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## Improvement on the performances of natural dye sensitized solar cell. I

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### ABSTRACT

*Natural dye sensitized solar cells using  $\text{TiO}_2$  with different haze were studied in this report, experiment revealed an improvement in the efficiency of the cells with increase in haze properties of the electrode. Energy conversion efficiency of 0.68% was obtained with high haze  $\text{TiO}_2$  electrode. This shows that the haze property of the photoanode could be used as an effective control of the cell performance.*

**Keywords:** haze, electrode, photoanode, solar cell, efficiency.

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### INTRODUCTION

All life on Earth depends on energy and the cycling of carbon. Energy is essential for economic and social development and also poses an environmental challenge. We must explore all aspects of energy production and consumption, including energy efficiency, clean energy, the global carbon cycle, carbon sources, and biomass, as well as their relationship to climatic and natural resource issues (1).

However, among all renewable energy technologies, such as wind turbine, hydropower, wave and tidal, solar power, solar cells, solar thermal, biomass-derived liquid fuels and biomass-fired electricity generation, photovoltaic technology utilizing solar energy is considered as the most promising one. Fortunately, the supply of energy from the Sun to the Earth is gigantic:  $3 \times 10^{24}$  J a year or about 10,000 times more than the global population currently consumes. In other words, covering 0.1% of the Earth's surface with solar cells with efficiency of 10% would satisfy our present needs (2).

Efficiency harvesting solar cell to generate electric power using photovoltaic technology beyond silicon system has undergone rapid development over the past few years. Dye sensitized solar cells (DSSC) are attractive because they are made from cheap materials and do not need to be highly purified and can be painted at low cost (3,4,5). DSSC are unique compared with almost all other kinds of solar cells in that electron transport, light absorption and hole transport are each handled by different materials in the cell. The sensitized dye in DSSC is anchored to a wide-band gap semiconductor such as  $\text{TiO}_2$ ,  $\text{SnO}_2$  or  $\text{ZnO}$  [6,7,8].

Among other factors affecting the efficiency of DSSC is the nanostructured  $\text{TiO}_2$  electrode, in a way one can say that the act of performing high efficiency DSSC is the act of controlling the morphology and interfacial properties of  $\text{TiO}_2$  electrode. The interdependence of the properties of  $\text{TiO}_2$  film and the performance of the cell are diverse, for instance; the large internal surface area provided by the sponge-like porous nature of the film determines the dye molecule uptake, the pore size distribution affects the ion diffusion, the particle size distribution determines the optical properties, and the electron percolation depends on the interconnection of the  $\text{TiO}_2$  particles. Therefore, when these  $\text{TiO}_2$  nanoparticles are stacked in a continuous network in the electrode, these fore-mentioned factors become related and optimization of these properties with respect to cell performance arises as a key issue (9, 10). Therefore, in this study the dependency of the performances of natural dye sensitized solar cell on the haze property of Anatase  $\text{TiO}_2$  semiconductor used as photoanode has been investigated.

## MATERIALS AND METHODS

### 2.1 Preparation of Dye sensitizer solutions

Red leaves of *A. cepa* were dried in an airy but dark place in the laboratory for several days until their weight becomes invariant. They were then crushed into tiny bits and extracted into a mixture of ethanol-fluka, 96% (v/v) and water (4:1 by volume) keeping them overnight. The residual part was removed by filtration and filtrate was washed with hexane severally to remove oil droplets and chlorophyll that may be present and then hydrolysed with few drops of HCl so that the extracts becomes deep red in colour as the natural pH of 3.1 was adjusted to 1.0. The resulting extracts were centrifuged to further remove any solid residue and filtrate was used directly as prepared for the construction of the DSSCs at room temperature. In this condition, the extract/filtrate remained stable for few months at room temperature in ethanol/ water solvent.

### 2.2 preparation of electrode

TiO<sub>2</sub> electrodes were coated on pre-cleaned fluorine-doped conducting tin oxide (FTO) glasses (1.2x1.2cm<sup>2</sup> dimension Nippon sheet glass, 10–12 Ω sq<sup>-1</sup>) by screen printing techniques, the haze was controlled by the addition of submicron particles (400nm) to the TiO<sub>2</sub> electrodes following a published procedure (11). Haze could be defined as the ratio of diffused transmittance to total optical transmittance of the TiO<sub>2</sub> electrode.

### 2.3 DSSC Assembly

The electrodes were immersed (face-up) in the natural dye sensitizer solution for 4 hours to chemoadsorb the dye onto the TiO<sub>2</sub> porous thick-film and this turn the fairly whitish photoanode to fairly reddish-brown colour. Other impurities/excess dye were washed away with anhydrous ethanol and dried using a moisture-free airflow.

DSSCs of 1cm<sup>2</sup> active were assembled by sandwiching a 60µm thick (before melting) Surlyn polymer foil as spacer between the photoanode and the Platinum counter electrode. Sealing was done by keeping the structure in a hot-press at 70<sup>0</sup> C for 12-15 seconds. The liquid electrode (0.5M KI + 0.0M I<sub>2</sub> in solvent of ethylene glycol + acetonitrile with a volume ratio of 4:1) was introduced into the cell gap via a pre-drilled hole on the counter-electrode. The hole was later covered to prevent the electrode from leaking.

### 3.0 Characterization and measurements

UV–visible absorption measurements of extracted pigments in acidified ethanol/water solution were carried out with a dual wavelength/double beam spectrophotometer (model UV-3000). Current–voltage (*I*–*V*) characteristics of the cells were examined with a standard solar irradiation of 1000W m<sup>-2</sup> (Xe-lamp with an Oriol AM 1.5 filter) as the light source.

An Eko pyranometer was used to measure light intensity and a fully computerized set-up consists of a multimeter (Keithley 2000) coupled to a potentiostat via a computer was used for data acquisition.

The power conversion efficiency ( $\eta$ ) was calculated according to the following equation:

$$\eta = (FF \times J_{sc} \times V_{oc})/I, \quad (1)$$

where;  $J_{sc}$  is the short-circuit photocurrent density (A cm<sup>-2</sup>),  $V_{oc}$  is the open-circuit voltage (volts),  $I$  is the intensity of the incident light (W cm<sup>-2</sup>) and  $FF$  is the fill factor defined as

$$FF = J_m V_m / J_{sc} V_{oc}, \quad (2)$$

where ;  $J_m$  and  $V_m$  are the optimum.

## RESULT AND DISCUSSION

**Table 1.0 Performance evaluation of DSSCs prepared under irradiation with simulated sunlight at 1000wm<sup>2</sup> intensity ( AM 1.5) at the working area of 1.0 cm<sup>2</sup>.**

$J_{sc}$ (mA)	$V_{oc}$ (mV)	$FF$	$\eta$ (%)	Haze
1.18	208	0.12	0.29	5%
2.22	435	0.53	0.51	13%
2.31	447	0.55	0.57	36%
2.35	452	0.57	0.61	53%
2.39	460	0.57	0.63	62%
2.44	471	0.62	0.68	75%

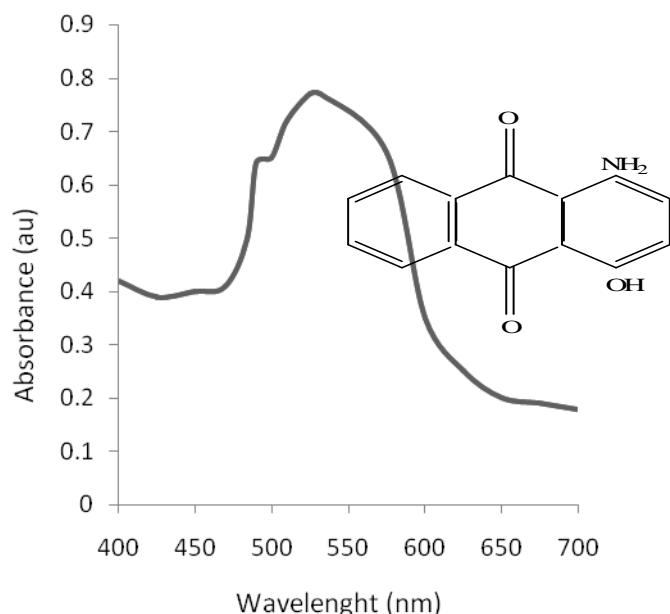


Fig.I; Absorption spectra of Duranol from *Allium cepa* (English ; Onion)

The absorption spectrum of the dye extract used in the development of the DSSCs is as shown in Fig.I, this exhibits a maximum at 532nm , the band is broadened with a shoulder at 490nm.

Table I shows the variation of the maximum reproducible value of the energy conversion efficiency , the open circuit voltage and the short-circuit photocurrent density with the percentage haze of the photoanode used in the development of the DSSCs. Since all the cells developed enjoyed sensitization at same peak of wavelengths ( 532nm, 590nm), the fairly increase in trend of the efficiency could consequently be attributed to the corresponding increase in the haze of the electrode.

The long time stability of these cells were systematically investigated with perfect sealing to avoid contact with moisture . However, all the cells examined displayed poor stability , this is reflected in the decrement of the efficiency of each cell after 5 hours of stimulation by sunlight (on an open field ). Moreover , a noticeable change in the colour of the electrodes from fairly red to fading light- red equally depicted the non-stability of the device following the long time exposure to sunlight.

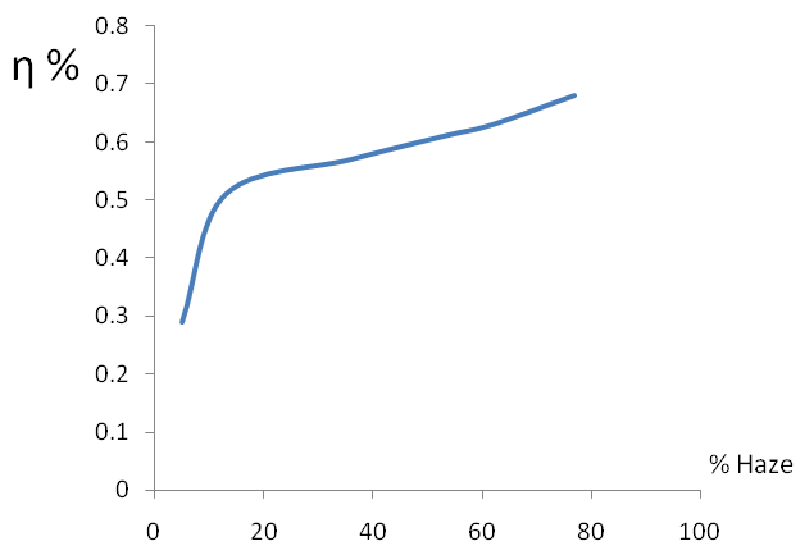


Figure II; Improvement on cell performance versus percentage increase in Haze of electrodes

Using Ruthenium- complex dye sensitized solar cell with about 76% haze  $\text{TiO}_2$  electrode , a  $J_{sc}$  of 21mA and conversion efficiency of about 11% have been reported (11) . However, in this study  $J_{sc}$  of 2.44mA and efficiency

of 0.68% have been recorded using natural dye sensitizer with TiO<sub>2</sub> electrode of about 75% haze. Even though, the trend of increase in efficiency with the photoanode haze property corresponds to the results obtained by Chiba *et al* (11), the low value of  $J_{sc}$  and efficiency could be attributed to the weak binding energy of the dye molecules with TiO<sub>2</sub> film which consequently resulted to low charge transfer absorption in the visible range.

### CONCLUSION

In this study, experimental evidence was thus found that the haze property of photoanode is a useful index in the development of high energy conversion efficiency naturally sensitized dye sensitized solar cell and this could enhance the development of natural DSSC for photovoltaic applications.

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