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Making Dye Solar Cells with Natural Extracts of Cabbage and *Rubia Tinctorum* and the Comparison of their Characteristics

Sedigheh Khayatzadeh Mahani*, Maryam Jafari Narenjbaghi, Hasan Fatemi Imam Geis
Faculty of Physics, Micro Optics Laboratory, Shahid Bahonar University of Kerman
*E-mail: Sediqekhayatzade@Yahoo.Com

Abstract

One of the key components of dye solar cell is a pigment. The most important characteristics of a pigment is wide range of absorption spectrum, and its more photonic absorption. This article reports the characteristics of a dye solar cell with pigments obtained from extracts of cabbage and *rubia tinctorum* on nanoparticles. Regarding the results of spectrophotometry, the scope and extent of absorption of these two pigments is relatively high. The results of the measurements for each square centimeter of produced cells via the declined radiation of Sun light in intensity of (90 mW/cm^2) are as follows:

A dye solar cell with extract of cabbage: $J_{sc}(\mu A/cm^2=4360$ $V_{oc}(mv)=400.4$ $\mu=0.9\%$

A dye solar cell with extract of ronas: $J_{sc}(\mu A/cm^2=3110$ $V_{oc}(mv)=399$ $\mu=0.42\%$

According to the simple method of production and low cost of these cells, compared to other imported ones, there is a great hope to its spread for the optimization of these features.

Keywords: dye solar cell, TiO_2, nanoparticles, Absorption spectrum

Introduction

Today, the economic growth of countries depends on the supply of energy sources. In most countries these energy resources include coal resources, oil, gas as well as nuclear energy. However, the use of these resources is faced with challenges, such as an increase in greenhouse gases in the environment and finishing of these resources. Therefore, clean energy sources such as wind, sun energy should replace these resources. Solar cell is a system that converts Sun's energy by photovoltaic effect (directly converts the Sun's energy into electricity) and without connecting to the external source to electricity.

Today, most commercial solar cells are made of silicon, and the use of Silicon in these cells is very expensive, while the cost of making dye solar cells is much lower. These cells for the first time were produced by Gratsel in 1991 at the Lausanne scientific research Institute of Swiss and were named dye solar cells (Andrasartopolo,et al, 1944).

So far, in articles that have been previously presented, the use of the chemical dye cells in the structure of these cells have been reported. While the use of local natural pigments referred in this article was not mentioned anywhere else.

Structures and Function of Dye Solar Cell

At the core of this cell there exist a semi oxide conductive with a large energy gap,in contact with the electrolyte and a reducer. Usually the opted substance for semiconductor is titanium dioxide nanoparticles with crystal structure which its surface is covered with a layer of pigment molecules. Under the radiation of light the electron of pigment move from the base to the meta process mode. In other word they move from the highest occupied molecular orbital (HOMO) to the lowest unoccupied molecular orbital (LUMO) and then are transferred to the semiconductor conduction. The empty spaces within pigments, with the transfer of electrons from the electrolyte to the pigment molecules, are filled and pigments gain their initial state. The used electrolyte usually have oxidation-reduction mechanism. (Like the iodine electrolyte (I^-/I_3^-). The electrons are transferred from the electrolyte to pigments and through reduction of electrolyte iodine, in the vicinity of the counter electrode (or cathode), is brought back to the electrolyte. The cycle is completed through transferring electrons, by means of an external circuit from the Andes to a cathode (Nazeeruddin et al, 1993; Grep Smestad, 1998)

The chemical reactions within the cell can be outlined as follows:

$Dye + h\nu \rightarrow Dye^*$ The process of photon absorbed by the pigment

$Dye^* \rightarrow Dye^+ + e^-(TiO_2)$ Electron injection into a semiconductor process

$2Dye^+ + 3I^- \rightarrow 2Dye + I_3^-$ The process of seed color and oxidation of iodide

$I_3^- + 2e^- \rightarrow 3I^-$ The process of reducing the triiodide

Production of Dye Solar Cell

In order to make a solar cell two conductive and transparent glass*(Indium Thin Oxide) ITO* with the same size of the square shape with resistance of $50\,{}^{\Omega}/_{cm^2}$,some powder of Nano titanium dioxide, iodine powder, potassium iodide powder, ethylene glycol and acetic acid were provided. In the first stage of the construction, photo electrode $TiO_2$was prepared. To do this, the conductive and transparent glasses were washed with distilled water and then dried. 1 gram of titanium dioxide Nanoparticles with crystal structure of Anatase with a few drops of acetic acid were mixed and then was poured on the conductive transparent glass (ITO).By a glass rod, a mixture was completely flattened on the glass in order to find the thickness of the Micron rhodium and in the temperature of 450°C for 30 minutes heat was given to it. To make the counter electrode (counter electrode) conductive and transparent glass (ITO) was washed and put up a candle flame. With this innovative approach, a layer of conductive carbon would be on the glass that can have a role of cathode in the cell. In the preparation of required electrolyte with oxidation-reduction mechanism, about two grams of iodide, one-tenth of potassium iodide is mixed in 25 ml ethylene glycol and for the sustainability of achieved electrolyte we have put it in contact with the heat of 50 °C for 2 hours. The next step was to prepare the natural pigments mentioned in this study. To this end first cabbage and *rubia tinctorum* extract were needed to be bought from local market. Then 40 grams of the cabbage leaves were placed in 100 ml of distilled water for 24 hours. The 70 gram of *rubia tinctorum* powder was mixed with distilled water and after 24 hours, the extract was ready respectfully.

In order to put dissolved pigments molecules (or cluster) on nanoparticles of Photo electrodes a few drops of dissolved electrolyte were put on the Photo electrodes. Then to make a dye solar cell, counter electrodes were put on Photo electrodes in a stairs like order and were connected together by two pegs.

Results

Absorption Spectrum and Pigments Analysis

Absorption spectrum of the extracts is measured by spectrophotometry in the wave length range of 400 to 800 nanometer. The maximum absorption spectrum length of *rubia tinctorum* extracts in the wave length range is400 to 550 nanometer, while the maximum absorption spectrum length of cabbage extract in the wave length range is 400 to 750 nanometers.In other words, the cabbage extract in comparison with *rubia tinctorum* extract, has possibility of absorbing more photon and wide absorption expanse. Therefore, sunlight can stimulate number of pigments. As a result it is expected that dye solar cell to produce more stream from cabbage extract.

Performance Analysis Dye Solar Cells

By changing the resistance in the circuit diagram, the I-V for each cell will be gained, which have been shown in Figure 1 and 2.

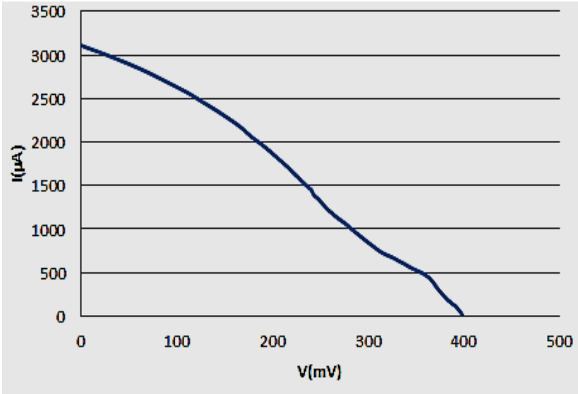

Figure 1: I-V Diagram of Dye Solar Cell for *Rubia Tinctorum* Extract

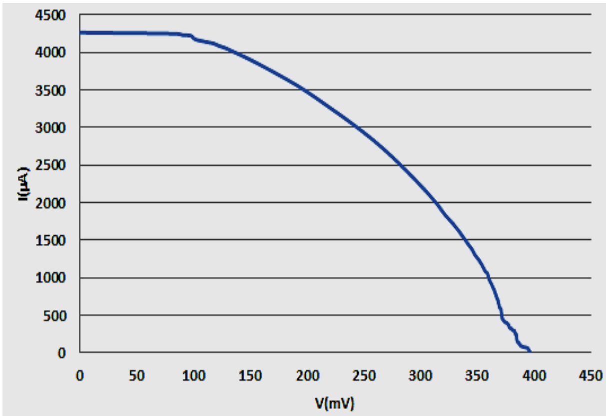

Figure 2: I-V Diagram of Dye Solar Cell with Cabbage Extracts

According to figure 1 and 2 and the following equations, the efficiencies of dye solar cells can be achieved.

$$P_m = V_m I_m$$

$$FF = \frac{P_m}{V_{oc} I_{sc}}$$

$$\eta(\%) = \frac{V_{oc} I_{sc} FF}{P_{in}} * 100$$

P_m: The highest possible production of a cell
P_{in}:The declined solar power light
V_{oc}:Open circuit voltage
I_{sc}:Short circuit current

Table 1: Dye Solar Cells Characteristic with a Cabbage and Rubia Tinctorum Extracts

Reference	η(%)	FF	$V_{oc}(mV)$	$I_{sc}(\mu A)$	Pigment
-	0.9	.0.40	400.1	4360	Cabbage
-	0.4	0.31	399	3110	*Rubia tinctorum*
[5]	0.36	0.65	280	200	Turmeric

The results have been recorded in table 1. As shown in table 1, solar cell efficiency with cabbage pigments has the highest efficiency.

Conclusion

In this study, two natural pigments derived from extracts of cabbage and *rubia tinctorum* for the production of dye solar cell were introduced. Cabbage extracts have more absorption and more absorption rate. The more the photonic absorption the more stimulated pigments and more electrons. As a result circuit flow become short and cell efficiency will increase so the solar cell made with pigments of cabbage has a better output in comparison to pigment of rubia tinctorum

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