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A Study on Dye Sensitized Solar Cell From 2-Naphthalehyde Dye as Sensitizer

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Abstract:- *The ZnO nanostructured electrodes were prepared using standard hydrothermal method on FTO coated glass as the substrate. These coated plates were used as working electrodes. Dye Sensitized Solar Cells (DSSC) was prepared incorporating 2-naphthaldehyde dye and iodide solution as electrolyte. The dye of 2-naphthaldehyde was synthesized using a novel procedure and characterized by IR, TGA and DSC. The crystallinity of prepared electrode was determined using X-ray diffraction technique. The effect of dye extract on the efficiency of the solar cell was studied by varying time. Power output was determined under standard conditions. With the help of the PV plots cell efficiency (%) was determined. The efficiency of synthesized dye of 2-naphthaldehyde was compared with that of the starting material 2-naphthol. The solar cells prepared were stable over a period of seven days and gave similar results. The effective energy conversion was obtained with a dye concentration of 100 mg/4cm^2 area of the working electrode. The controls showed no power output and the starting material 2-naphthol had considerable conversion rates. The synthesized dye due to anchoring effect showed promising results.*

Key words: *2-Naphtaldehyde, ZnO, Hydrothermal, X-ray diffraction, DSSC.*

1. INTRODUCTION

Solar cells have gained momentum since past two decades. The third generation of solar cells i.e. Dye Sensitized Solar Cells (DSSC's) have 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. The light absorbing dye helps in promoting the electrons to the conduction band of the semiconductor substrate more effectively. Nano-porous semiconductor materials allow large number of dyes to adsorb on its surface, leading to widening of the band gap and large exciton binding energy, thereby improving the power efficiency of DSSC. TiO_2 based DSSC's have been reported to show higher efficiencies of nearly 11%. The major limitation of the TiO_2 DSSC's is that it is less stable. Aneesh et al. and Vittal et al. found that DSC's with mesoporous ZnO layers provide excellent anchorage to the light harvesting dye and give notable energy conversion with highest efficiency of 0.25-0.3 % [1,2]. Even though the efficiency of ZnO DSSC's is less, they are stable to various electrolyte solutions and give reproducible results. DSSC is a redox system, hence there is an intensive effort in optimizing the various parameters of the like the nature of electrolyte, thickness of the semiconductor layer, the type of dye and variation in functional groups of the dye. The dye should have intense absorption spectrum with anchoring groups such as carboxylic, carbonyl and hydroxyl to anchor to the semiconductor mesoporous layer. This strong absorption leads to efficient injection of electron into the conduction band of the semiconductor ZnO. Energy is produced in this process. After the electrolyte donates electron back to the dye, de excitation occurs. This process is reversible and reproducible. As there is limited source of work reported till now, in the present work the effort is made to show that, 2-hydroxynaphthaldehye and its polymer form are excellent anchoring dyes due to extended conjugation and presence of aldehyde and phenol functional groups. Due to their less toxicity, large stability and cost effectiveness, these compounds have been investigated for their conversion efficiencies. Carbon coated counter electrodes and I^-/I_3 electrolyte solutions were adopted for the study as a preliminary investigation.

2. EXPERIMENTAL

2.1 Synthesis of dye

The dye was synthesized according to the following scheme.

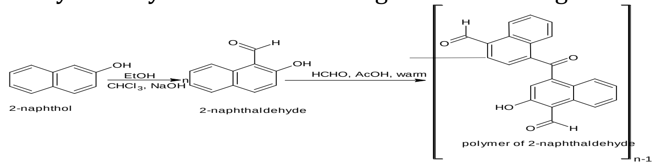

Fig. 1 Scheme for synthesizing dye

2-hydroxy-1-naphthaldehyde was prepared from 2-naphthol by Reimer-Teiman reaction. To a solution of 2-naphthol (1.7 g, 0.01mol) in ethanol (25 ml), aqueous sodium hydroxide (1 g, 0.02mol) was added. To the reaction mixture, chloroform (1 mL, 0.001mol) was added dropwise with continuous stirring. After complete addition, the reaction mixture was strongly refluxed, poured into ice cold water and neutralized using HCl. The residue was filtered the obtained product was further purified to obtain shining ash colored 2-hydroxy-1-naphthaldehyde. Obtained yield was 96 % with m.p. of 76^o C. It was recrystallized from ethanol. 2-hydroxy-1-naphthaldehyde was warmed with formaldehyde and acetic acid. The solution was checked for completion of reaction over TLC. The reaction mixture was then washed with water followed by ethanol, filtered and dried. Obtained yield was 86 % with m.p of 180^o C. It was recrystallized from ethanol. Solution of the polymer was prepared by dissolving 10 mg of the compound in 1mL of ethanol. The solution was properly stored, protected from direct sunlight and refrigerated until use.

2.2 Preparation of electrodes and assembling

The conductive glass plates (FTO glass, fluorine-doped SnO_2, sheet resistance 8-12 Ω/cm^2) and the Zinc oxide (ZnO) were purchased respectively from Aldrich and sd fine chemicals respectively. Solvents and chemicals were of reagent or spectrophotometric grade and were used as received. Photo anodes were prepared by depositing ZnO film on the FTO conducting glass: two edges of the FTO glass plate were covered with a layer of adhesive tape (3M Magic) to control the thickness of the film and to mask electric contact strips; successively the ZnO paste was spread uniformly on the substrate by sliding a glass rod along the tape spacer. FTO substrates were cleaned in an ethanol-water mixture for 30 min and then heated at 450 °C during 30 min prior to film deposition. The ZnO photo-anodes were then soaked in synthetic solution for ten minutes. Later, the photo-anodes were rinsed with distilled water and ethanol and dried. Carbon coated counter electrodes were prepared.

An electrolyte solution was prepared by mixing 0.1 M of I_2 with 0.05 M of KI and 0.05 M of 3-methoxypropionitrile in 50 mL of acetonitrile (C_2H_3N) and stirring for 60 min. This electrolyte solution was poured in the mesoporous ZnO film which was previously prepared using paraffin-film as framework to seal the cells to prevent evaporation of the liquids. The counter electrode was pressed against the impregnated anode and clamped firmly in a sandwich configuration. No leaks (solvent evaporation) were detected. The synthesized compounds were characterized using FTIR (Perkin Elmer), TGA (Perkin Elmer, Diamond TG/DTA), DSC (Mettler Toledo DSC 822e) and XRD (Powder X-Ray Diffractometer - Bruker D8-Advance).

3. 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 plot 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).

4. RESULTS AND DISCUSSION

4.1 Characterization of the synthesized compounds

The XRD of 2-naphthaldehyde showed clear crystalline pattern (Fig-2), whereas the polymer showed amorphous pattern (Fig-3). FTIR of 2-naphthaldehyde showed peaks at 1578 -1621 (-CHO) and 3200-3600 (-OH), the –OH peak was reduced in the polymer indicating that the polymerization has occurred via –OH functional groups. The TGA (Fig-4) of polymer shows two plateaus hence the polymer decomposes in two phases. In DSC (Fig-5) two endothermic dips (80°C and 180°C) are observed. The higher dip corresponds to the melting point of the compound.

4.2 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-7). The XRD (Fig-6) shows reduction in the 100, 002 and 101 planes. The ZnO nanoparticles have hexagonal Wurtzite structure and are effectively coated with the polymer (Fig-8).

4.3 P-V studies

2-Naphthol showed a cell efficiency of 0.244 %, this indicates that the –OH group in the compound has helped in anchoring it to the semiconductor ZnO nano particle layer effectively and acted as a good dye. Polymer of 2-hydroxy naphthaldehyde showed cell efficiency of 0.266%. The improved efficiency is seen over the starting material. The current output was steady and the cell was fairly stable. 2-hydroxy-naphthaldehyde showed high current output, due to non-linearity in results maximum power could not be determined. However the current output was constant during the week study. The results are shown in Table 1 and (Fig 9-11).

TABLE- 1: Dye sensitized solar cell efficiency

Compound	P_{max}	% Cell efficiency η
2-Naphthol (BN)	0.134	0.224
2-Hydroxy naphthaldehyde (BNA)	NO P_{max} observed	
Polymer of 2-Hydroxy naphthaldehyde (PBNA)	0.160	0.266

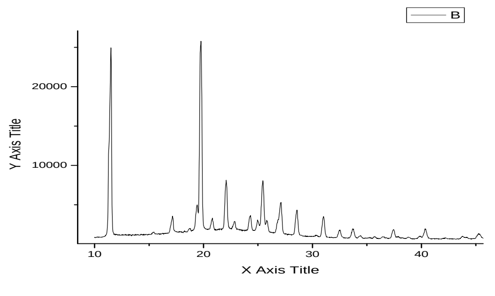

Fig. 2 XRD of 2-hydroxy- naphthaldehyde

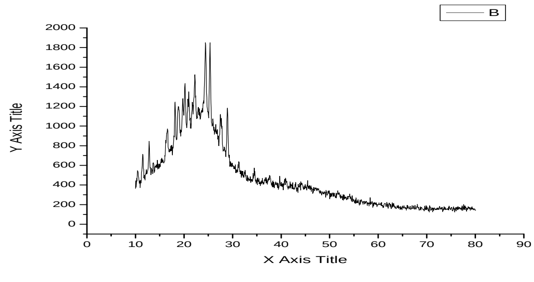

Fig. 3 XRD of polymer

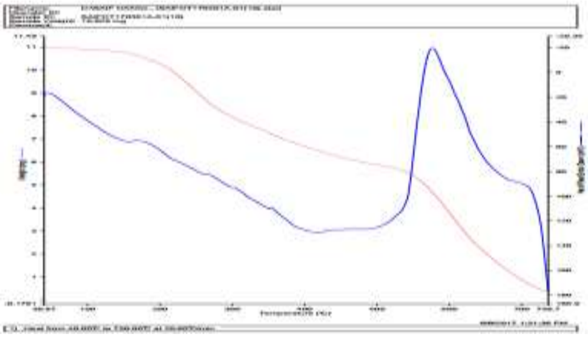

Fig. 4 TGA of polymer

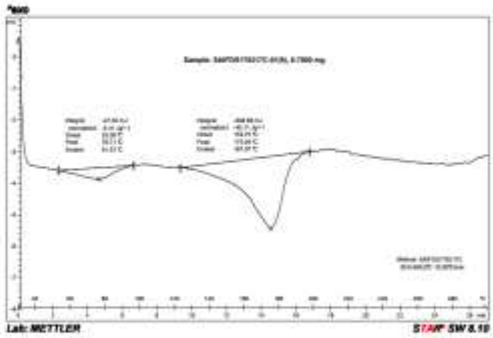

Fig. 5 DSC of polymer

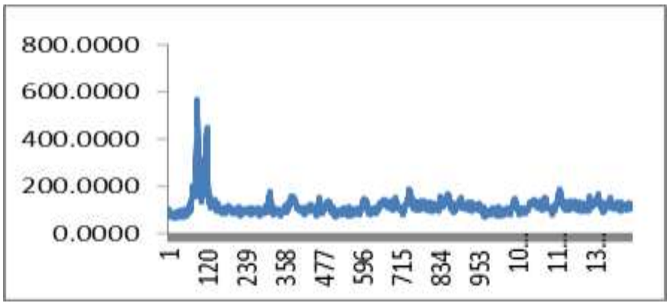

Fig. 6 XRD of ZnO nanoparticle

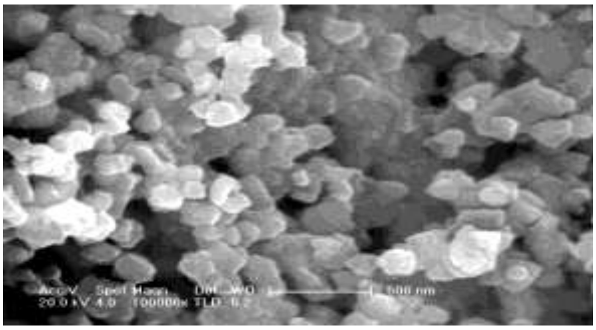

Fig. 7 SEM images of FTO coated plain ZnO nanoparticle

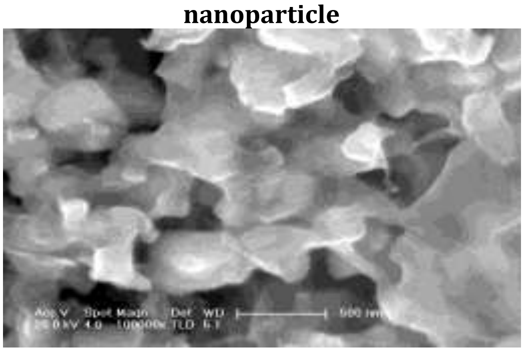

Fig. 8 SEM of FTO coated ZnO with dye

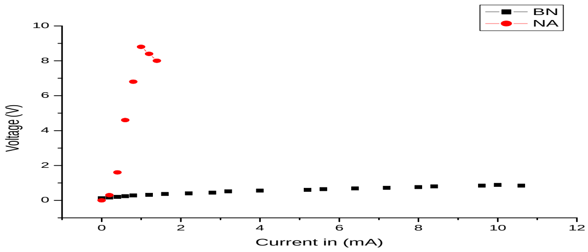

Fig. 9 a PV plots of DSSC for Beta naphthol (BN), Naphthaldehyde(NA)

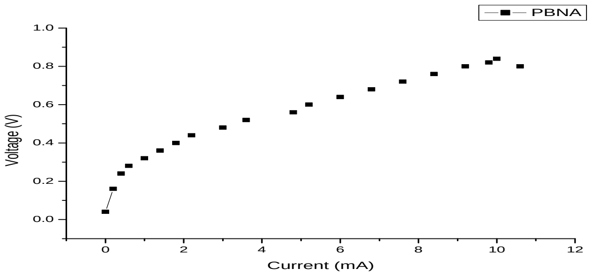

Fig. 9 b PV plot of DSSC for Polymer (PBNA)

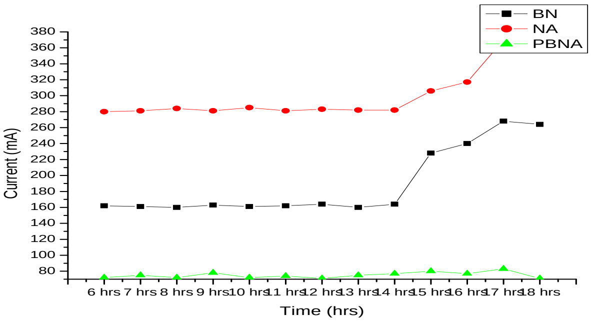

Fig. 10 Time dependent efficiency for synthetic compounds DSSC under sun illumination (100mW &air mass 1.5)

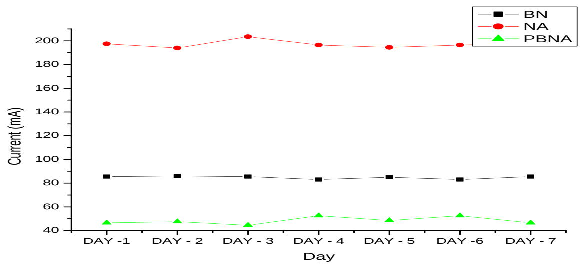

Fig. 11 Time dependent efficiency of DSSC under sun illumination (100mW &air mass 1.5) for a week

5. CONCLUSION

The synthesized polymer of 2-hydroxynaphthaldehyde is an efficient and stable DSSC. The variations in parameters like counter electrode and electrolyte solutions can add the voluminous work being carried out on such solar cells.

6. ACKNOWLEDGEMENT

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7. REFERENCES

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