Optical Materials 66 (2017) 552–558

Contents lists available at ScienceDirect

Optical Materials

journal homepage: www.elsevier.com/locate/optmat

Dye ingredients and energy conversion efficiency at natural dye sensitized solar cells

Mücella Özbay Karakuş [a], İrfan Koca [b], Orhan Er [c], Hidayet Çetin [d, *]

[a] Bozok University, Engineering and Architecture Faculty, Department of Computer Engineering, Turkey
[b] Bozok University, Art and Science Faculty, Department of Chemistry, Turkey
[c] Bozok University, Engineering and Architecture Faculty, Department of Electrical and Electronics Engineering, Turkey
[d] Bozok University, Art and Science Faculty, Department of Physics, Turkey

A R T I C L E I N F O

Article history:
Received 29 December 2016
Received in revised form
3 March 2017
Accepted 5 March 2017

Keywords:
DSSC
Natural dye
Single-diode model
Double-diode model
GC-MS

A B S T R A C T

In this work, natural dyes extracted from the same genus but different species flowers were used as sensitizer in Dye Sensitized Solar Cell (DSSC). To clearly show dye ingredients effect on electrical characteristics, the same genus flowers were selected. The dye ingredients were analyzed by Gas Chromatography Mass Spectrometer (GC-MS). The dyes were modified by a procedure that includes refluxing in acetone. All results indicate a relationship between gallic acid quantity in dyes and solar cell efficiency. To gain further insight, the solar cell parameters were obtained by using the single-diode and double-diode models and they were compared to each other. It was observed that the applied process causes a decrease in series resistance. How the modification process and gallic acid affect energy conversion efficiency were argued in detail in the frame of results that were obtained from solar cell models.

1. Introduction

Even today, people in some region of the world are living without electricity. Furthermore, in the developed part of the world, increasing energy demand as a result of human life-style is a main problem. To overcome this problem, fossil fuels are widespreadly used. Nowadays, environmental pollution forces people to use clean energy sources. Solar cells are one of the most promising clean energy sources. The different types of solar cells have been produced, investigated and as a result of research and development, they have been fabricated as a commercial product. Nowadays, cheaper and easier fabricated solar cell demands have been continued. Dye sensitized solar cells, a third generation solar cells are promising for the future with easy and cheap fabrication steps and the ability of generation of electricity under closed days that have low light intensity [1,2]. However, DSSCs have several problems. After overcome these problems, they could be commercial products. Thus, scientists need more research to convert the small cell module into commercial products.

In DSSCs, dye plays a key role to generate electricity. Although DSSCs have 11–12% energy conversion efficiency with Ru-based dyes [3–5], Ru-like metals are limited in amount and Ru-based dyes contain harmful material which is undesirable from environmental aspects [6]. On the other hand, organic dyes extracted from fruits and plants are cheap and easy to find [7,8]. With the simple extraction method and non-toxicity, natural dyes is indispensable and worth working on. However, DSSC with organic dyes have been remembered with low efficiency and poor stability [9]. Thus, each research step that will increase energy conversion efficiency or optimize cell performance will be valuable. For this purpose, we had a goal to achieve relatively high energy conversion efficiency with natural dyes and to find determinative factors for high efficiency solar cells. In this study, dyes extracted from two flowers which are the same genus but different species were used to make easy comparison between energy conversion efficiency and dye ingredients obtained from GC-MS. After the extraction procedure, dyes were used as sensitizer at DSSCs. The cell performance and dye ingredients have been analyzed; a relationship between them is questioned. In the direction of obtained results, a procedure is offered to enhance energy conversion efficiency in natural dye sensitized solar cells.

* Corresponding author.
E-mail address: hidayet.cetin@bozok.edu.tr (H. Çetin).

http://dx.doi.org/10.1016/j.optmat.2017.03.007
0925-3467/

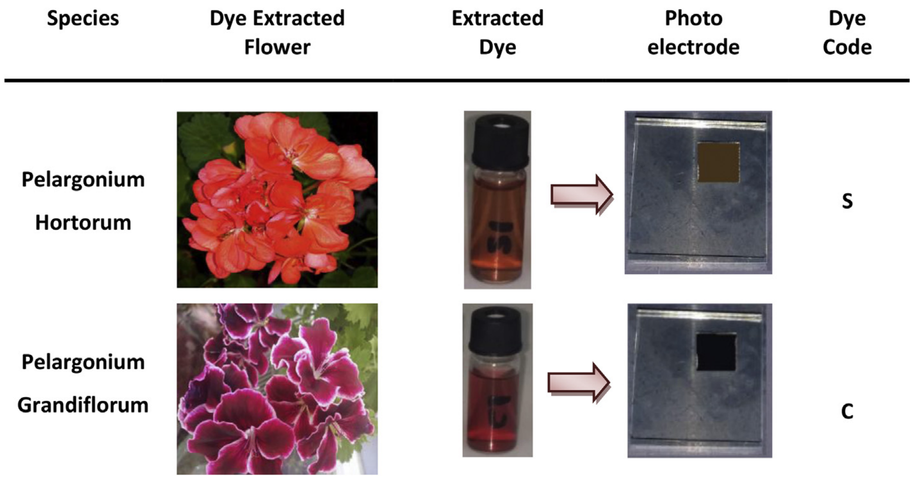

Fig. 1. Pelargonium Hortorum and Pelargonium Grandiflorum flowers, extracted dyes and photo anodes of solar cells.

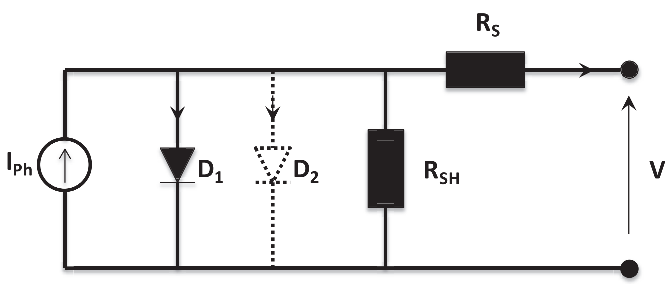

Fig. 2. The equivalent circuit of DSSC for the single and double diode models. When the double diode model is used, the second diode is added to the circuit.

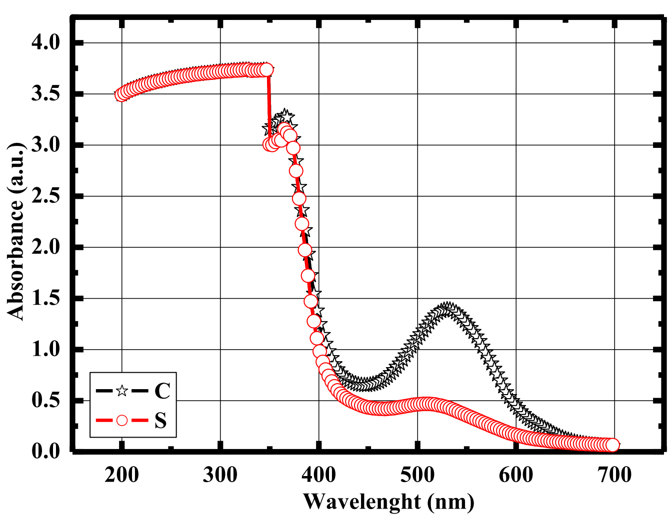

Fig. 3. UV–Vis absorption spectra of **C** and **S** dyes.

2. Materials and methods

2.1. Materials

Titania active opaque paste, platinum paste, Nbutyl-Nmethyl-imidazolium iodide (BMII), LiI, 4-*tert*-butylpyridine (TBP), I_2, acetonitrile and valeronitrile were purchased from Sigma Aldrich. FTO glass substrates (AN-10; sheet resistivity is 10 Ω/sq) were

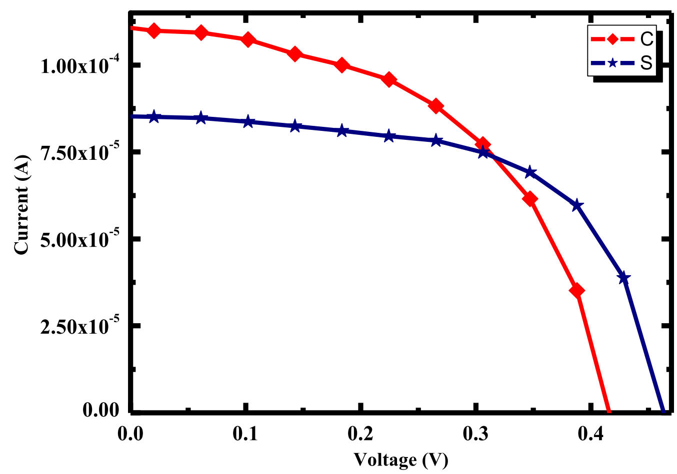

Fig. 4. Current-Voltage characteristics of DSSCs those are fabricated by using **C** and **S** dyes.

obtained from AGC SOLAR. All used solvents and gallic acid (*A.R. grade*) were obtained from Merck. 18.2 MΩ de-ionized water is used for preparation of dyes and cleaning procedures.

2.2. Characterization and measurements

The dyes were primarily characterized by absorption spectra (obtained from Hach Lange DR 5000 Model UV–Vis spectrometer). The dyes ingredients were analyzed by Shimatsu OP2010 Ultra Gas Chromatography–Mass Spectrometry (GC–MS). Surface morphology of the deposited TiO_2 films was investigated by a metallurgical microscope (Nikon Eclipse LV 150). Firstly, TiO_2 surface photos were taken under 1000× magnification and the photos were transformed into a contour plotting scheme to make the heights and pits more apparent. The images show reflected light intensities from surface to CCD camera pixels. The FTIR spectra have been recorded by Perkin-Elmer Spectrum Two FT-IR model Spectrometer with ATR method at room temperature. Whole solar cell measurements were done under AM1.5 illumination intensity.

2.3. Preparation of natural dye sensitizers

The fresh flowers, *Pelargonium Hortorum* and *Pelargonium*