Dye Sensitized Solar Cells by Using Natural Dyes Anthocyanin Dye Extracted from Red Cabbage and Chlorophyll Dye Extracted from Palm Leaf as Photosensitizer

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Abstract

In this work of Dye-sensitized solar cells (DSSCs) were fabricated using Nano particle titania (TiO_2) (deposited on ITO glass) as photo anodes and carbon counter electrode, sensitized dye were natural dye anthocyanin dye was extracted from red cabbage and chlorophyll dye was extracted from palm leaf and the electrolyte (I^-/I_3^-). The absorption spectra of natural dye was investigated by UV-Visible spectroscopy which showed that the beetroot dye and palm leaf absorbed light at 550 nm and (664,420) nm respectively. The efficiency of prepared DSSCs were estimated through I-V characterization, the fall factors (ff) and electrical conversion efficiencies (η%) were measured using potentiostat. The conversion efficiency of chlorophyll and anthocyanin was 0.892%, 0.502% respectively.

Key words: Dyes sensitized solar cells, red cabbage, palm leaf, TiO_2 Nanoparticles

خلايا شمسية ذات صبغات متحسسة باستعمال اصباغ طبيعية صبغة الانثوسيانين المستخلصة من الملفوف الاحمر و صبغة الكلوروفيل المستخلصة من سعف النخيل كمحفز ضوئي

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الخلاصة

في هذا البحث تم تصنيع خلايا شمسية محفزة بالصبغة باستخدام دقائق (TiO_2) النانوية (مطلية على زجاج الانديوم المشوب بأوكسيد القصدير ITO) كأنود ضوئي وقطب الكاربون كقطب موصل و نوعين من الاصباغ الطبيعية صبغة الانثوسيانين المستخلصة من الملفوف الاحمر وصبغة الكلوروفيل المستخلصة من سعف النخيل والمحلول الالكتروليتي هو (I^-/I_3^-) . اطياف الامتصاص للاصباغ الطبيعية تم تشخيصها بمطيافية UV-Visible والتي تبين بأن اعظم امتصاص لصبغة الملفوف الاحمر عند 550 nm .ولصبغة الكلوروفيل المستخلصة من سعف النخيل عند 420 nm . تم تخمين كفاءة الـ DSSCs من خلال تشخيص I-V، عامل الملئ (ff) و كفاءات التحويل (%η) تم قياسها باستخدام المجهاد الساكن.كفاءة التحويل لصبغة الكلوروفيل ولصبغة الانثوسيانين 0.892%, 0.502 % على التوالي .

الكلمات المفتاحية: خلايا شمسية ذات صبغات متحسسة، سعف النخيل، الملفوف الاحمر، دقائق TiO_2 النانوية.

Introduction

Dye-sensitized solar cells (DSSCs) its clean, low cost, easy preparation, good durability and high conversion efficiency [1-5]. DSSCs were first proposed by Grätzel et al [3] .It is the third generation photovoltaic device for low cost conversion of solar energy into electrical energy .In DSSCs ,the dyes plays an important role in harvesting solar energy and converted it to electrical energy with aid a semiconducting photo anode. Many metal complexes and organic dyes used as sensitizers ,Ruthenium complexes good sensitizers for DSSCS because of their intense charge –transfer absorption over the entire visible range and highly efficient metal –to-ligand charge transfer [6] . Research has focused on the easily available yes extracted from natural sources and as a photosensitizer because of its large absorption coefficients, low cost, easy preparation and environment friendliness .So ,it is feasible to use natural dyes [7-11].

In this work, natural dyes anthocyanin dye extracted from red cabbage and chlorophyll dye extracted from palm leaf as Photosensitizer and characterized by UV-VIS absorption spectrum. DSSCs were fabricated using titania (TiO_2 nanoparticle) semiconductors as photo anodes and carbon counter electrodes, and the electrolyte (I^-/I_3^-) are the same. Nano size particle TiO_2 and carbon deposited on ITO glass.

Experimental

Materials and instruments

All chemicals used were of the highest purity available. apparatus were used in this work. Potentiostat (Miab 200with software, Bank Eleikronik, Germany, 2000) used for l-V evaluation for DSSC, Avometer digital Taiwan origin for measurement of voltage, current, resistance. Xenon lamp 100Watt japan for I-V characterization, power supply GW Instek, PSP- 603. UV - Vis spectroscopy160 V Shimadzu Japan.

Cleaning of ITO:

Indium doped Tin Oxide (ITO) glasses (2x 2) cm^2 were cleaned by sonicate 8 mints with distilled water and 8 mints with ethanol and dried by hat gun.

Fabrication of TiO_2 Nano particles photo anode:

1gm of TiO_2 Nano powder (assay 99,9%MTI, USA) was treaded with few drops of (0.1M) HNO_3 to give a viscous paste. The paste was applied on a conductive side of cleaned ITO glass which determined by avometer via the doctor blade method [12]. It then annealed in furnace at 400°Cfor 2 hour, the annealed TiO_2 Paste is cooled down to room temperature gradually and then soaked into a nature dye solution 3 hr and washed with ethanol after soaking

Fabrication of Black carbon counter electrode:

The carbon black electrode was fabricated by an easy way with moving the conductive side of (ITO) glass above the flame of candle, after ITO glass get black. The ITO was left for 5 mints until it was cooled then a few drops of ethanol was placed to diffuse across the carbon film and dried by heat gun.

Preparation of cell electrolyte:

The cell electrolyte prepared by dissolving (0.5M) of KI and (0.05M) of I_2 in ethylene glycol to obtain an (I^- /I_3^-) ions which served as acceptor and donor for electrons through an oxidation – reduction reaction with anode and counter electrode.

The dye was prepared by extraction the juice from the small pieces of clean Dye red cabbage and palm leaf by electric mixer and the resulting extracts were filtered to remove any solid residue at ambient temperature and were used for sensitization. Solution without exposure to sunlight and stored in the refrigerator.

Assembling the dye sensitive solar cells (DSSCs):

The cell assembly was performed by adding a few drops of (I^-/ I_3^-) electrolyte on the photo anode and fix both electrodes (anode and counter) facing each other using a clips binder. The space between two electrodes was obtained by using two sides scotch as a spacer.

Evaluation of the fabricated DSSCs:

The evaluation system for DSSCs equipment's (light source (Xe lamp), cables, potentiostat) connect solar cell with potentiostat using cables, shine the light, control the voltage value through potentiostat which give a table and diagram for I –V characterization. The I-V curves were measured at 100 m W/cm^2 irradiations using Xe lamp.

Results and Discussions

Absorption spectrum of red cabbage and palm leaf dyes:

The absorption characteristic is a very important property in DSSCs as it directly reflects the optical transition probability [13]. Figure (1) exhibit the UV-VIS absorption spectrum of red cabbage dye which show that maximum absorbed light in the region visible (λmax 550nm) and figure (2) show spectrum for chlorophyll dye extracted from palm leaf absorbs strongly in the blue and red regions (420 and 664 nm) .

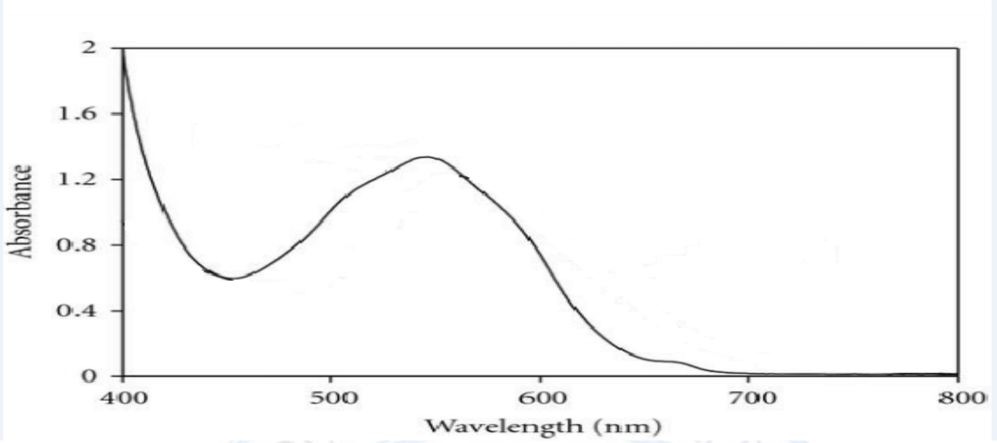

Figure 1: UV-Vis spectrum for red cabbage dye (Anthocyanin dye)

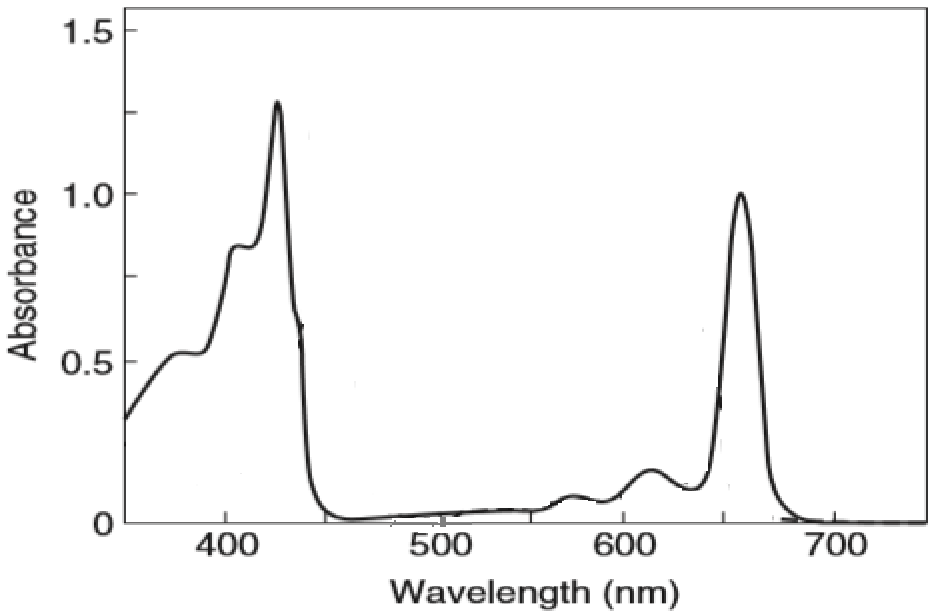

Figure 2: UV-Vis spectrum for palm leaf dye (chlorophyll dye).

Characterization of Assembled DSSCs:

The assembled DSSCs were subjected to I-V characterization by fast scan with two electrodes potentiostat to evaluate all parameters of each them; current short circuit (Isc), voltage of open circuit (Voc), maximum cell power (Pmax), the full factor (ff) and conversion efficiency (η) were estimated, Figure (3) show the 1-V curves of assembled DSSCs and they reflect the effect of dye on the performance of the assembled DSSCs.

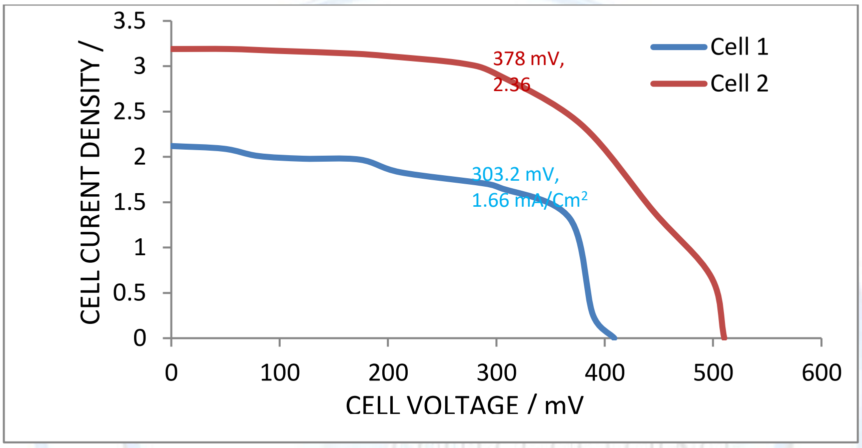

Figure 3: I –V tests of the two assembled DSSCs from TiO_2/ITO glass as anode and carbon cathode with Anthocyanin dye (Cell 1) and chlorophyll dye (Cell 2).

The cell parameters; Isc, Voc, I_{max} and V_{max} were estimated from the above I-V curves, while the full (ff) and the cell efficiency were calculated using the following equations. All measurements are tabulated in table (1)

$$\%\eta = \frac{Isc \times Voc \times ff}{Pin} \times 100\%$$

$$\text{Where ff} = \frac{\text{Imax} \times \text{Vmax}}{\text{Isc} \times \text{Voc}}$$

Table 1: Values of assembled DSSCs.

DSSC Cathode anode	Voc mV	Isc mA/cm^2	Vmax mV	Imax mA/cm^2	ff	Pin mW/cm^2	Pmax mW/cm^2	E%
Cell 1 ITO/carbon ITO/TiO_2	408.8	2.12	303.2	1.66	0.58	100	0.503	0.502%
Cell2 ITO/carbon ITO/TiO_2	510.3	3.19	378	2.36	0.548	100	0.892	0.892%

The best efficiencies were achieved using (Ti /ITO as anode and ITO/carbon as cathode, chlorophyll dye and anthocyanin dye) showing 0.892%, 0.502% respectively. chlorophyll dye bind better to the TiO_2 nanostructure, the steric hindrance in anthocyanin dye, which affects bond formation on oxide surface of TiO_2, therefore, it is lack of electron transfer from the dye molecules to conduction band of TiO_2 [14].

Conclusion

Two natural dyes anthocyanin dye extracted from red cabbage and chlorophyll dye extracted from palm leaf as Photosensitizer were used to make dye- sensitized solar cells. The dyes were attached to TiO_2 thin film and they showed absorption in the visible region. Chlorophyll and anthocyanin dyes showing 0.892%, 0.502% respectively.

References

1. Grätzel, M. (2001) Photoelectrochemicalcells. Nature., 414, 338 - 344.
2. Wang. P. et al. (2003) A stable quasi – solid - state dye - sensitized solar cell with an amphiphilic ruthenium sensitizer and polymer gel electrolyte. Nat. Mater., 2, 402-407.
3. O'Regan, B& Grätzel, M. (1991) A low- cost, high-efficiency solar cell based on dye – sensitized colloidal TiO2 films. Nature., 353,737-740.
4. Wu. J. et al. (2008) An all-solid-state dye-sensitized solar cell-based poly (N-alkyl-4-vinyl-pyridine iodide) electrolyte with efficiency of 5.64%. J. Am. Chem. Soc.,130,11568-11569.
5. Wu. J. et al. (2014) Bifacial dye-sensitized solar cells: A strategy to enhance overall efficiency based on transparent polyaniline electrode. Scientific Reports, 1-7,

6. S. Hao, J. Wu, Y. Huang, J. Lin, (2006) Sol. Energy, 80, 209-214.

7. Zhang D, et al, (2002) Natural dye sensitized solar cells. Trans Mater Res SOC Jpn, 27 (4), 811-814.

8. Kumara GRA, et al, (2006) Shiso leaf pigments for dye –sensitized solid-state solar cell. Sol Energy Mater Sol C, 90 (9) 1220-1226.

9. Polo AS, Murakami Iha NY, (2006) Blue sensitizers for solar cells, natural dyes from Calafate and Jaboticaba. Sol Energy Mater Sol C, 90 (9), 1935-1944.

10. Wongcharee K, et al, (2007) Dye-sensitized solar cell using natural dyes extracted from rosella and blue pea flowers, Sol Energy Mater Sol C, 91(7), 566-571.

11. Wang X-F, etal (2007) Fabrication of dye – sensitizes solar cells using chlorophylls C1 and C2 and their oxidized forms and from Undaria pinnatifida (wakame). Chem Phys Lett, 447(1-3), 79-85.

12. E. M. Genies and M. Lapkowski, (1988), polyaniline films, electrochemical redox mechanisms. Synthetic metals. 24, 61-68.

13. J. Vivekanandan et al (2011), Synthesis characterization and conductivity study of polyaniline prepared by chemical oxidative and electrochemical methods,.Arch. Appl. SCi. Res, 3(6), 147-153.

14. Hee-Je Kim et al, (2013) Natural dye extracted from Rhododendron species flowers as a photosensitizer in dye sensitized solar cell, Int. J. Electrochem. Sci, 8, 6734- 6743.