CHARACTERIZATION DYE EXTRACTED FROM *Amherstia nobilis* FLOWERS AS A SENSITIZER OF SOLAR CELLS

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ABSTRACT

As a sensitizer for dye-sensitized solar cells (DSSC), a natural dye extracted from the pink flower of the *Amherstia nobilis* (Pride of Burma) plant was used in this research. Flower petals 20g were cut into little pieces 50ml of ethanol was added, and it was kept at room temperature for 24 hours in order to extract the dye. A thin film of TiO_2 nanoparticles was deposited on fluorine-doped tin oxide (FTO) glass plates to fabricate the solar cell. FTO glass coated with platinum was used as the counter electrode, and iodin/tri iodide(I_2 / I_3^-) was used as the electrolyte. The solar cell was tested with a light source with an intensity of 100mW/cm^2. The open circuit voltage (V_{oc}) of this cell was 511mV and its short circuit current (I_{sc}) was 2.811mA. The cell had an efficiency of 0.865% and a fill factor of 0.601. The energy gap between the HOMO and LUMO levels of the dye was calculated as 2.2eV using the Tauc plot according to the data obtained for the UV visible absorption spectrum which has given an absorption peak at 527nm. The cyclic voltammogram was assisted in finding out the LUMO level of the dye by observing its redox potential which is approximately -1.20V vs the Ag/AgCl reference electrode. It was identified that the LUMO level of the dye extracted from *Amherstia nobilis* flower is positioned at a higher level, feasible to inject electrons to the conduction band of TiO_2 energetically, which resulted in a higher voltage, current, and efficiency for this dye.

Keywords: DSSC, TiO_2, Solar cell, Doctor-blade, IPCE, I-V Characteristics

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1. INTRODUCTION

The energy needs of humans heavily rely on fossil fuels; nevertheless, the pollution due to the emission of greenhouse gases causes climatic changes and endangering particles released into the atmosphere, which has alarmed health effects. Although fossil fuels are naturally produced, they do not replenish at the consumption rate. To solve the energy crisis, eco-friendly and affordable green energy sources must be substituted with fossil fuels. In this regard, solar energy has become a very viable alternative due to the enormous amount of energy reaching the earth's surface (700 megawatts per minute) (Zamrani R A, 2013). When converting solar energy to electrical energy, solar cells provide great overall benefits, and inexpensive and highly efficient solar cells made using photosensitizers have attracted great interest. Michael Gratzel and coworkers discovered an efficient solar cell that uses dyes as the photosensitizer in 1991 (Zamrani R A, 2013). Dye Sensitized Solar Cells (DSSC) fall under third-generation solar cells, and they could be made using synthetic and natural dyes. Synthetic dyes generally have higher efficiencies than natural dyes, but they are more expensive. However, inexpensive natural dyes are readily available, thus they are still widely used. Natural pigments like chlorophyll, carotene and anthocyanin are extracted from plant's leaves, fruits, bark, seeds, flowers etc. The efficiency of DSSC with natural dyes is also continually being improved through extensive research.

Anthocyanins are natural pigments in blue, red and purple colors, especially in flowers, fruits, and tubers. Cyanidin, delphinidin, pelargonidin, peonidin, petunidin, and malvidin are the most frequently available anthocyanins in plants (Hock Eng Khoo. etal 2017). The petal color of the *Amherstia nobilis* (Pride of Burma) flower is reddish-orange, and cyanidin 3-O-glucoside has been reported as the main pigment in this flower (Tsukasa Iwashinaa.etl, 2019). Cyanidin 3-O-glucoside is often found in fruits rather than in flowers (Takayuki Mizuno.etl, 2019) (Tsukasa Iwashinaa. Etl, 2019) (Ivana Serrainoa.etl, 2019) (Chongde Sun..etl, 2011). Therefore, having cyanidin 3-O-glucoside in the flowers of *Amherstia nobilis* is a rare occasion. In this research study, a dye extracted from the petals of the *Amherstia nobilis* flower is characterized to be used as a sensitizer in DSSC with the objective of achieving higher efficiency**.**

2. METHODOLOGY

2.1 Natural dye extraction

Amherstia nobilis (Pride of Burma) flower petals (20 g) were cut into small pieces, and 50 ml of ethanol was added. It was kept at room temperature for 24 hours in a covered beaker until flower petals became pale in colour. Finally, the extracted, red-coloured dye was filtered and collected into a sample bottle covered with aluminum foil, and the sealed bottle was stored in a refrigerator at 4°C until use.

2.2 Preparation of dye-coated film

Fluorine-doped Tin Oxide (FTO) glass plates which were cut into 2 cm×1cm pieces, were cleaned properly after placing the glasses in a small beaker half filled with distilled water. After that, a few drops of washing liquid were added and sonicated for 10 minutes by using an ultrasonic bath. After sonication, the beaker was taken out and the glasses were rewashed with distilled water with a few drops of con. H_2SO_4. After that FTO glasses were washed with distilled water and boiled in isopropyl alcohol at 80^0. Then the FTO glasses were taken out and dried with mild heat and identified its conducting side using a conductivity meter.

0.25 grams of TiO_2 nanoparticle (20 nm) powder, 0.1 mL of 0.1M HNO_3 one drop of Triton x-100 and a drop of PEG 400 were used to prepare, TiO_2 past. The prepared TiO2 paste was applied on the FTO glass plate's conductive surface using the doctor blade method. The film was sintered for 45 minutes at 450°C in a furnace. After 45 minutes, the TiO_2 film was allowed to cool down to room temperature. Finally, TiO_2 film-coated FTO glass was dipped in the dye extract of *Amherstia nobilis* flower for 6 hours in a covered test tube.

2.3 Fabrication of the cell

To prepare the electrolyte for the dye-sensitized solar cells, Iodine (I_2) 0.127 g and potassium iodide (KI) 0.83 g were dissolved in 10 ml of acetonitrile and ethylene carbonate in an 8:2 ratio in a volumetric flask. After that, the solution was stirred for 5 hours to ensure all the solid particles were dissolved.

The dye-coated TiO_2 film was used as the anode and the Pt sputtered glass plate was used as the counter electrode, which were placed side by side and fastened together using crocodile clips to fabricate the DSSC. Then the electrolyte was filled into the capillary gap between the two plates.

2.4 Dye and Solar Cell Characterization

To determine the absorption spectra of the natural dye, a UV-visible spectrometer was used and with the help of a computerised PK-I-V 100 I-V Analyzer, the photovoltaic measurements of the dye-sensitive solar cell were measured under a light source of $100mW/cm^2$ intensity. Metrohm Autolab PGSTAT204 was used to take the cyclic voltammetric measurements.

3. RESULTS AND DISCUSSION

Anthocyanins (1-3) and flavonols (4-11) were to be present in the *Amherst nobilis* flower which is an endemic species to Myanmar. (Tsukasa Iwashinaa.etl,2019) pigments, (1) cyanidin 3-O-glucoside (R_1 = glucosyl, R_2 = OH), (2) 3-O-xyloside (R_1 = Xylose, R_2 = OH) and (3) peonidin 3O glucoside (R_1 = glucosyl, R_2 = OMe) were recognized as anthocyanins. Flavanols, on the other hand, were identified as (4) isorhamnetin 3-O-glucoside (R_1 = glucosyl, = R_2 = OMe, R_3 = H), (5) 7- O-glucoside (R_1= H, R_2 =OMe, R_3 = glucosyl), (6) 3,7-di-O-glucosiden (R_1=R_3= glucosyl, R_2=OMe), and (7) 3-O-rutinoside (R_1= rutinosyl, R_2=OH, R_3=H), (8)quercetin 3-O-rutinoside (R_1=rutinosyl, R_2 = OH, R_3=H), and (9) kaempferol 3-O-rutinoside (R_1=rutinosyl, R_2=R_3=H), (10) Pelargonidin 3-O-pentoside (R_1=glucosyl R_2=R_3=H).Also(11) an anthocyanin pelargonidin 3-O-pentoside (R_1=glucosyl, R_2=R_3=H) has been reported from *Amherstia nobilis* flower.

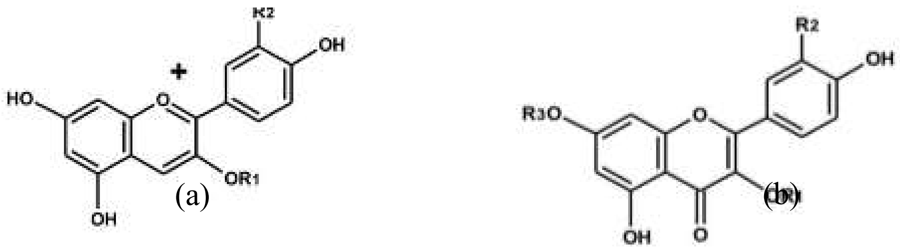

Fig.1. Chemical structures of (a) anthocyanins (**1**–**3**) and (b) flavanols (**4**–**11**) found in the flowers of *Amherstia nobilis*.

The pH of the solution affects the colour of anthocyanins. This is due to the ionic character of the anthocyanins' molecular structure. Some anthocyanins appear red, orange, reddish-orange in acidic conditions (low pH range). When the pH is neutral, anthocyanins are purple, but when the pH rises, they turn blue.

Although the primary anthocyanin in flowers, cyanidin 3-O-glucoside, is originally red and not reddish orange, the colour of anthocyanins is hypsochromically shifted when the pH is lowered. Although the flowers of *Amherstia nobilis* express reddish orange despite flower pigments being cyanidin glycosides, the pH of the pressed juice from petals is lower (pH 3.3). It was proved by a Vitro examination. (Takayuki Mizuno, etl, 2019).

4.1 UV-Visible Absorption Spectrum

Figure 2 displays the UV-Vis absorption spectrum of the dye extracted from *Amherstia nobilis* flower. The absorption measurement used a wavelength range of 400 nm to 800 nm., Specific peaks at 527 nm in the absorption spectra could be observed for the dye.

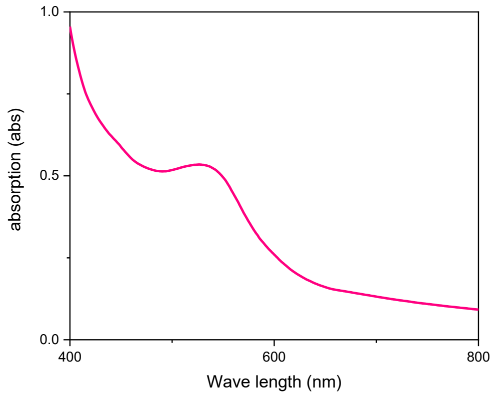

Figure 2 : UV-Vis absorption spectra of dye extracts of *Amherstia nobolis* flowers in Ethanol

A Tauc plot was obtained with the data from the absorption spectrum of the dye (figure 3

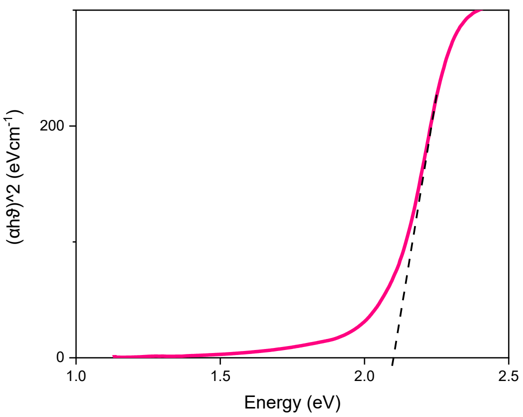

Figure 3: Tauc plots for calculating the energy gap of the ground state and excited states of *Amherstia nobilis* flower dye.

The Tauc relation provided by the following equation was used to determine the energy band gap between the Highest Occupied Molecular Orbital (HOMO) and Lowest Unoccupied Molecular Orbital (LUMO).

$$(\alpha h\vartheta)\ n = A(h\vartheta - Eg)$$

$$\alpha = 4\pi k/\lambda\ ,\ \ E = Ah\vartheta$$

$A = 1$, $h\vartheta$ = the photon energy, α = the absorption coefficient, k = absorbance,
Eg = the band gap between LUMO and HOMO levels. n = 2 for the direct band gap and n =1/2 for the indirect band gap. Natural dyes have a direct band gap and n=2 is used in there. The band gap energy was determined using the graph plotted $(\alpha h\vartheta)^2$ vs $Ah\vartheta$ and was discovered as 2.20 eV.

4.2 Cyclic voltammetry and energy band diagram

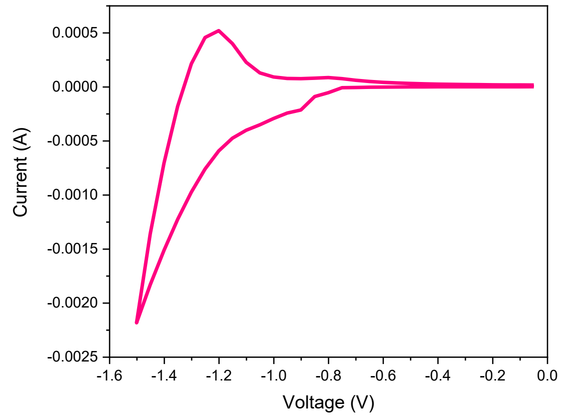

Figure 4: Cyclic Volta monogram of dye (extracted from *Amherstia nobilis* flower) attached to TiO_2 Film

The pigment's pink colour turned pale when the electrode potential moved in a negative direction, and it turned dark blue when it moved in a positive direction. The pigment that is attached to the TiO_2 electrode may be reduced and oxidized as a result of this colour shift. The cyclic voltammogram, which is approximately -1.20V vs the Ag/AgCl reference electrode, can be used to determine the oxidation and reduction potential of the pigment. The energy at the beginning of the dye's absorption edge in the absorption spectrum, which is 2.2 eV, was used to calculate the energy difference between the lowest unoccupied molecular orbital (LUMO) and the highest occupied molecular orbital (HOMO). The dye's oxidation-reduction potential, corresponds to the LUMO level's energy -3.2eV in vacuum scale. Since the energy of the dye's excited state is higher than that of the TiO2 conduction band, excited dye molecules may inject electrons into the bands of TiO2. Therefore, using this electrochemical system, it is possible to convert light energy to electrical energy.
Figure 5 displays the corresponding energy levels of the pigment, semiconductor, and I_2/I_3^- redox pair.

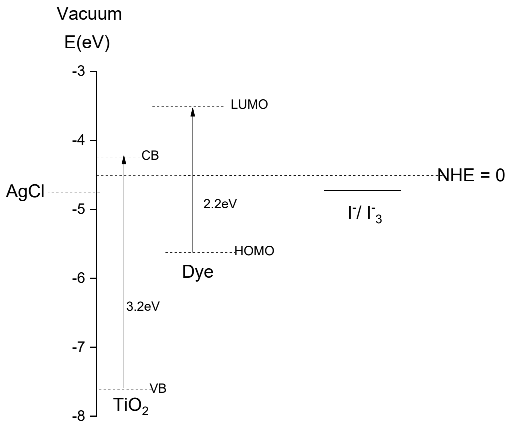

Figure 5: Energy band diagram of DSSC with the configuration TiO_2/ Dye/ electrolyte

4.3 I-V characteristics of the DSSC

Photovoltaic measurements of the Dye-Sensitized Solar Cell were measured under a light source with an intensity of 100 mW/cm² as depicted in Figure 3. The photocurrent, photovoltage and efficiency of the *Amherstia nobilis* flower Dye-sensitized solar cell (DSSC) were respectively 2.811 mA, 511.6 Mv and 0.865% and the fill factor of the cell was 0.601.

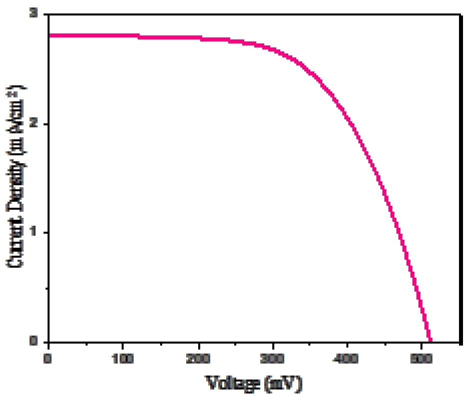

Figure 6: JV Characteristic curve of Amherstia nobilis flower dye- Dye-sensitized solar cell (DSSC) under the Light source of 100 mW/cm^2

5. CONCLUSION

Natural dye was extracted from *Amherstia nobilis* flower (Pride of Burma) for the sensitization of DSSCs. An absorption peak could be observed at 527 nm in UV-Vis spectra for this dye in the wavelength range of 400-800 nm and the band gap was calculated using a tauc plot which was found to be 2.2 eV. The Solar cell produced a short circuit photocurrent of 2.811 mA and an open circuit voltage of 511.6 mV with an efficiency of 0.865%. The fill factor of the cell was around 0.601. Since the excited state of the dye is located at a higher level with respect to the conduction band of TiO_2 electron transfer from the dye to the TiO_2 is energetically feasible.

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