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The Influence of Environmental Factors on DSSCs for BIPV

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The influence of environmental factors on the I-V measurement of DSSCs was meausured for integrated into a building as photovoltaic modules. The photoelectric conversion efficiency of DSSC had no dramatic changes according the incident light angle. For the incident angle from 60°to 90°, the efficiency did not change more than 5%. Further more, DSSC cells have a very good temperature coefficient, which is about 0.1% at 30 ° to 50 °. The performance of DSSC depends on irradiance and temperature of input means the DSSCs response to environmental factors based on BIPV application situations.

Keywords: Dye-sensitized solar cell, Equivalent circuit,Current voltage characteristic

1. INTRODUCTION

When photovoltaic modules are integrated into a building, other design considerations, such as aesthetics, compete with maximizing energy production, building integrated photovoltaic (BIPV) systems often produce a greater proportion of energy at low irradiance than conventional photovoltaic systems due to architectural constraints in the design of BIPV arrays. Important points are not only the efficiency of the solar cell panel itself but also effective applications under different conditions of buildings to reduce heating and cooling load.

Many scientists analyzed the temperature, angle, light-level on the performance of the BIPV. For example, Yoo et al. applies the simulation program SOLCEL about BIPV[1]. Stamenic et al. calculated the empirical factor on the the STC performance data of BIPV[2].

Due to the different solar cells have the different reactions to the varyings of temperature, angle of incidence, and light intensity, there are more in-depth research for each special type of solar cell response to environmental factors. For instance, Han et al. applies thermal behavior of a novel type see-through glazing system with integrated PV cells[3], Radziemska anlysised about Si and GaAs BIPV [4], and Mercaldo discussed about thin film silicon photovoltaics [5].

However, there are many new solar cells emerging, and which in BIPV application prospects can not be ignored. For example, dye-sensitized solar cell (DSSC) applications is a very promising next-generation PV cells[6, 7]. DSSC has been intensively studied as one of the most promising solar cells due to its desirable lower cost, and simpler manufacturing process than conventional Si solar cells[8, 9]. Pre-analysis of these new cells in BIPV applications, is likely to discover some important implications of the field present or future.

It is impressive to note that the DSSC efficiency record of 11.1% measured under the irradiance of AM 1.5G sunlight is held by the well-known N719 or black dye in combination with a thick mesoscopic titania film[9].

The performance of DSSCs deponds on irradiance and temperature of input means DSSCs response to environmental factors should be anlysised based on BIPV application situations.

In this paper, we report that the measured energy conversion efficiency of DSSC as a BIPV modul under different environmental factors. These experiments is important basis to determine DSSC usation for BIPV.

2. EXPEREMENT

Dye-sensitized solar cells were prepared as follows[10]. A TiO_2 film was made by extruding a precursor paste onto a F:SnO2 conductive glass substrate and heating it at 500° C for 30 min. Dye absorption was carried out by dipping TiO_2 electrode in a $4x10^{-4}$ M ethanolic solution of Ru (2,2--bipyridine-4,4-dicarboxylic acid)$_2$(NCS)$_2$. The electrolyte is composed of 0.6 M PMII, 0.1 M I_2, and 0.45 M NMBI in MPN solvent. The Si cell is commercial product of Young&Strong Inc.of Taiwan.

FTO substrates of DSSCs were flushed with diluted solution of Triton X-100, and then flushed again with the alcohol. These substrates were baked for 30 minutes with theinfrared lamp to remove the liquid which may remain. $TiCl_4$ ($TiCl_4$ 99% A.R, Nanjing Chemical Reagent Co., Ltd.) was diluted with water to 2 M at 0 °C to make a stock solution, which was kept in a freezer and freshly diluted to 50 mM with high purity water at each $TiCl_4$ treatment.

FTO substrates submerged freshly diluted 50 mM $TiCl_4$ solution and keeped in at 70 ℃ for 30min.

The I-V curve was obtained using a source measure unit (Model 236, Keithley Instruments, Inc.) under irradiation (0.1 W/cm^2, AM 1.5) using a Solar Simulator (92251A, ASTM class A solar simulate, Oriel Instruments, Inc.).

By the stepwise changing of bias power supply of Model 236, the values of voltage and current in cells are measured by means of current–voltage (I-V) characteristic curves, which have been used as the I-V measurement method. Current voltage characteristic curve (I-V curve) could offer the short-circuit current (Isc), open-circuit voltage (Voc), fill factor (FF), and the energy conversion efficiency

(g) of DSSCs. Therefore I-V curve is convenient to evaluate the improvement of DSSCs on materials, structures and manufacture. I-V curve has been widely used as a typical tool in the research of DSSCs's photovoltaic characteristic.

The stepwise change of bias power supply is described by Td, Tm and △V, as shown in Figure 3. Td, Tm and △V are sampling delay time, measuring integration time and step source level, respectively. The speed of bias power supply's stepwise change is obtained by such expression as $\frac{\Delta V}{T_m + T_d}$.

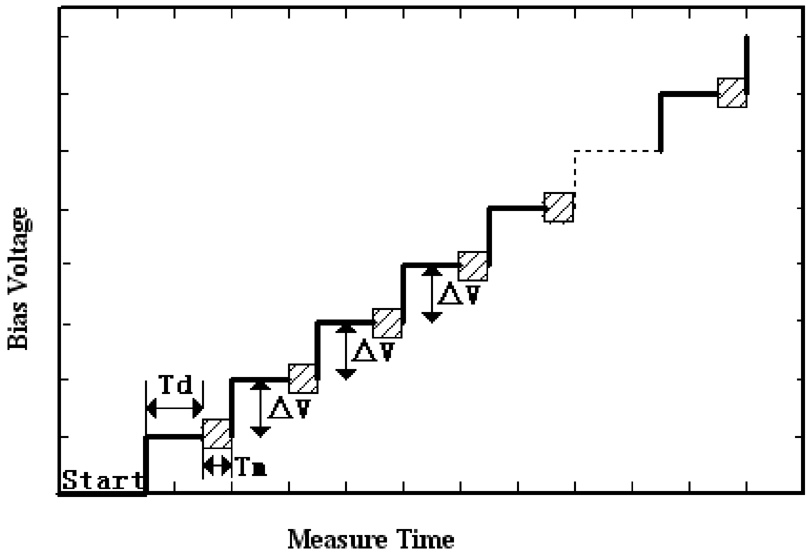

Figure 1. Stepwise change of bias voltage supply. Td,Tm and △V are sampling delay time, measuring integration time and step source level respectively

Oriented irradiation were modulated by changing inputting current of the solar simulate, or adding glass sheets with a comparatively avarage absorption in the wavelength range of 300- 800 nm in the light-path to reduce light intensity. Cell response photovoltages under irradiation of different irradiation light were respectively measured, and the origins of these responses are analyzed.

The relationship between the I-V curves of DSSC and the angle of incident light were abtained by successive angling the DSSC manually.

The temperature of DSSCs is controllable in the heat chambers respectively with being maintained for more than ten minutes to stabilize the cell's temperature.

3. RESULT AND DISCUSSION

3.1. The relation between measurement speed and measured I-V curve

As shown in Figure 1, the incident light is a beam of the solar simulator with under an initial irradiation (0.1 W/cm2, AM 1.5), and the intensities of light in the perpendicular plane are adjustment in the range of irradiation from 0.8 AM 1.5to 1.1 AM 1.5.

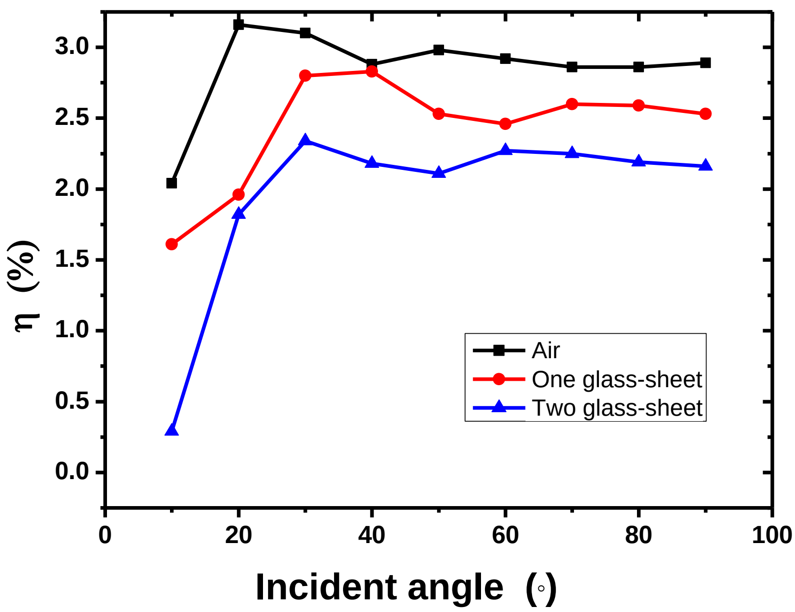

Figure 2. The DSSC I-V curves with the irradiation changed by glass-sheet.

It can be seen from Figure.2, the photoelectric conversion efficiency of DSSC is not dramatic changes according the incident light angle. For the incident angle from 60°to 90°, the efficiency did not change more than 5%. That BIPV is not sensitive to the incident angle is an important factor for its electricity energy generation effect.

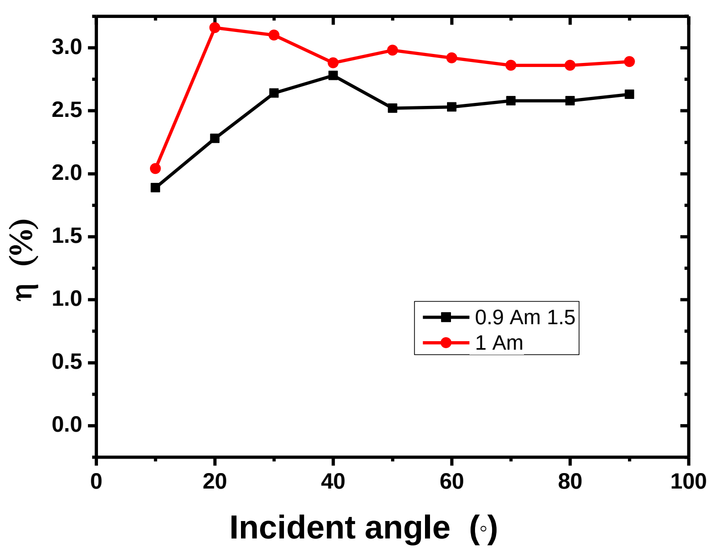

Figure 3. The DSSC I-V curves with the irradiation changed by input current

Therefore, according to these results, DSSC meet the incident angle requirment of BIPV for the building design restrictions, fixed installation restrictions. The experments in Figure 2 were abtained by adding glass sheets with a comparatively avarage absorption in the wavelength range of 300- 800 nm in the light-path to reduce light intensity. In order to eliminate the uneven spectral absorption of glass sheets on the simulator beam to the measurement results, we also measured the I-V curve of DSSC under differnets irradation by changing the simulator input current, which was shown in Figure 3.

Figure 3 also shows that, the photoelectric conversion efficiency of DSSC is even under the incident angle from 60°to 90°, not only in irradiation of AM 1.5, but also setting up in the low irradiation conditions of 0.9 AM 1.5. In fact, low-light situations is more important, because , for example, most of the time in most areas of China, irradiation are weaker than AM1.5

As thermal behavior of a novel PV cells in BIPV were concerned, such as Si cell [3], GaAs cell [4], thin film silicon photovoltaics [5], The photovoltage behavious of DSSCs in differnet temperature is showned in Figure 4.

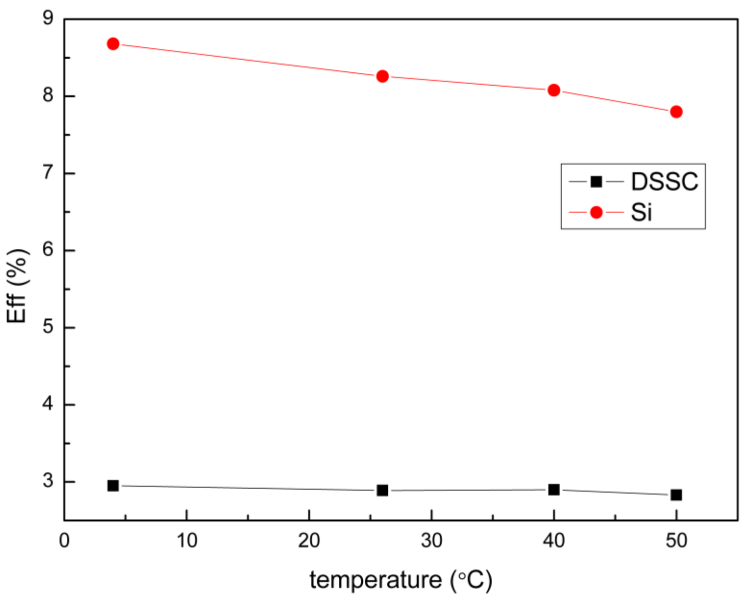

Figure 4. The photoelectric conversion characteristic of DSSCs and Si cell in differnet temperature.

Figure 4 shows, DSSC cells have a very good temperature coefficient, which is about 0.1% at 30° to 50°. However, due to the use of liquid electrolyte in DSSC, the vapor pressure of the liquid generated by the high temperature may produce cracking of the battery package and the decomposition of organic matter, so the situation higher than 50° were not tested. In fact, under the conditions to ensure package integrity, 80° or higher temperature also should be tested in our farther test.

Here we only analyzed the impact of environmental factors on DSSCs, but not seek a high photoelectric conversion efficiency. Because usually we make the high conversion efficiency of the cell in relatively small sizes. The small cells produces very weak current, so that the temperature, angle of incidence and other effects are easy to drown in the noise inside. Therefore, we used 18mmx25mm relative large cell.

In fact, we also tried a multi- layer of TiO_2[11], and La_3^+ doping and got a good result in the pursuit of efficiency. DSSCs with only one layer could not meet all the requirements of the cell, so double-layer or multilayer electrode was investigated. One advantage of the structure is that it can increase light scattering, which facilitates the light harvesting of DSSCs. Multilayer cells by using particles of various porosity as light scatting layer as discussed, which enhanced back scattering and suppressed light loss. Other researchers reported obvious improved performance of DSSCs by using 100 and 400 nm TiO_2 particles, big hollow spheres,and even nanofibers as light scattering layer.

4. CONCLUSIONS

We have analyzed the influence of environmental factors on the I-V measurement of DSSCs. For DSSCs to implied in BIPV, the photoelectric conversion efficiency of DSSC is not dramatic changes according the incident light angle. For the incident angle from 60°to 90°, the efficiency did not change more than 5%. Further more, DSSC cells have a very good temperature coefficient, which is about 0.1% at 30 ° to 50 °.

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