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Fabrication and Properties of Dye Sensitized Solar Cell from Dye Extract from *Callindra Haematocephala* as Sensitizer

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ABSTRACT

The nanostructured ZnO electrodes were prepared by using standard hydrothermal method on FTO coated glass as the substrate. These plates coated with ZnO were used for working electrodes, carbon coated FTO glass was taken as counter electrode. Dye Sensitized Solar Cells (DSSC) were prepared incorporating natural dye extract from *Calliandra haematocephala* and iodide solution as electrolyte. The natural dye from flowers of *Calliandra haematocephala* was extracted with solutions of pH varying from 1 to 10 using distilled water, hydrochloric acid and sodium hydroxide. Absorption maxima of all the extracts were detected using UV- Visible spectrophotometer. The crystallinity of prepared electrode was determined with help of X-ray diffraction technique. The efficiency of the solar cell due to variation in natural dye extract was studied by varying two main parameters like dye solution, pH and time. The efficiency of dye solution did was considerable at pH-8. The solar cells prepared were stable over a period of seven days and gave similar results. Minimum concentration of the dye solution was sufficient to bring about effective energy conversion. With the help of the PV plots maximum power were determined.

KEY WORDS: *Calliandra Haematocephala,* ZnO, hydrothermal, X-ray diffraction, pH, Time.

1. INTRODUCTION

Solar cells have gained momentum since past two decades. The DSSC's (Dye Sensitized Solar Cells) i.e. third generation of solar cells has come to the forefront recently. Dye-sensitized solar cells are cost efficient, versatile and electricity generators that have attracted the attention of academicians and industrialists. These DSSC's are alternative energy producers, they mimic natural photosynthesis (Aneesh & Vittal 2017). The vital component of DSSC is photo-anode, variation of its components lead to optimization and enhanced cell activity. Main variants of the photo-anode are the nature of semiconductor, the type of dye, electrolyte combination and nature of counter electrode. ZnO nanoparticles form excellent semiconductor, it has considerable stability and is insensitive towards the type of electrolyte. Adsorption of the dye to the semiconductor surface is required to efficiently introduce electron into conducting band. A well anchored dye sensitizer on the surface of zinc oxide absorbs photons and gets electronically excited. Energy is produced when the excited electron moves from the valence band to the conduction band of the semiconductor. The electrolyte (I^-/I_3^-) donates electron back to the dye. In this paper we have opted ZnO nanoparticle semiconductor and carbon black counter electrode. Iodide solution was used as electrolyte. These foresaid parameters were kept constant and the dye solution was varied. Dyes can be synthetic or originated from plant (Angel, 2011; William, 2017). Natural dyes are economical, easily available and environmental friendly. In addition, they turn to have large absorption coefficient owing to allowed π to π * transitions.

Calliandra haematocephala having the synonym: *Anneslia haematocephala* (Hassk.) Britton & P. Wilson, *Calliandra inaequilatera* Rusby, *Calliandra novaesii* Hoehne, and *Feuilleea haematocephala* Kuntze belongs to the family Fabaceae. These plants flower all year round, but the best blooming is in spring and summer. They can be easily pruned. Marlier have reported the isolation of natural amino acid 4, 5-dihydroxy-L-pipecolic acid and pipecolic acid derivative 2*S*, 4*R*-carboxy-2-acetylamino-4-piperidine from leaves of the legume of *Calliandra haematocephala* (Marlier, 1972, 1979). Reports on isolation of quercetin rhamnosides from *Calliandra haematocephala* Hassk. (Fabaceae) are found in literature. Their structures were established as quercitrin 2′′-*O*-caffeate, quercitrin 3′′-*O*-gallate and quercitrin 2′′, 3′′-di-*O*-gallate. Also, 17 known compounds were identified as gallic acid, methyl gallate, caffeic acid, myricitrin, quercitrin, myricetin 3-*O*-β-D-$^4C_1$-glucopyranoside, afzelin, isoquercitrin, myricetin 3-*O*-(6′′-*O*-galloyl)-β-D-glucopyranoside, myricitrin 2′′-*O*-gallate, quercitrin 2′′-*O*-gallate, afzelin 2′′-*O*-gallate, myricitrin 3′′-*O*-gallate, afzelin 3′′-*O*-gallate, 1, 2, 3, 4, 6-penta-*O*-galloyl-β-D-$^4C_1$-glucopyranose, myricitrin 2′′, 3′′-di-*O*-gallate, quercetin 3-*O*-methyl ether, for the first time from the genus *Calliandra*, most of the compounds that were isolated, these exhibited anti-oxidant properties in comparison to quercetin as positive control *In Vitro* (Moharram, 2006). The flowers of this plant had attractive red colour and could possibly have anchoring groups like carboxylic acid, aldehyde or ketone based on the literature survey. Hence extraction of dye using solutions of varying pH was performed and tested for solar efficiency.

2. MATERIALS AND METHOD

Natural dye solutions: Fresh flowers of *Calliandra haematocephala* were harvested from the college campus, the herbaria was maintained and identified from the Department of Botany, IDSG Government College, Chickmagalur (Herbarium number 56). Dried flowers (1g) were ground separately in 500 mL of acidulated/alkalified water with pH ranging from 1 to 10. NaOH and CH_3COOH were used for this purpose. The extracts thus obtained were filtered, centrifuged and stored frozen until use to protect denaturing due to degradation.

Preparation of electrodes and assembling: Fluorine-doped SnO_2, FTO conductive plates with sheet resistance of 8-12 Ω/cm^2 and the Zinc oxide (ZnO) were purchased respectively from Aldrich and SD fine chemicals respectively. The solvents/chemicals used were of spectrophotometric grade and used as received.

ZnO paste was prepared and spread on the FTO conducting glass slides. This served as photo anode. Care was taken to avoid coating over electric contact strips with the help of adhesive tapes. The coated plates were thoroughly cleaned for 30 minutes using EtOH: H_2O and heated to 450ºC (30 min). These prepared ZnO anodes were impregnated with various dye solutions, followed by water rinsing and drying with EtOH. The counter electrodes of carbon were then combined and electrolyte of I_2 (0.1 M), KI (0.05M) and 3-methoxyproponitrile (50 mL) in acetonitrile (C_2H_3N) was added. This system was clamped to avoid leakage.

The synthesized nano ZnO layer and was characterized XRD (Powder X-Ray Diffractomere- Bruker D8-Advance).

P-V studies: The prepared DSSC cells were illuminated with tungsten filament source (2370 Lux = 15 W) and maximum power was determined using Zener Diode. A PV graph was plotted and η_{max} (maximum efficiency) % was calculated. The stability of prepared cells was checked under one sun illumination and for one week duration (sun illumination between 12 noon to 3 PM).

Figure.1. ***Calliandra haematocephala***

3. RESULTS AND DISCUSSION

Characterization of semiconductor electrode: The ZnO coated on FTO was converted into nanoparticles of size between 50-100 nm as indicated in the SEM images (Fig.2). The XRD (Fig.3) shows reduction in the 100, 002 and 101 planes. The ZnO nanoparticles have hexagonal Wurtzite structure.

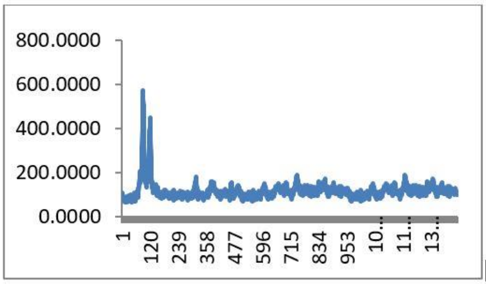

Figure.2. XRD of ZnO nanoparticle

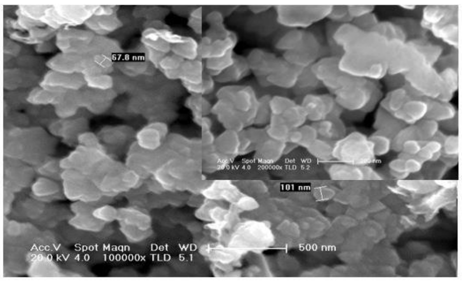

Figure.3. SEM images of FTO coated plain ZnO nanoparticle with insert

P-V studies: The extract of pH 8 showed maximum efficiency of 0.272%. The plant extract of pH 6 has shown less efficiency of 0.154 %. All other solutions have shown considerable efficiency with an average of 0.25%. The current output was steady and the cell was fairly stable and was constant during the week study. The results are shown in table.1 and (Fig.4-6).

Table 1: Dye sensitized solar cell efficiency

Code	P_{max}	% Cell efficiency η	Code	P_{max}	% Cell efficiency η
pH 1	0.156	0.261	pH 6	0.092	0.154
pH 2	0.160	0.266	pH 7	0.160	0.266
pH 3	0.128	0.213	pH 8	0.163	0.272
pH 4	0.144	0.240	pH 9	0.160	0.266
pH 5	0.160	0.266	pH 10	0.160	0.266

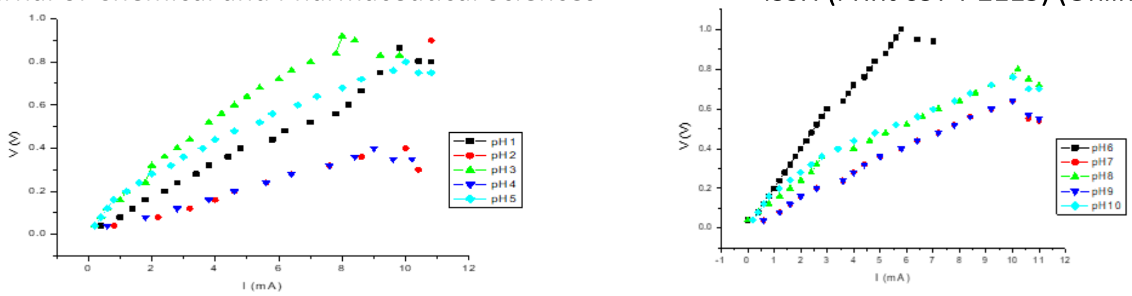

Figure.4. PV plots of DSSC for natural dye solutions

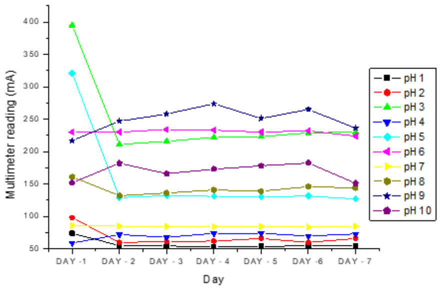

Figure.5. Time dependent efficiency for natural dye DSSC under sun illumination (100mW &air mass 1.5)

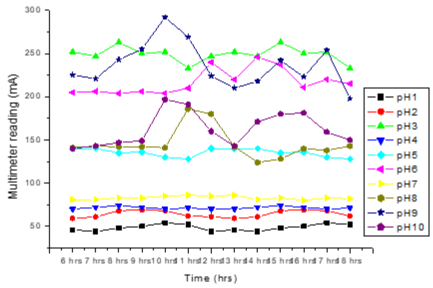

Figure.6. Time dependent efficiency for natural dye DSSC under sun illumination (100mW & air mass 1.5) for a week (average voltage of 12 and 13 hrs taken)

4. CONCLUSIONS

The active dye extracted from the flower was present in all the extracts (pH 1-10). All the ten solutions showed good solar efficiency which is in line with the other DSSC prepared using ZnO nanoparticles. The results were stable. Variations in parameters like counter electrode and electrolyte solutions can add the voluminous work being carried out on such solar cells.

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