EXPLORATION OF NATURAL DYE EXTRACTED FROM ANNATTO SEEDS TO FABRICATE DYE SENSITIZED SOLAR CELL

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INTRODUCTION

The various types of solar cells that convert solar energy into electricity have been innovated and the solar cell that has recorded the highest photon to current conversion efficiency is the multiple junction GaAs solar cell which has efficiency around 44% (Gratzel, 2001). The problem with this kind of solar cell is its high cost of production and toxicity of the materials. Large number of research groups has worked on solar cell devices consisting of semiconductor thin films to reduce the high cost of production and to improve efficiency. Accordingly, development of solar cells sensitized with a dye, the dye sensitized solar cell (DSSC), is a relatively new class of low cost and environmental friendly device. This solarcell was developed by Gratzal and co-workers as a practicable device which is an interesting field of research at present (O'Regan and Gratzel, 1991). Conversion of visible light into electricity in DSSCs base on the photosensitization of wide band gap TiO_2 semiconductor nanoporous film using dye molecules.

Usually DSSCs are fabricated using Ruthenium bipyridyle dye which is synthesized particularly to sensitized solar cells. Ruthenium complexes are considered as good sensitizers for DSSCs but synthesis of these dyes are complicated and costly due to the rarity of transition metal use in this dye (Escobar and Jaramillo, 2015). Therefore, DSSC prepared using natural pigments are encouraged to replace the Ruthenium dye. The natural dyes found in flowers, leaves and fruits can be extracted by simple procedures. Due to the abundance and low cost, natural dyes are popular subjects of research even though they are biodegradable (Haryantoet al., 2013). Some natural dyes can be extracted by using organic solvents which can be applied to sensitized DSCCs without further purification of the dye extraction because only the pigments with particular functional groups could attached on the oxide semiconductor surface.

In this study, DSSC were prepared using natural dye extracted from Annatto (*Bixa Orellana)* seeds as the sensitizer. Bark of the Annatto seeds contain pigment bixin which is a carotenoid. In this paper, we report on the fabrication of dye sensitized solar cell with natural dye extracted from bark of Annatto seed using ethyl acetate as the solvent of extraction of bixin.

METHODOLOGY

Extraction of dye

Annatto (*Bixaorellana*) seeds were put into a mortar. Then, ethyl acetate was added into the mortar and the red coat of the seed was carefully peeled off into ethyl acetate solution using a pestle. When the seed coat was dissolved in the ethyl acetate solution, it was collected into a test tube using a pasture pipette and solid residues were filtered out to obtain a clear dark orange colour dye solution. After that the dye solution was transferred into a boiling tube and kept close until use.

Preparatin and assembling of the cell

FTO glass sheets of dimensions 1.5cm × 3cm were cleaned in an ultrasonic bath respectively with tape water, tepole and distilled water. Adhesive tape was fixed on the conducting glass sheet to restrict the thickness and area of TiO_2 film. TiO_2 paste was prepared by mixing 0.5 g of TiO_2 powderwith 1.5ml of ethyl acetate, 1 drop of triton-x-100, 1 drop of terphenol and

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0.6ml of ethanol in a mortar until a thick paste was obtained. After that the past was spread on the conducting sheet using the doctor blade methodto preparethe TiO_2 film. TiO_2films on the conducting glass plates were sintered in a furnace at 450°C for 30min to burn the volatile materials. After that sintered TiO_2 films on conducting glass sheets were immersed in Annatto seed dye solution in the boiling tube. The TiO_2 filmsin the boiling tube with dye solution were heated in a hot water bath for 5minutes. After that TiO_2films in the dye were kept for 12 hours to absorb the dye adequately on the TiO_2 films.

The photochemical solar cells were assembled by filling the liquid electrolyte between the dye coated TiO_2 film and counter electrode. Pt sputtered conducting glass sheets were used as the counter electrodes of the cells. The electrolyte composed of 8ml of ethylenecarbonate, 2ml of acetonitrile,0.83g of potassium iodide (KI) and 0.1269g of iodine (I_2).Then the two electrodes were clipped together to form the photochemical solar cell.

Characterizations of the dye and the solar cell

I-V curves of the cells were obtained using a galvanostat potentiostat coupled to a computer while illuminating themwith white light LED bulb ($10Wm^{-2}$). The extracted dye was characterized by UV-3000 spectrometer and FTIR spectrometer.

RESULTS AND DISCUSSION

The Annatto seed contains pigment bixin which is a red colored organic chemical compound. Figure 1 shows the schematic chemical structure of bixin.

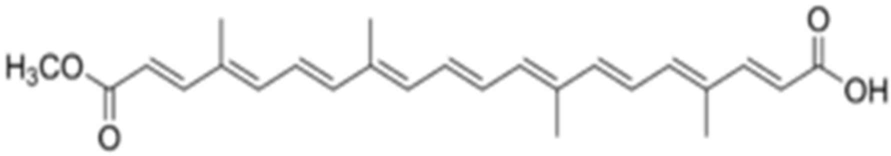
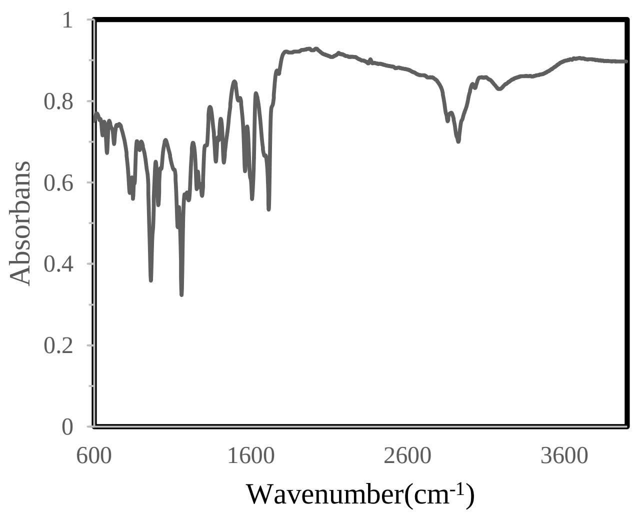


Figure 1. Schematic chemical structure of bixin in Annatto seed

The absorption spectrum of Annatto seed extractedinethyl acetate solution is shown in Figure 2. The pigment exhibits an absorption band within the visible region having two peaks appearing at 459nm and 489nm. The energy difference between the lowest unoccupied molecular orbital (LUMO) and highest occupied molecular orbital (HOMO) was calculated using absorption spectrum which is found
to be 2.21 eV.



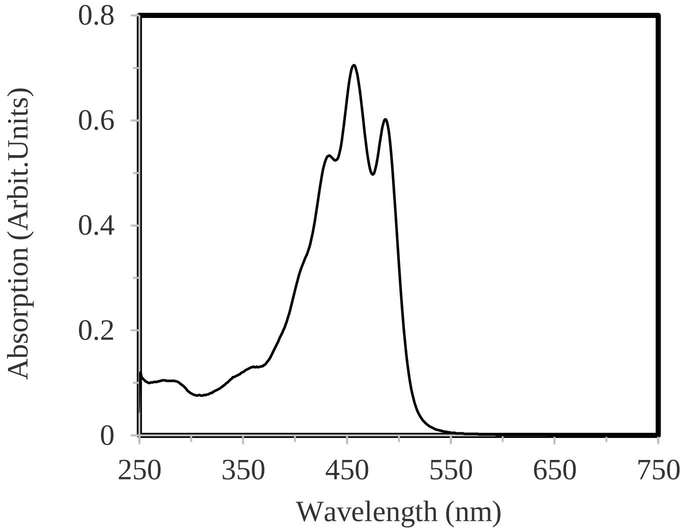


Figure 2. UV visible spectra of dye extracted from the bark of Annatto seed

Figure 3. FTIR spectra of dye extracted from the bark of the Annatto seed

The FTIR data in figure 3 convinces that the dye contains hydroxyl group which helps the dye to attach effectively on TiO_2 film. The band at around 3000cm^{-1} suggests that the dye molecule accompanies with hydroxyl groups in carboxylic acid. The C-O stretching of an ester emergesin the range from 1000cm^{-1} to 1300cm^{-1}. The C=O stretching occurs at about 1720cm^{-1}. These absorption peaks verify the characteristic bonds in dye extraction.

The I-V characteristic of the FTO /TiO_2/dye/electrolyte/Pt photochemical solar cell is shown in figure 4.The open circuitphoto voltageof the cell was ~0.55V and short circuit photocurrent was ~ 1.0 mA when illuminated with 10Wcm^{-2} white light LED lamp. The efficiency of solar cell is around 0.02 % and fill factor was 41.2%.

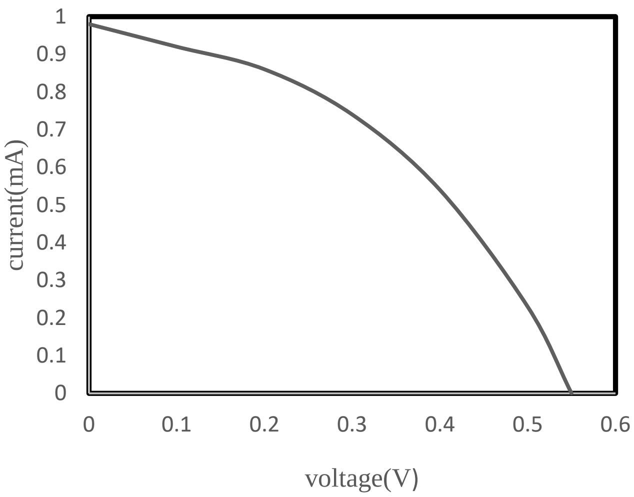


Figure 4. I-V characteristic of a solar cell sensitized with dye extraction of Annatto seeds

CONCLUSION

The photoelectrochemical solar cells sensitized with the dye which was extracted from bark of Annatto seeds in ethyl acetatehave shown photocurrent of ~ 1.0.mA and photo voltage of ~0.55 V. The efficiency of FTO/TiO_2/Dye/electrolyte/Pt cell reached 0.02 % under irradiationwith white LED lamp of 10 Wcm^{-2}. The active pigment in the Annatto seeds was found to be bixin which was characterized with UV-visible and FTIR spectroscopy.

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