Photovoltaic Properties Of Nano-Sized TiO_2 Electrode With Chlorophyll Based Photosensitizer For DSSC Application

Htet Htet Nwe[1], Yin Maung Maung[2*], Zeya Oo[3] , Win Win Thar[1]
Than Than Win[4] and Ko Ko Kyaw Soe[5]

[1]Department of Physics, Dagon University, Myanmar
[2]Department of Physics, Kyaing Tong University, Myanmar*
[3]Department of Electrical and Computer Engineering/School of Engineering and Science, Curtin University, Sarawak, Malaysia
[4] Department of Physics, University of Yangon, Myanmar
[5]Yangon Institue of Education, Yangon, Myanmar
*Email: [1]htet2nwe@gmail.com, [*2]dryinmgmg@gmail.com*

Abstract. Dye sensitized solar cell (DSSC) is a kind of device that converts visible light into electrical energy and it has been attractive due to its low fabrication cost and reasonable efficiency. Nano-sized TiO_2 powder was obtained by ball-milling for 24 h and it was confirmed by XRD and FeSEM analyses. XRD showed that the anatase phase TiO_2 and well-defined TiO_2 nano-sized powder with size of about 30 nm was given by FeSEM analysis. Rolling method by using glass rod was used to coat TiO_2 film onto FTO coated conductive glass. The natural photosensisitizers based on chlorophyll were extracted from the sansevieria trifasciata and bougainvillea leaves. The absorption spectra from UV-Vis spectroscopy indicated the existence of chlorophyll in dye solution. The carbon was used to deposit onto FTO coated glass for counter electrode. The experimental results showed that the DSSCs which were sensitized with chlorophyll based photosensitizer can achieve the reliable photoelectric conversion efficiencies.

Keywords: Nano-sized TiO_2 powder, FTO coated glass, Photosensitizer, Photovoltaic properties

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INTRODUCTION

A dye-sensitized solar cell (DSSC) is a device for the conversion of visible light power into electricity, based on the sensitization of wide band gap semiconductors. It is well known that a typical dye-sensitized solar cell (DSSC) consists of porous TiO_2 film, dye molecules which are sensitive to sunlight, and an organic liquid electrolyte, essentially containing iodide and triiodide ions as a redox couple [1-2]. Oxide semiconductor photocatalysis has attracted extensive attention due to its wide potential application in environmental protection procedures such as air purification, water disinfection, hazardous waste remediation, and water purification [3–10]. Among various oxide semiconductor photocatalysts, titania has proven to be the most suitable for widespread environmental applications for its high chemical stability, nontoxicity, low cost, and excellent degradation for organic pollutants [11–14].

The performance of the cell mainly depends on a dye used as photo-sensitizer. The absorption spectrum of the dye and the anchorage of the dye to the surface of TiO_2 are important parameters determining the efficiency of the cell. Generally, transition metal coordination compounds (ruthenium polypyridyl complexes) are used as the effective sensitizers, due to their intense charge-transfer absorption in the whole visible range. However, ruthenium polypyridyl complexes contain a heavy metal, which is undesirable from point of view of the environmental aspects. Moreover, the process to synthesize the complexes is complicated and costly [15-17]. Alternatively, natural dyes can be used for the same purpose with an acceptable efficiency .The advantages of natural dyes include their availability and low cost [18–21].

In nature, some fruits, flowers, leaves and so on show various colors and contain several pigments that can be easily extracted and then employed in DSSCs. The leaves of most green plants are rich in chlorophyll, and the application of this kind of natural dye has been frequently investigated in many related studies. On the other hand, natural dyes extracted from fruits and flowers have attracted the attention of many researchers and many natural dyes have been proven to be efficient dyes as photosensi-tizers in DSSCs [22-24]. In this paper, the optical properties of the natural photosensitizers extracted from sansevieria trifasciata and bougainvillea leaves were studied. The photovoltaice properties of nano sized TiO_2 electroded

DSSC with natural photosensitizers were also observed.

EXPERIMENTAL PROCEDURE

TiO_2 Photoelectrode Preparation

The TiO_2 powder was fabricated by ball milling for 24 h. It was confirmed by XRD and FeSEM analyses. The XRD pattern of TiO_2 powder was shown in figure 1 and figure 2 that indicated the FeSEM photo of TiO_2 powder. XRD results showed that the anatase phase TiO_2 with tetragonal structure. The crystallite size could be calculated by Debye Scherrer formula and it was about 37 nm. Well-defined nano-sized TiO_2 powder with size of about 30 nm was given by FeSEM analysis.

3 g of TiO_2 powder was mixed with 10 ml of acetic acid and stirred for 1 h. Then it was aged for 1 day to get better performance. Fluorine doped tin oxide (FTO) glass was used as transparent substrate. The FTO glass was cleaned with DIW followed by 2-propanol and dried at room temperature. (1×1 cm^2) of FTO glass was used for the coated area and another area was masked by using scotch tape. TiO_2 paste was placed onto the FTO glass and slided by glass rod. The TiO_2 coated FTO glass was preheated at 100˚C for 15 min and then annealed at 450˚C for 1 h.

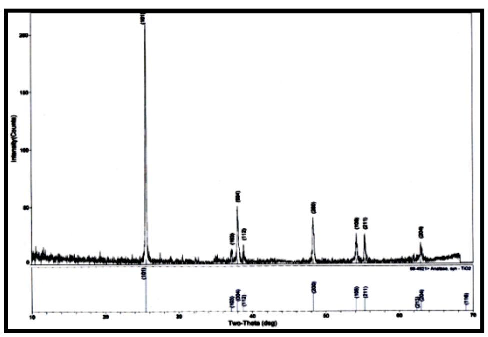

FIGURE 1. XRD pattern of TiO_2 powder

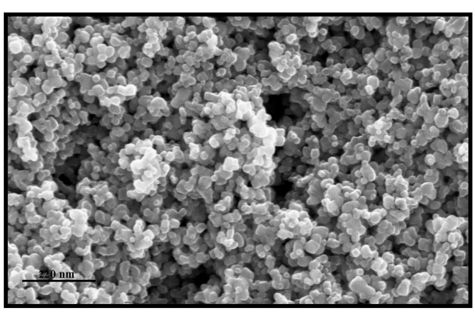

FIGURE 2. FeSEM photo of nano-sized TiO_2 powder

Natural Photosensitizer Preparation

First of all, the sansevieria trifasciata and bougainvillea leaves were taken and cleaned with DIW. They were dried at room temperature for 1 day and cut into small pieces. They were immersed in DIW: ethanol (50:50) solution and kept in dark place for 1 day. And then, they were filtered and the filtrated solutions were heated by water bath for 8 h until 10 % of solution was left. The solution was mixed with ethanol and centrifuged for measurement of the UV-Vis spectroscopy. The UV- Vis spectra of sansevieria trifasciata and bougainvillea leaves were shown in figure 3 and figure 4. The sansevieria trifasciata extract showed 6 peaks in the range between 400 nm and 700 nm while bougainvillea leaves extract occurred 5 peaks in the same interval. The maximum absorbance was of 0.84 for sansevieria trifasciata extract and 2.72 for bougainvillea leaves extract. As a detail analysis of UV-Vis result, the absorption spectra indicated the existence of chlorophyll in dye solution.

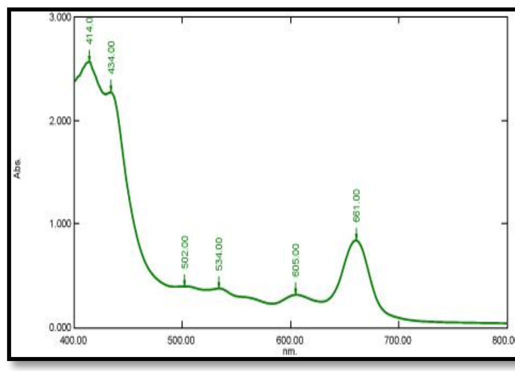

FIGURE 3. UV-Vis spectrum of sansevieria trifasciata

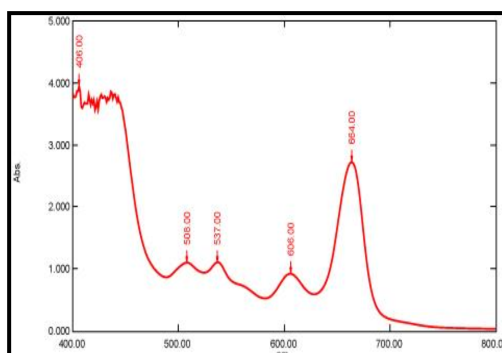

FIGURE 4. UV-Vis spectrum of bougainvillea leaves

Counter Electrode Preparation

The conductive side of FTO/glass substrate was also holed as the same dimension of TiO_2 electrode and filled with carbon to the entire hole of the slide in order not to miss any spots by using oil heater. And then, the film was heated at 100˚C for 30 min.

DSSC Assembly

The TiO_2 photoelectrode was immersed in dye solution for 24 h to stain the dye molecules on TiO_2 film and dried at room temperature. The TiO_2 photoelectrode, sensitized in dye solution, and the carbon counter electrode were assembled by touching the coated sides each other by using binder clips. The iodine electrolyte solution was used as mediator and it was filled between two electrodes to be capillary action.

OUTPUT CHARACTERISTICS

In this work, the experimental setup involved the voltmeter and variable resistor. The solar cells properties were measured under illumination condition (Lux 2000) and the important parameters such as efficiency and fill factor were calculated by using I-V characteristic curves. Figure 5 and figure 6 showed the variation of current- voltage curves of chlorophyll (sansevieria trifasciata and bougainvillea leaves) based DSSCs. Table 1 described the photovoltaic properties of DSSCs in terms of short-circuit current (J_{sc}), open-circuit voltage (V_{oc}), solar energy conversion efficiency (η) and fill factor (FF) for chlorophyll based DSSCs. The solar cell properties J_{sc}=1.01 mA/cm^2 , V_{oc} = 3.17 mV , η= 0.55 % and FF= 0.51 were observed for DSSC (sansevieria trifasciata dye). The J_{sc}= 1.07 mA/cm^2, V_{oc} =3.17 mV , η= 0.94 % and FF= 0.67 were obtained for DSSC (bougainvillea leaves dye). The DSSC, sensitized with bougainvillea leaves dye gave better efficiency than the DSSC, sensitized with sansevieria trifasciata dye.

TABLE 1. Photovoltaic properties of DSSCs with chlorophyll dyes

Dye	J_{sc} (mA/cm^2)	V_{oc} (mV)	η (%)	FF
sansevieria trifasciata	1.01	3.17	0.55	0.51
bougainvillea leaves	1.07	3.95	0.94	0.67

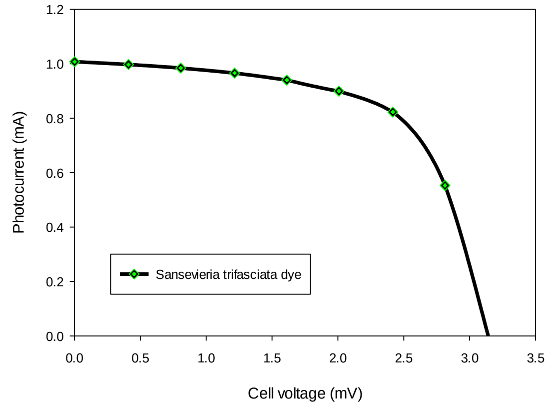

FIGURE 5. Current – voltage curve for DSSC with sansevieria trifasciata dye

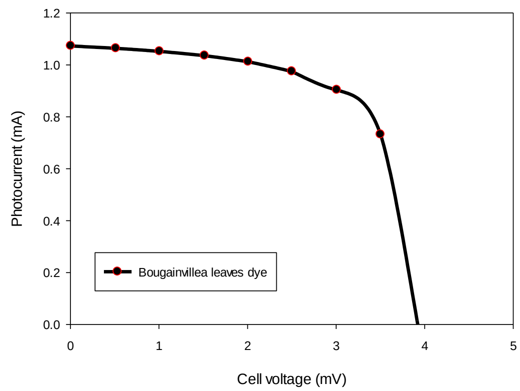

FIGURE 6. Current – voltage curve for DSSC with bougainvillea leaves dye

CONCLUSION

The nano sized TiO_2 powder was formed by ball milling for 24 h. The anatase phase TiO_2 with tetragonal structure showing the crystallite size of 37 nm was observed by XRD analysis. Well defined TiO_2 powder with grain size (30 nm) was confirmed by FeSEM analysis. The UV-Vis spectra gave the absorbance and wavelength which indicated that the dyes could absorb visible light. As a result, the natural dyes extracted from sansevieria trifasciata and bougainvillea leaves could be used as a photosensitizer. The conversion efficiencies of DSSCs were determined to be 0.55 % and 0.94 % for sansevieria trifasciata and bougainvillea leaves dyes. Hence, compared to two dye sensitizers, bougainvillea leaves dye has been investigated and operated over sansevieria trifasciata dye. The fill factors of both cells were quite acceptable for DSSC application. The result indicated the industrial and special requirements for cost effective DSSC although the method used is not complicated and involved. The research done is certainly said to be of low cost and by unsophisticated techniques. Both conversion efficiencies are good provided that chlorophyll is contained in sansevieria trifasciata and bougainvillea leaves. Thus DSSC with bougainvillea leaves dye has given better absorbance and thus the outcome is much better.

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