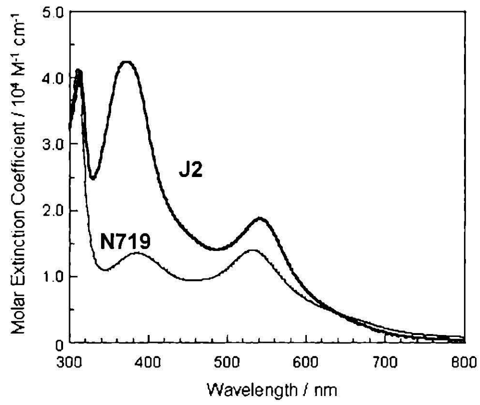

Fig. 2 Absorption spectrum of J2

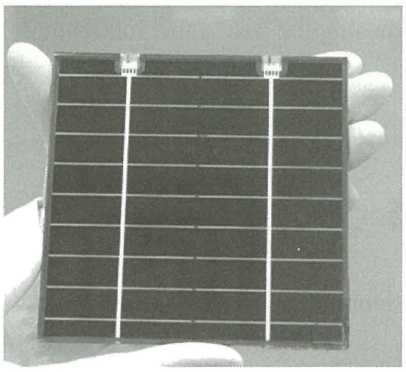

Fig. 3 DSSC sub-module of 120 x 120 mm2

The electrolyte optimized by iodine and some additives in the high boiling point solvent was used. After the electrolyte was filled through the hole, the hole was sealed to complete the sub-modules.

3. Results and discussion

Figure 3 shows typical DSSC sub-module of 120 x 120 mm square. The efficiency of this module was 6% as shown in Fig.3. It should also be mentioned that in cells with size less than 1cm^2 much higher efficiency above ten 10 % was easily obtained.

We have also developed transparent see-through color DSSC sub-modules with excellent characteristics utilizing a glass substrate as a counter electrode.

The efficiency of this module is comparable to that of amorphous Si cell but it is much lower than that of the single crystal Si cell and also polycrystalline Si cell. However, what is important is the characteristics in the practical use under various conditions. For example, in Si solar cells it is well known efficiency drops for the light coming with low incident angle and also at high temperature. That is, in morning and evening, sun light comes in low angle. Also in day time in summer, the temperature of photovoltaic device under strong sun light increases remarkably. So we studied characteristics of our DSSC photovoltaic device (DSC) in Fig.4(a) as functions of incident light angle and temperature in comparison with single crystal Si photovoltaic device (Single-Si PV), poly-crystalline Si photovoltaic device (Polyp-Si PV) and amorphous Si photovoltaic device (Amorphousa-Si PV) shown in Fig.4(b), (c), (d), respectively.

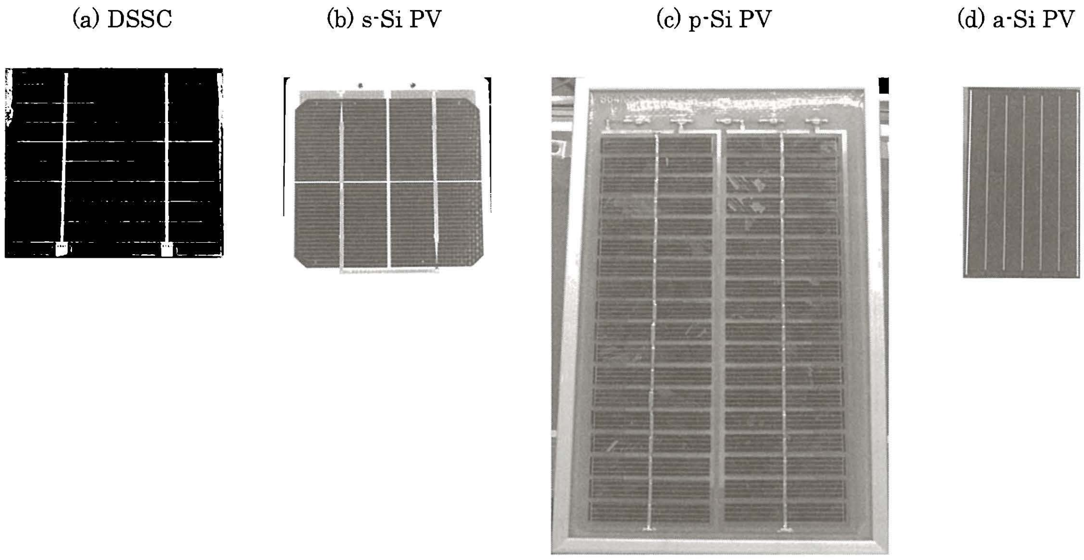

Fig. 4 Appearance of the solar cells for the test of PV performance dependency on incident light angle and temperature

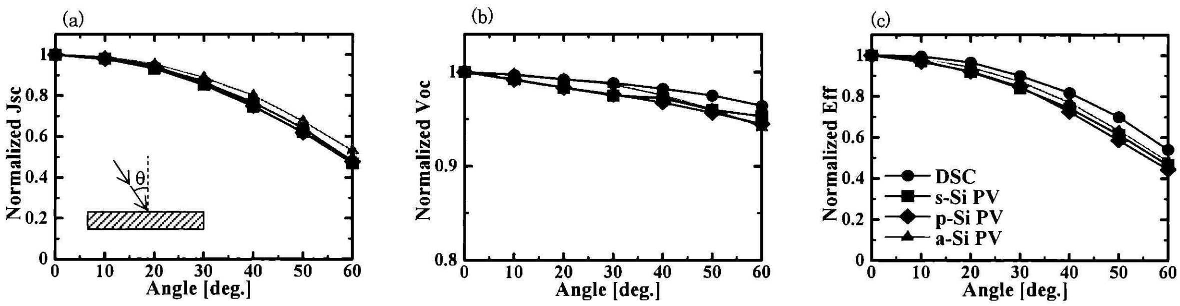

Fig. 5 Dependence of Jsc (a), Voc (b) and efficiency (c) on incident light angle (q).

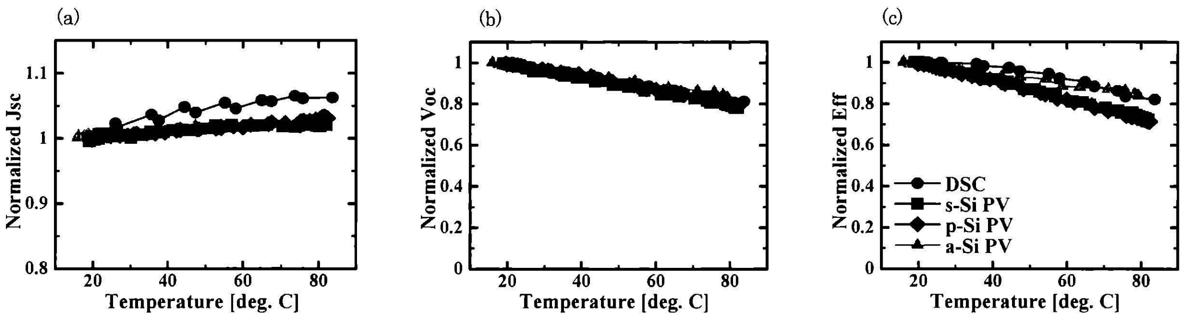

Fig. 6 Dependence of Jsc (a), Voc (b) and efficiency (c) on temperature

Figure 5 (a), (b) and (c) show normalized short circuit current (J_{sc})open circuit voltage (V_{oc}), normalized open circuit voltage (V_{oc}) short circuit current (J_{sc}) and the normalized efficiency, respectively as function of incident angle indicated in the inset of Fig.5(a).

As evident from these figures, for low incident angle light, the characteristics of DSSC are better than s-Si PV, p-Si PV and a-Si PV.

Figure 6 (a), (b) and (c) show temperature dependences of normalized open circuit voltage (V_{oc}), normalized short circuit current (J_{sc}) and the normalized efficiency, respectively .

As evident from these figures, at high temperatures, the characteristics of DSSC are better than s-Si PV, p-Si PV and a-Si PV

Figure 7 (a), (b) and (c) show irradiation light intensity dependences of normalized short circuit current (J_{sc}), normalized open circuit voltage (V_{oc}) and the normalized efficiency, respectively.

As evident in these figures, under low irradiation light intensity, the characteristics of DSSC are better than s-Si PV, p-Si PV and a-Si PV. This means that under room light and evening DSSC can be used effectively.

Figure 8 (a), (b) and (c) indicates output characteristics of DSSC and Si-PV in clear day, cloudy day and rainy day from morning until evening. It should be noted that the characteristics of DSSC are more uniform compared with Si-PV. This stable Vpm of DSSC in different weather condition would facilitate a controlling circuit for tracking maximum power point, which can lower a

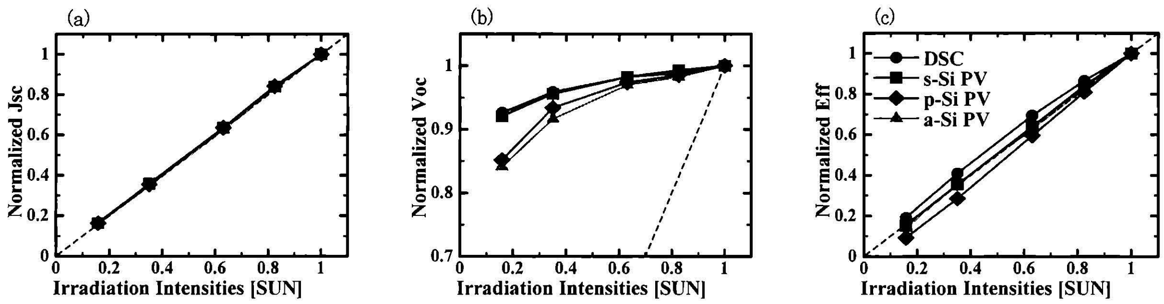

Fig. 7 Dependence of Jsc (a), Voc (b) and efficiency (c) on irradiation light intensity.

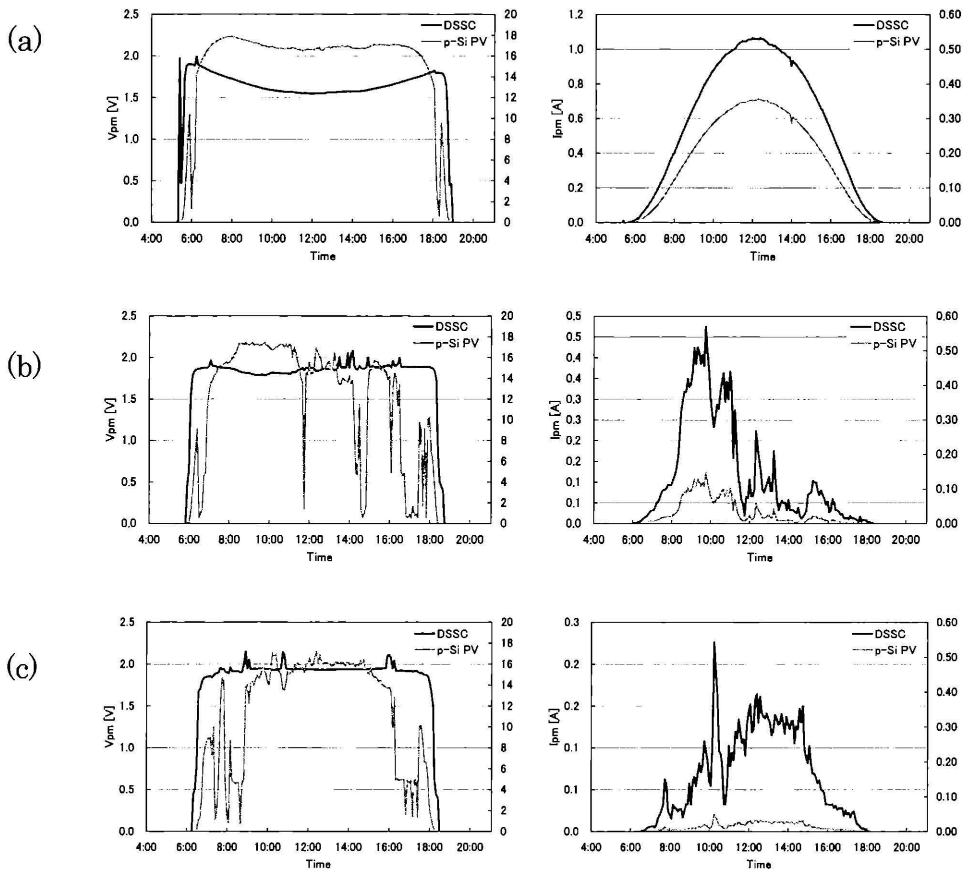

Fig. 8 Voltage and current at maximum power point in clear day (a), cloudy day (b) and rainy day (c)

cost of solar cell system.

Figure 9 (a), (b), (c) and (d) show the out-put characteristics of s-Si PV, p-Si PV, a-Si PV and DSSC in spring, summer, autumn and winter seasons, respectively. These figures indicate that the characteristics of DSSC is suitable for some uses.

Figure 10 (a) and (b) show the out-put characteristics, generated energy per unit area and generated energy per rated output of s-Si-PPV, p-Si PPV, a-Si PPV and DSSC in four seasons, respectively.

These figures indicate that the characteristics of DSSC is suitable for some uses.

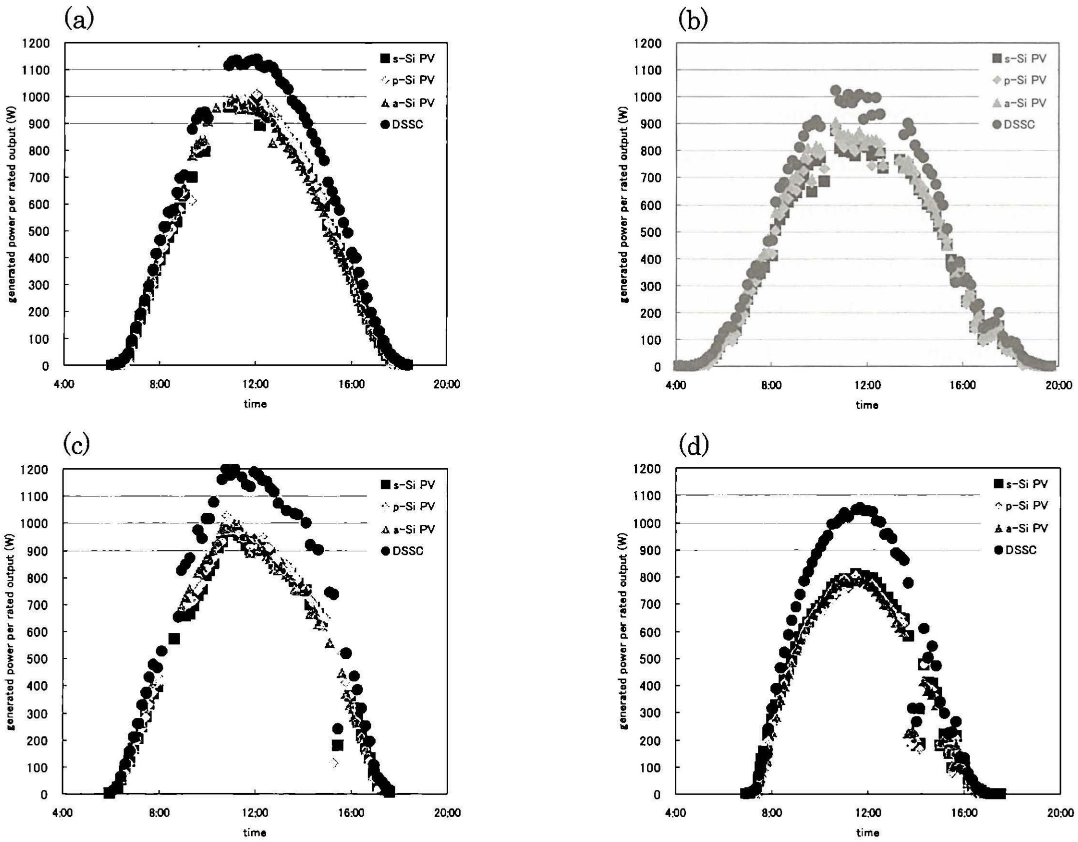

Fig. 9 Output power changes throughout the day in spring (a), summer (b), autumn (c), winter (c) seasons.

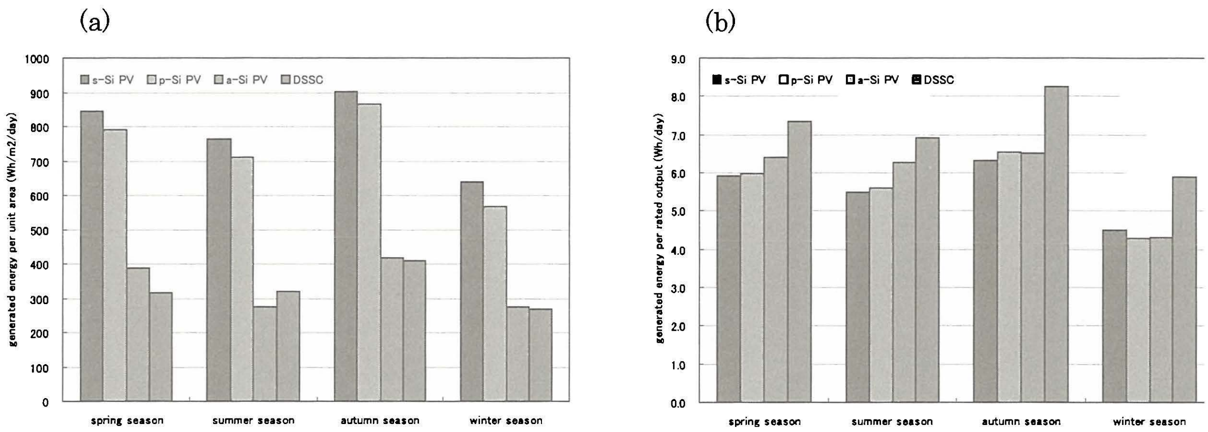

Fig. 10 Generated energy per unit area (a) and per rated output (b) of 4 different types of solar cells in four seasons.

4. Summary

Large area of DSSC sub-modules and modules with high conversion efficiency, excellent high temperature durability were fabricated using ruthenium-complex dye developed by us, most appropriate TiO_2 nano-particles, suited electrolytes containing iodine, the improved sealant, protective material of collecting grids. By assembling many sub-modules, large size of modules and also see-through type DSSC modules were developed. By the study of characteristics of DSSC on the incident angle of light, light intensity, temperature from morning until evening for four seasons, the advantage of DSSC has been demonstrated comparing with other Si solar cells.

For light of low incident angle DSSC exhibits higher relative efficiency compared with Si solar cells.

At higher temperature, lowering of efficiency is less in DSSC than Si solar cells.

At low light intensity, DSSC exhibits better characteristics than Si solar cells.

Therefore even in evening DSSC exhibits relatively good characteristics.

It should also be mentioned that even under room light, DSSC exhibits relatively good characteristics.

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