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Solar cells based on natural dyes prepared using anatase phase titanium dioxide

Falah H. Ali

Department of Physics, College of Science, University of Baghdad, Baghdad, Iraq

E-mail: falah_h75@yahoo.com

Abstract

Natural dye sensitized solar cell was prepared using strawberry and pomegranate dyes with anatase nanocrystalline titanium dioxide powder. A study of the optical properties of the two dyes, involving the absorption spectrum was determined in the visible region. I-V characteristics under illumination were performed. The results showed that the two prepared dye sensitized solar cells have acceptable values efficiency about (0.94 with Fill factor (45)) and (0.74 with Fill factor (44)) for strawberry and pomegranate dyes, respectively.

Key words
Natural dye, low cost, DSSC, efficiency.

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الخلايا الشمسية المنشأة على الأصباغ الطبيعية المعدة باستخدام ثاني أكسيد التيتانيوم في طور الانتس

فلاح حسن علي

قسم الفيزياء، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

في هذا العمل تم تحضير الخلايا الشمسية الحساسة للصبغة الطبيعية عن طريق استخدام أصباغ الفراولة والرمان مع مسحوق النانو كريستال طور الانتس لثاني اوكسيد التيتانيوم. من خلال دراسة الخواص البصرية للصبغتين، تم تحديد طيف امتصاصهما في المنطقة المرئية. وأظهرت خصائص I-V تحت الإضاءة أن الخلايا الشمسية المحضرة بالصبغتين لهما كفاءة قيم مقبولة (0.94% مع عامل الملئ (45)) و (0.74% مع عامل الملئ (44)) لأصباغ الفراولة والرمان على التوالي.

Introduction

Dye sensitized solar cells (DSSCs) are subject to extensive research works. Since the color of the device can vary easily by selecting different dyes and cells on flexible substrates that have already been demonstrated, DSSCs are particularly attractive for building integrated photovoltaic cells [1].

The cell concept is supposed to decrease production costs and the duration of energy recovery significantly compared to standard silicon cells. The conversion efficiency ranges from 0.6 % to 10 % depending on the size of the unit. The technology is currently being used on the experimental plant scale [2].

The history of dye-sensitive solar cells (DSSCs) began in 1972 with the Zinc Chloride Oxide (ZnO). For the first time, photons were converted into an electric current by injecting excited dye particles into large bandgap semiconductors [3].

The main problem was that the monolayer of dye molecules on a flat surface could absorb only 1 % of the incident light. The introduction of TiO_2 nanoporous electrodes with roughness factor of 1000 significantly enhanced the efficiency of light harvest and in 1991 solar cells were introduced of 7% efficiency [4]. This triggered a flow in research activities and today's cells efficiency of 11.2 % [5].

Fig.1 illustrates the DSSC operation principle which can be clarified by the following:

- The electron is crossed through a complete cycle of excitation, injections into TiO_2, then diffusion in TiO_2.
- Reduce of iodine in the counter electrode led to proliferation in the electrolyte and regeneration of the oxidizing dye.

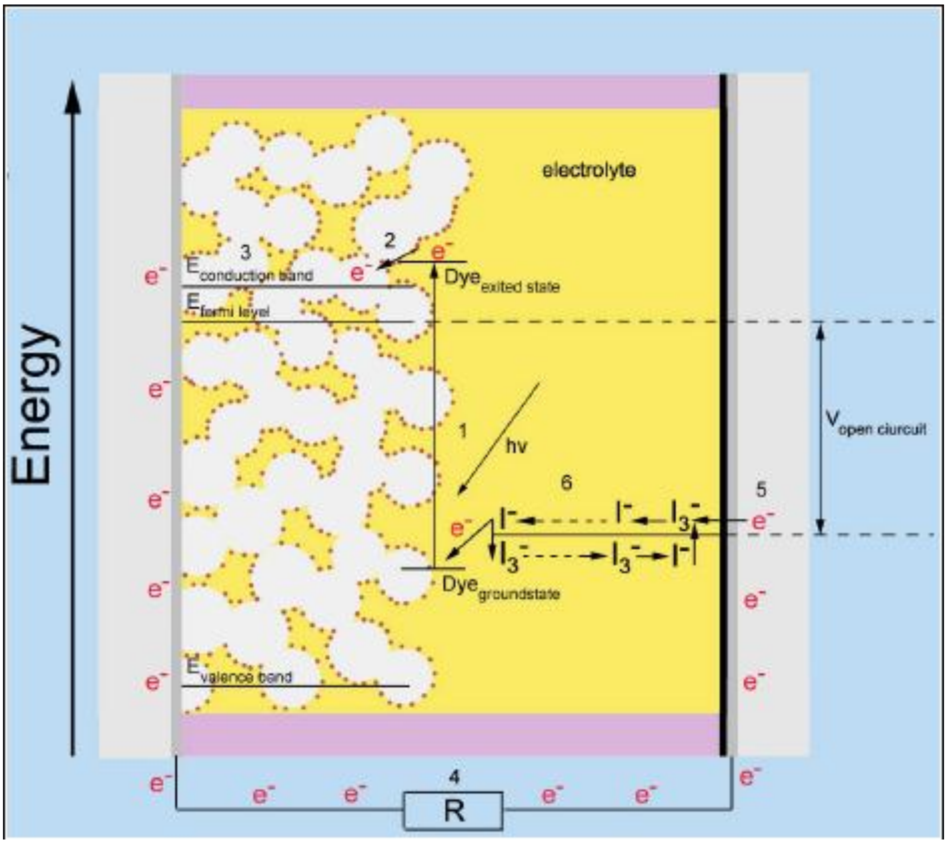

Fig. 1: Operation principle of dye sensitized solar cell [4].

The dye, usually a metallorganic Rucomplex, is excited to absorb the photon. Absorption starts at the 720 nm range for most dyes, which is the equivalent to photon energy of 1.72 eV. The formal potential of the dye redox pairs (D + / D *) ranged from -0.7 to -0.8 V vs Natural Hydrogen Electrode (NHE) [4]. The life time of the excited state is within the range of nanosecond. The high concentration of iodine reductase concentration may interrupt the excited state representing the loss channel [5]. The dye injects an electron into the conduction band in TiO_2. About 60% of the electrons are injected from the singlet state and about 40% of the triplet are injected. The corresponding injection rate constants are in the femtosecond range (the state of the jump), about one femtosecond of the lower amount for the triplet state [6, 7]. In the following years, much researches were completed on C-ZnO [8], but the efficiency of these devices was weak. Because the triplet state energy level is slightly higher than the TiO_2 conduction band edge. The driving force of the electron injection has a lower electron transfer probability, which is supposed to be the cause of the relatively slow injection rate [9,10]. For the suitable charge injection, the dye level must be between 0.2 volts and 0.3 volts above the edge of the TiO_2 conduction band, which corresponds to -0.5 volts versus the NHE on the electrochemical scale [11].

In this work, dye sensitized solar cell was prepared by use strawberry and pomegranate dies (which is studied by measuring UV-VIS absorption) with TiO_2 nanopowder (38 nm).

Then, I-V characteristics under illumination [419.9 W/m²] was measured.

Experimental part

1- Extraction of dye

The anthocyanin built natural dyes were extracted from strawberry and pomegranate using distilled water. They were squelch in distilled water and the sieve solution was an anthocyanin solution. The solutions were kept in a dark colour bottle for 1 hrs. The filtered solutions were chlorophyll based dye. The optical properties of thin films dropped on glass slide which includes the absorbance spectra are studied over the wavelength range (200-1100) nm using "Shimadzu UV/VIS recorder spectrometer model (Centra 5)".

The absorbance of strawberry and pomegranate dyes in the spectral range of (200–800) nm is shown in Fig. 2.

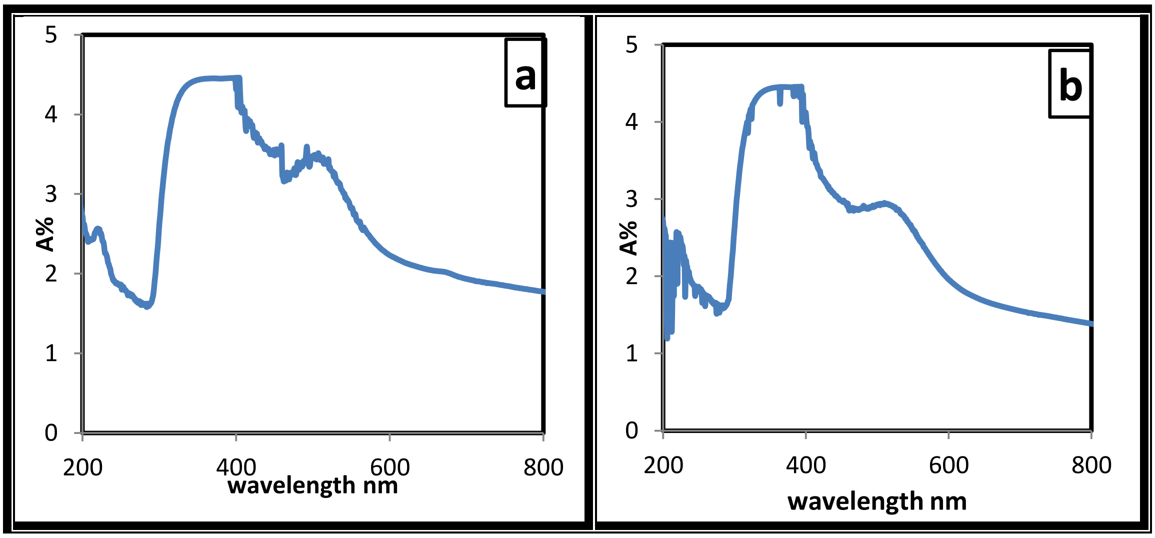

Fig.2: The absorption spectra of natural dyes a: strawberry b: pomegranate.

This Figure illustrates that strawberry and pomegranate dyes have wide-ranging peak in visible region and this very importance for DSSC work.

2- TiO_2 electrode

Prepared anatase phase of TiO_2 used in this work. XRD pattern was examined as shown in Fig. 3. It is seen that the film characteristic peak represent anatase crystal plane (101) at (2θ= 25.14°) and the other angles represent weak peaks. The particle size was determined 38nm using Scherrer's equation.

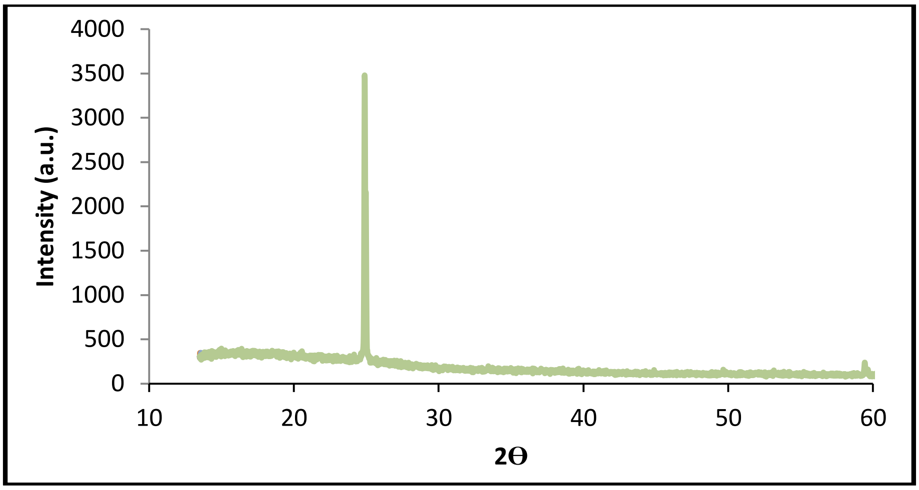

Fig.3: XRD pattern of prepared TiO_2.

One ml acid (nitric acid) was mixed with one gram of TiO_2 (38nm). The paste was prepared on Indium Tin Oxide (ITO) glass with 15 ohms surface resistivity using a doctor blading method with a thickness of 12-14 micrometers. The area of the cell was 1 cm. Then the coated sheet was set at 450 °C for 15 minutes. The glass plate coated with TiO_2 is saturated in a natural dye for 5 hours in a dark, isolated place. After that, the glass was washed using ethanol and dried in air for five minutes.

3-Preparation of electrolyte and counter electrode

Iodine (0.05M) and potassium iodide (0.5M) were mixed in 10 mL of ethylene glycol. The solution is kept in a black bottle. This solution is used as an electrolyte. The electrode is set by exposing the ITO-plated glass conductor to candlelight for 2-4 minutes leaving a black thick film of carbon on the glass.

4-Solar cell assembly and measurements

The electrodes together with each other were gathered face to face to keep the surface coated TiO_2 paste and face carbon coated in touching.

Slowly 15 µm of electrolyte solution was set in the contact between the two glass work and by electrolytes the electrolyte was uniformly spread throughout the TiO_2 nanoparticles. When completed, the DSSC system was activated with a light source for a (55-watt xenon lamp) set up in a $500W/m^2$ solar simulator. The lamp shines almost sunlight. The test temperature was 23 °C-25 °C. The Cell performance was measured using AGILENT 34401A multimeter precision.

The efficiency of two DSSCs

The photovoltaic conversion efficiency is another important parameter [12]. It is the amount of the light energy that is converted into electrical energy and is given by

$$\eta = P_m/P_{in} = F.F * I_{sc} * V_{oc}/P_{in} *100\% \quad (1)$$

where P_{in} is the incident power, and P_m is maximum power output. Another parameter of importance is the Fill factor (F.F) given by the relation:

$$F.F = V_m I_m / V_{oc} I_{sc} \quad (2)$$

where (V_{oc} and I_{sc}) are the open circuit voltage and the short circuit current, while (V_m and I_m) are the voltage and current matching to maximum power point [13, 14].

The efficiency and Fill factor are put in Table 1.

Table 1: Efficiency and fill factor for two DSSCs.

Type	V_{oc} (V)	I_{sc} (mA)	F.F%	η%
1-DSSC with strawberry Dye	0.61	0.41	45	0.94
2-DSSC with pomegranate Dye	0.60	0.45	44	0.73

Conclusions

Crushed strawberries and pomegranate as dyes with TiO_2 electrode may be used for preparing dyes sensitized solar cell.

Finally the prepared DSSCs have low cost and acceptable efficiency value.

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