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INVESTIGATION OF TiO_2/GRAPHENE NANOCOMPOSITE BASED PHOTOANODE IN DYE-SENSITIZED SOLAR CELL

Suhaidi Shafie[1,2], Nursyaliana Misri[1], MohdAmrallah Mustafa[1] and Fauzan Ahmad[3]

[1]Dept. of Electrical and Electronic Engineering, Faculty of Engineering, Universiti Putra Malaysia, Serdang, Selangor, Malaysia

[2]Functional Devices Laboratory, Institute of Advanced Technology, Universiti Putra Malaysia, Serdang, Selangor, Malaysia

[3]Dept. of Electrical and Electronic Engineering, MJIIT, UniversitiTeknologi Malaysia, Kuala Lumpur, Malaysia

*Corresponding author: suhaidi@upm.edu.my

ABSTRACT

Dye-Sensitized Solar Cell (DSSC) which is the third generation photovoltaic solar cell is a promising low cost solar cell. This type of solar cell is robust and do not require clean environment for fabrication. This paper focuses on implementation of graphene in the DSSC photoanode to improve the electron path from photoanode to FTO transparent electrode. In this research, N719 synthetic dye is used as synthesizer and three different types of graphene nanopowder namely 8 nm flakes, multilayer flakes and nanoplatelets were implemented in titanium dioxide as photo-anode. I-V measurement was done under illumination of 1000 W/m^2 using solar simulator and the results show that the DSSC with titanium dioxide photoanode doped with graphene multilayer flakes performs the best in term of open circuit voltage (0.782 V), short circuit current density (12.408 mA/cm^2) and energy conversion efficiency (4.4%).

Keywords: Dye Sensitized Solar Cell; Graphene

INTRODUCTION

Dye Sensitized Solar Cell (DSSC) has attracted researchers since it was developed in 1991 by Professor Michael Graetzel and Dr Brian O'Regan at École Polytechnique Fédérale de Lausanne (EPFL), Switzerland. It was due to the advantages such as low cost [1], environmental friendly and simple fabrication process. DSSC contains nanostructure materials in photoanode so that dye loading can be improved and more photons can be absorbed and induce the electron-hole pair excitation. The highest reported DSSC energy conversion efficiency is 11.9% using black dye and Cobalt electrolyte [2]. Apart from that, DSSC can also be used for low light application such as to power up small electronics devices and as indoor energy harvester. Although the efficiency of DSSCs is less than many of the best thin-film cells, the price-to-performance ratio obtained through these solar cells is better to others. The DSSC can be implemented on glass and flexible material as well. Many technique has been propose to improve the DSSC efficiency, including doping of silver and gold nanoparticles in TiO_2 photo anode [3], [4]. This paper deliberates on the effect of doping of graphene nanopowder in TiO_2 photoanode to the DSSC energy conversion efficiency.

EXPERIMENTAL

PHOTOANODE

In DSSC, photoanode material is generally composed of metal oxide semiconductor. This metal oxide semiconductor requires to have high surface area for improvement of dye loading. Therefore enough dye can be absorbed by the photoanode. This is important because the amount of dye is translated into produced current by the DSSC. Furthermore, the photoanode is made by the highly porous metal oxide semiconductor for effective mass transport by diffusion and the suitable band gap that matches with the sensitizer for effective electron injection and fast electron transport [3]. There are many types of wide band gap metal oxide semiconductor. For instance, Titanium Dioxide (TiO_2), Zink Oxide (ZnO), Tin Dioxide (SnO_2) and others. These materials are commonly used as photoanode materials due to their good stability against photocorrosion and good electronic properties. In this research, the photoanodewere fabricated using Titanium Dioxide (TiO_2). TiO_2 was used due to its large surface area to volume ratio and it gave the highest record of efficiencies among the other photoanode materials.

CARBON IN PHOTOANODE

Carbon materials have attracted a great deal of interests for both fundamentals and potential applications in various new optoelectronic devices such as solar cell. Generally, carbon material can improve the performance of the DSSCs since some studies have proved that carbon in photoanode enhanced the value for the open circuit voltage (Voc), short-circuit current density (Jsc), and photoelectrical conversion efficiency (η) of DSSCs [5].

In this research, we propose the doping of graphene nanopowder in TiO_2 photoanode to improve electron transfer from the dye to the FTO electrode. Three types of graphene namely Graphene 8nm Flakes (A), Graphene Multilayer Flakes (B) and Graphene Nanoplatelets (C) from graphene supermarket [6] has been implemented and studied. Table 1 below shows the specifications for each graphene used in this research.

Table 1: The specifications of the graphene used in this research

Graphene Nanopowder (8nm flakes) – A	Graphene Nanopowder (multilayer flakes) – B	Graphene Nanopowder (nanoplatelets) – C
• Specific surface area: 100 m^2/g • Color: Black • Purity: 99.9% • Average flake thickness: 8 nm (20-30 monolayers) • Average Particle (lateral) size: ~ 550 nm (150-3000) nm	• Specific surface area: <15 m^2/g • Color: Black • Purity: 98.5% • Average flake thickness: 60 nm • Average Particle (lateral) size: ~ 3-7 microns	• Specific surface area: 20-40 m^2/g • Color: Black and Grey • Purity: 99.5% • Average flake thickness: 2-10 nm • Average Particle (lateral) size: ~5 microns

PHOTOANODE SYNTHESIS

Photoanode is synthesized by combinations of P25 TiO_2 powder from Sigma Aldrich, acetic acid, deionized water, ethyl alcohol, α-terpineol and ethyl cellulose. The material is ground using pestle and mortar for several minutes and sonicated in ultasnic bath for several hours. Finally the solution is evaporated so that it can be used for screen printing.Each of graphene nanopowder namely Graphene 8nm Flakes, Graphene Multilayer Flakes and Graphene Nanoplatelets has been implemented in each synthesized TiO_2 paste with ratio of 1wt %, followed by sonication in ultrasonic bath for 30 minutes.

RESULTS AND DISCUSSION

Figure 1 shows the I-V characteristics of DSSC including those with graphene doped TiO_2 photoanode. Whilst, Table 2 shows the detail characteristics of fabricated DSSC measure using source measure unit and solar simulator. It shows the maximum voltage (Vmax), maximum current density (Imax), open circuit voltage (Voc), short circuit current (Isc), fill factor (FF) and energy conversion efficiency (η). In term of energy conversion efficiency, DSSC with multilayer flakes + TiO_2 photoanode shows similar efficiency as DSSC with un-doped TiO_2photoanode of 4.4%. However the current density for the first is higher of about 1 mA/cm^2. This may be contributed by the improvement of electron path from photoanode to the FTO transparent electrode due to doping of graphene multilayer flake in TiO_2 photoanode.

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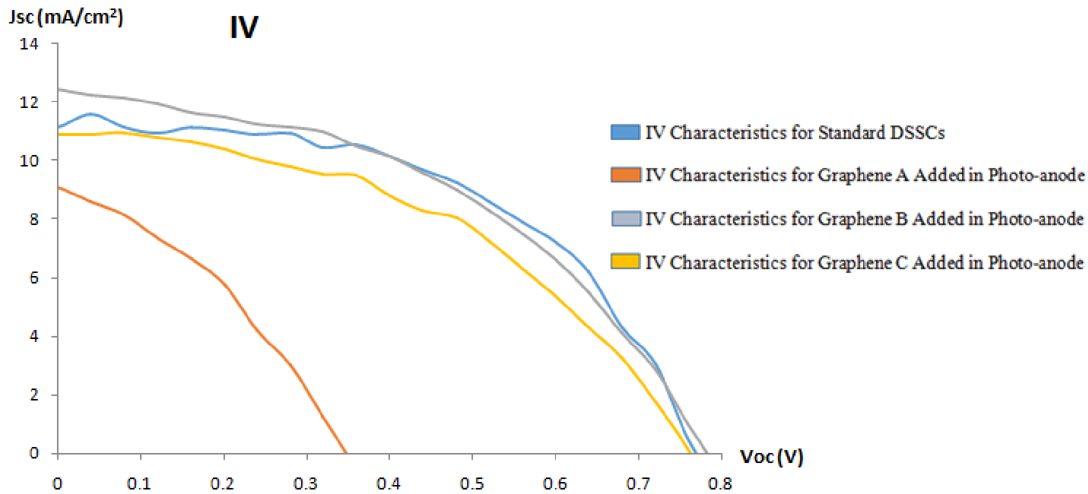

Figure 1: I-V Characteristics of fabricated DSSC

Table 2: Measurement results

	Vmax (V)	Jmax (mA/cm^2)	Voc (V)	Jsc (mA/cm^2)	FF	η (%)
Standard DSSCs (TiO_2)	0.51977	8.604	0.80	11.604	0.482	4.4
8nm flakes + TiO_2	0.200068	5.76	0.36	8.608	0.350	1.15
Multilayer flakes + TiO_2	0.481202	9.008	0.782	12.408	0.45	4.4
Nanoplatelets + TiO_2	0.480305	8.016	0.759	10.88	0.48	3.97

CONCLUSION

Three different types of graphene nanopowder which are the 8nm flakes, multilayer flakes and nanoplatelets were implemented in TiO_2 photoanode by doping 1%wt of them into photoanode solution to improve the electron transfer from photoanode to FTO transparent electrode. Among them, the DSSC with graphene multilayer flakes shows the highest efficiency of 4.4% with the highest current desities of 12.408 mA/cm^2. This may be due to improvement of electron path from photoanode to FTO transparent electrode. In the future the amount of graphene multilayer flakes in photoanode will be optimized for better DSSC performance.

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