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The Conductivity Study Of Hybrid Solar Cells Of TiO_2 and Doped with *Bixa Orellana* For Solar Cells Application

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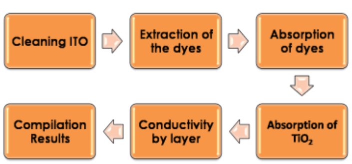
Graphical abstract



Abstract

The application of nature dyes was explored for solar cells due to several advantages for green technology. These can be supporting in renewable energy alternatives, which must include solar energy. This system was fabricated as hybrid solar cells, which consist of organic and non-organic materials. Metal oxide semiconductor (MOS), TiO_2, was selected as charge separation and transport. *Bixa orellana* used as extracted natural dyes solution in order to enhance the absorption of photons. The dyes were extracted by using immerging in methanol solution and left until dyes being extracted. The dyes were coated on ITO glass by using Electrochemical Impedance Spectroscopy (EIS) varied by 1, 3, 5, 7 and 10 layers of scan. This work focuses on conductivity and charge carrier study of thin film. The result shows the conductivity was increase due to several parameters that are, thickness of thin films, and intensity of light, mixture of natural dyes and concentration of dyes solution. The conductivity was then supported with the energy band gap via UV-Vis Spectroscopy.

Keywords: Charge carrier, conductivity, hybrid solar cells, natural dyes, TiO_2

Abstrak

Penggunaan pewarna semulajadi telah dikaji untuk sel-sel solar bergantung kepada beberapa kelebihannya terhadap teknologi hijau. Ini boleh menjadi alternatif kepada tenaga yang boleh diperbaharui, termasuklah tenaga solar. Sistem ini telah direka sebagai sel solar hibrid, yang terdiri daripada bahan-bahan organik dan bukan organik. Oksida logam semikonduktor (MOS), TiO_2, telah dipilih sebagai pemisahan dan pengangkutan. Bixa orellana digunakan sebagai ekstrak pewarna semulajadi untuk meningkatkan penyerapan foton. Pewarna telah diekstrak dengan menggunakan kaedah larutan metanol sehingga pewarna diekstrak. Pewarna telah disalut pada ITO kaca dengan menggunakan Elektrokimia Galangan Spektroskopi (EIS) sebanyak 5 dan 10 lapisan imbasan. Kerja-kerja ini memberi tumpuan kepada kajian kekonduksian dan pembawa cas kajian filem nipis. Hasil kajian menunjukkan kekonduksian meningkat disebabkan oleh beberapa parameter antaranya adalah ketebalan filem nipis, dan keamatan cahaya, jenis pewarna semulajadi dan kepekatan larutan pewarna. Kekonduksian itu disokong dengan jurang jalur tenaga melalui UV-Vis Spektroskopi.

Kata kunci: Cas pembawa, konduktif, sel solar hybrid, pewarna semulajadi, TiO_2

1.0 INTRODUCTION

Hybrid organic solar cells have great innovation toward renewable energy consumption to generate electricity from solar radiation. These solar cells was commonly interest due to abroad advantages of efficient, mechanically robust, lightweight, and fabricated with techniques scalable for mass manufacturing despites due to low cost, no pollution and relatively high energy conversion [1]. As a transparent conducting subtracts, ITO glass were chosen due to several advantages such as easy to handle and durability of heat. Moreover, the wide uses of ITO glass represent an important research goal as conducting material [2]. The conducting materials were support by coating the surfaces by adding the TiO_2 as an electron donor. TiO_2 one of key component of hybrid solar cells which acts as a scafford for the dyes and transfer media for photogenerated electron. TiO_2 nanoparticle film is used for the photoanode in high-efficiency DSSCs due to the large specific surface areas. However, electron scattering and trapping in the grain boundaries among nanoparticles seriously influence DSSCs performance [3]. Poly(3-hexylthiophene) (P3HT) is one of promising material for industrial application which is conjugated polymer commonly used for hole transport in organic solar cells because of the high mobility of charge carrier in the material [4]. Another advantage of using the P3HT/PCBM blend as a polymeric interfacial layer in MPS SBDs is its easy processing. Previous studies examined the enhancement of MPS device performance by using organic interfacial layers. The molecular dye is an essential component of the Dyes Solar Cells (DSC), and improvements in efficiency over the last 15 years have been achieved by tailoring the optoelectronic properties of the dye.

The most successful dyes are based on ruthenium bipyridyl compounds, which are characterized by a large absorption coefficient in the visible part of the solar spectrum, good adsorption properties, excellent stability, and efficient electron injection [5]. However, ruthenium-based compounds are relatively expensive, and organic dyes with similar characteristics and even higher absorption coefficients have recently been reported; solar cells with efficiencies of up to 9% have been reported [6–12]. Organic dyes with a higher absorption coefficient could translate into thinner nanostructures metal oxide films, which would be advantageous for charge transport both in the metal oxide and in the permeating phase, allowing for the use of higher viscosity materials such as ionic liquids, solid electrolytes or hole conductors. Organic dyes used in the DSC often bear a resemblance to dyes found in plants, fruits, and other natural products, and several dye-sensitized solar cells with natural dyes have been reported [13]. In this work, we explore the use of natural dyes obtained from the extract of achiote seeds, which are characterized by a high content of red pigments with a high absorption coefficient.

2.0 EXPERIMENTAL

2.1 Material Preparation

TiO_2 were purchased from Sigma Aldrich. The TiO_2 solution was prepared using mass of nano-TiO_2 powder that is 0.05 g. The powder will be stirred in 30 ml of ethanol mixed with 6 ml of acetic acid. Then the solution was mixed using magnetic stirrer for 20 hours.

2.2 Sample Preparation

The contamination and impurities were minimizing on ITO coated glass by go through cleaning process. The dust and dirty from surrounding can be avoided and maximize the fixed and consistence of the results. Thus, ultrasonic water bath was chosen to clean ITO glass. 2 cm x 2 cm coated ITO glasses were immersed in 20 ml in detergent for 10 minutes for 30 °C. Then, the same processes were repeated by using distilled water for 3 times in 5 minutes each. The step were continue by acetone for 5 minutes and end up with distilled water before left dry to completely dry at room temperature. Thus, the samples were stored in dry box to control humidity of the samples.

2.3 Extraction

The nature dyes *Bixa orellana*, were collected from the rural area and the seed were left dried in oven to remove residual water. This bixin were expected to have colorants dyes. These dyes were extracted by using immerging in methanol solution. 5 g of dried dyes was then immersed in 50 ml of methanol and stored in blue cap bottle tightly to avoid evaporation. Then, all the dyes were stored in freezer for one week in order the nature dyes getting extracted during this period.

2.4 Characterization of UV-Vis Spectroscopy

The optical characterizations to obtain the absorption of colorant and achive the value of optical band gap energy were measures by using Lambda 25 UV/VIS spectrometer UV-Vis Spectroscopy. The optical properties solution was prepared in ratio of 1:10 in methanol concentration as a single-phase solution.

2.5 Deposition via Electrochemical Impedance Spectroscopy (EIS)

The samples were coated to ITO glass by using Electrochemical Impedance Spectroscopy (EIS) technique, (PGSTAT302). A typical electrochemical impedance experimental set-up consists of an electrochemical cell (the system under investigation) a potentiostat/galvanostat and a General Purpose Electrochemical System (GPES).

2.6 Characterization of Four Point Probe

Four-point probe characterization is a standard method for studying the electrical properties of solids and thin films in material science and semiconductor industries due to its low demand on sample preparation and high accuracy. Electrical conductivity is the capacity of any object or substance to conduct an electric current. When the electrical potential difference was placed across a conductor, the movable charges will flow thus giving rise to an electric current. The conductivity can be measured as follow:

$$R_s = 4.532\,\frac{V}{I} \tag{1}$$

where,

R_S= sheet resistance (resistivity),
4.532 = correction factor,
V = voltage measured and
I = the current applied from the test unit.

3.0 RESULTS AND DISCUSSION

3.1 Energy Gap

In present study, UV-Vis spectroscopy gives an initiative of band gap energy (E_g). The absorption of the light energy by the dyes in the ultraviolet and visible region consist of the promotion of electron in σ, π and n-orbital from the ground states to higher energy states which are described by molecular orbital [13].

The electronic transitions (→) that are involved in the ultraviolet and visible regions are of the following type σ → σ*, n → π*, and π → π*. Many of the optical transitions which result from the presence of impurities have energies in the visible part of the spectrum; consequently the defects are referred to as color centers. Ion beam interaction with dyes generates damage which leads to the formation of new defects and new charge states [14].

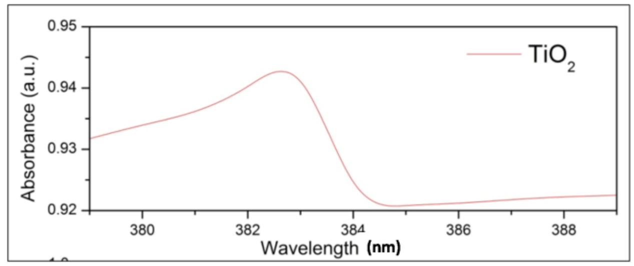


Figure 1 The absorption of TiO_2

Figure 2 UV-Vis shows that the sample of dyes absorbs light having wavelength below 500 - 320 nm where it was induce red-shift. These samples show even the absorption at the lower wavelength regions. The reason possibly is the difference in particle size of the same sample. In the case of VT, the interaction between dyes is the explanation for its red region and for the increase in its absorption coefficient [15].

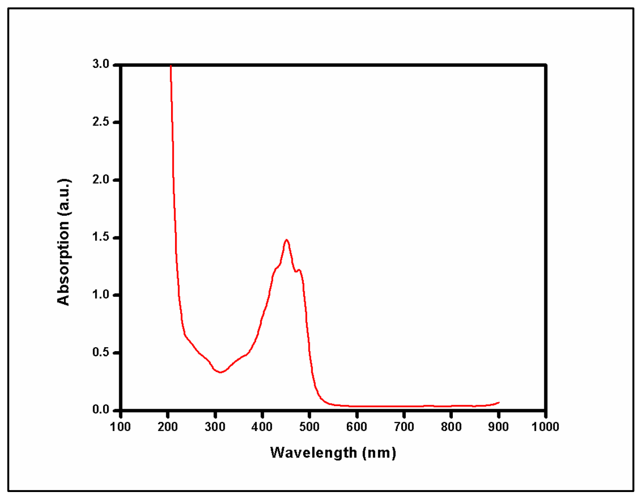


Figure 2 The absorption of *Bixa orellana*

By comparing the both graph, the UV absorption spectra of desorbed dyes from methanol solution and TiO_2 solution shows that, a large amount of dyes absorption represent high light harvesting efficiency and leads to a high rate of photogenerated electron. Herein, the photoanode employing TiO_2 nanoparticles, which have a large surface area, exhibit the greatest amount of dye absorption, which might result in higher rate of photogenerated electron. These characteristics ensure high photocurrent and high conductivity [16].

3.2 Conductivity

The conductivity result was depicted as Figures 3. The Four points probe test shows the conductivity were increase due to increasing the intensity of light. Besides that, the number of layer also affected the values of conductivity. The initial increase in the ionic conductivity were attribute to the built up of charge carrier to the system. A further increase in intensity effecting the by reduce the ionic conductivity [17].

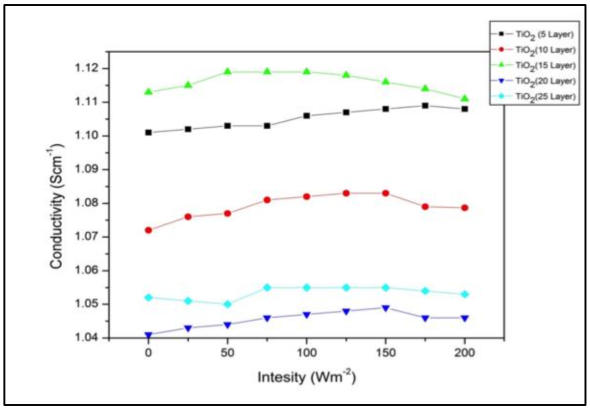


Figure 3 The conductivity of TiO_2 varied by layers

Figure 4 conductivity shows the conductivity of 5 types of different layer of *Bixa orellana* as coated dyes. From the graph, the conductivity for 1 layer of *Bixa orellana* gives conductivity value 0.73 Scm^{-1}.

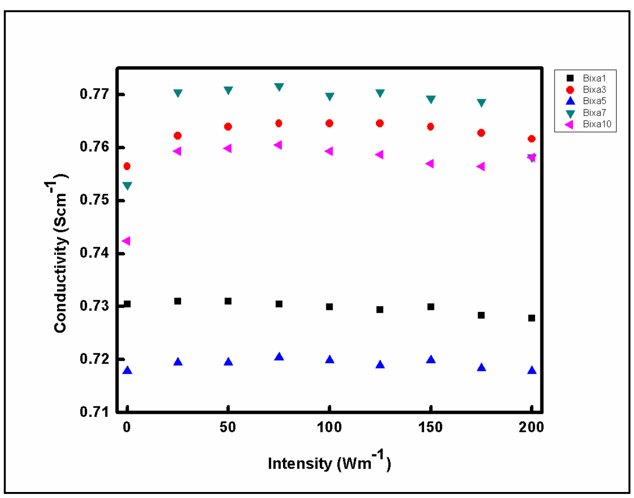


Figure 4 The conductivity of *Bixa orellana* varied by layers

Thus, the conductivity enhancement after increments the layer up to 0.77 Scm^{-1} which is 7 layer of *Bixa orellana* gives the highest conductivity. The enhancement is found associated with the hydrophilicity and dielectric constant. The further increment may operate due to the creation of transient hopping sites and additional pathways through the interaction by cationic species by adding the layer of *Bixa orellana*. Besides that, by adding the layer of *Bixa orellana* were effect for low colorant where shielding effect, which could explain the increase at higher colorant make any changes. Faughnan states that, the polaron to be localized by 93% at one W-atom [18-19].

The dependence of *Bixa orellana* films electrical resistivity was investigated throughout by increase the intensity of light. Figure 5 shows that, the increment slightly affect the conductivity. It can be seen the comparison the variation of resistivity in function of different intensity. The changes of conductivity by intensity are more significant when samples are irradiated. It was indicated a photon activated mechanism in addition to the thermal activated mechanism [20]. The decreases of conductivity were found after 7 layers of *Bixa orellana* which is associated to an electron from site to another.

4.0 CONCLUSION

In summary, the absorption of the dyes and TiO_2 from UV-Vis spectrum were investigated and contributed to enhancement for conductivity value. The variation of coating layer shows different value of conductivity where, the conductivity were increasing up to 7 layers of *Bixa orellana* gives 0.77 Scm^{-1}. Thus, the result indicating the there are interaction of electron on the surface area of ITO. As the other change, the increase of layer onto surfaces improved absorbance of the sample.

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