**Fabrication of dye sensitized solar cell using produced platinum doped multiwall carbon nanotube as counter electrode**.

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Carbon nanotubes (CNTs) were synthesised by catalytic chemical vapour deposition (CCVD) method. The synthesised CNTs was purified with acid to remove the catalyst impurities and to enhanced deposition platinum (Pt) onto the CNTs surface. Platinum multiwall (Pt-MWCNTs) nanocomposites were produced by a wet impregnation technique and a known amount (0.5 g) nanocomposites was dispersed in Texanol and Acrylic resins to form a paste. The paste was screen printed on an FTO glass substrate. Surface morphology, chemical composition, crystallographic structure electrical performance of the obtained Pt-MWCNTs nanocomposites were confirmed by HRSEM, HRTEM, EDS, XRD. The produced MWCNTs and Pt-MWCNTs were used as counter electrode to fabricate the dye sensitized solar cell. The efficiency of MWCNTs, Pt-MWCNTs solar cell were found to be 0.28 and 1.71 respectively and the cell with Ecolcarb was found to: $η=0.16\%.$

**INTRODUCTION**

Dye sensitized solar cells (DSSCs) have attracted much attention recently and becomes potential alternatives to conventional silicon solar cells. This is due to their ease fabrication process, environment friendly materials, relatively low cost and moderately power efficiency values (O’Regan and Gratzel, 1991; Nakade, *et al,* 2002*;* Siwach *et al*., 2017; Siwach *et al*., 2019). A typical DSSC device is made up of four main components: a photoanode (TiO2 or ZnO), a sensitizer which is the dye, a redox coupled electrolyte, and a counter electrode (CE). The photoanode is usually fabricated from titanium oxide (TiO2) or zinc oxide (ZnO) nanoparticles and the surface is covered with the sensitizer dye molecules. A redox couple made up of iodide/triiodide ions dissolved in acetonitrile serves as a liquid electrolyte in DSSCs. As a result of high catalytic activity towards reduction of electrolyte, platinum (Pt) is the most common material been employed as a CE in this device (Sedghi and Miankushki, 2014; Siwach, 2019). Pt based DSSCs have achieved high efficiency values of about 13.0 % (NREL 2024) but high cost and limited stores of this metal are the major factors that increase the overall cost of DSSCs and hence hinders the commercialization of this cell on large scale (Chiba *et al*., 2006). Recently, many carbonaceous materials such as carbon black, graphene, carbon nanotubes etc. are being studied and introduced into DSSCs system as a low-cost replacement of Pt CEs owing to their special properties such as high surface area, good corrosion resistance towards iodine, high catalysis for triiodide reduction and low cost when compare with the cost of platinum metal (Siriroj, *et al*., 2012; Siwach *et al*., 2019). Among them carbon nanotubes (CNTs) have attracted huge attention due to their outstanding properties like excellent electronic properties, high mechanical strength, and good thermal stability (Zheng, *et al*., 2015). Lee and his groupemployed single wall carbon nanotubes (SWCNTs) and multi wall carbon nanotubes (MWCNTs) as CEs in DSSCs and obtained efficiency of 4.03 % and 4.36 % for SWCNTs and MWCNTs CE respectively (Lee *et al*., 2010; Siwach *et al*., 2019). This value which is higher than the DSSC based on Pt based counter electrode. Hence there is a crucial need for a low-cost CE which possess high catalytic activity that can significantly increases the practical applications as well as commercialization of DSSCs.

In this paper, CE based on Pt, MWCNTs, and Pt/MWCNTs were Synthesized and their effect on photoconversion efficiency of DSSCs were investigated.

**MATERIALS AND METHODS**

**Materials for Dye sensitized Solar Cells (DSSCs).**

All chemicals that were employed for this study were analytical grade, ranging from 98.0 to 99.9 % purity.

Synthesis and characterization of MWCNTs and Pt/MWCNTs counter electrodes for dye sensitized solar cells was previously done in our earlier study (Ibrahim *et al*., 2017; Aliyu *et al*., 2017; Afolabi, 2009). N749 dye (Black dye), FTO (15 Ω sq-1) were purchase from Solaronix in Switzerland, and MWCNTs which was previously synthesized was used to produced Pt-MWCNTs and finaly the prepared Pt-MWCNTs was used as counter electrode (CE) material. The

 Polyethylene glycol (PEG20000) was purchased from Himedia (India). De-ionized water was used throughout the experimental procedure to avoid contamination. The DSSC photoanodes were fabricated by doctor blading the TiO2 nano powder on pre-cleaned FTO substrate as it was discussed by (Siwach, *et al.,* 2017).

The MWCNTs was treated with acid before their use as CE of DSSCs. The procedure for acid treatment of MWCNTs was described in our previous studies (Ibrahim, *et al*., 2017; Afolabi *et al*., 2011) The Pt CE film was prepared by dropping H2PtCl6 solution on the FTO glass and then annealed at 400 °C for 30 min. The MWCNTs CE and Pt/MWCNTs CE films were prepared by coating their pastes on the conducting side of the FTO glass with doctor blade method and annealed at 400 °C for 30 min.

The paste of MWCNTs was prepared by grinding the acid treated MWCNTs powder and the binder carboxymethyl cellulose (CMC) with de-ionized water in a mortar & pestle for about 1 h. Similarly, Pt/MWCNTs paste was also prepared by treating MWCNTs (0.2 wt%), CMC and H2PtCl6 (0.2 wt%) with acid using pestle and mortar for about an hour. (Ibrahim *et* al., 2020: Abdulkareem *et al*.,2016)

The DSSCs having different CEs were assembled by using a sandwich-type configuration. Now, the DSSCs with different CEs such as Pt CE, MWCNTs CE, and Pt/MWCNTs CE were assembled in a sandwiched configuration i.e. by putting dye loaded TiO2 photoanodes on the top of each CE, respectively and finally filled with an iodide/triiodide based liquid electrolyte to complete the cell structure. Solar simulator was used to to determine the current-voltage(I-V) characteristics of the cell.

For UV- Spectroscopy measurement, UV-VIS Spectrometer, 1800 series was used to measure the absorbance of the particular layer:

**RESULTS AND DISCUSSION**

Figure 1: The peak absorbance of MWCNTs and Pt-MWCNTs.

The optical band gap of CNTs and Pt-MWCNT were evaluated from the absorption spectra using Tauc plot and using the equation (1) below.

$$αhv=A\left(hv-E\_{g}\right)^{n} \left(1\right)$$

Where:

A is a constant, Eg is band gap, n is different allowed transition



Figure 2: Optical band gap of MWCNTs was found to be 1.62 eV

 

Figure 3: Optical band gap of Pt-MWCNTs was found to be 2.52 eV

**Current-voltage analysis**

The efficiency of the cells was calculated by the product of Voc, Jsc and *FF* divided by a Voc of 100mW/cm2. It was under an illumination of AM 1.5 (Pin).

The formula that was used for the fill factor (FF) and efficiency are:

FF (fill factor) = $\frac{P\_{max}}{\left(V\_{oc} ×I\_{sc}\right)}$

 $η$ = $\left(\frac{P\_{max}}{P\_{in}}\right)$ x 100

**ECOLCARB:** - Current voltage analysis



Figure 4: Current-voltage Curve for Ecolcarb

**DSSC Efficiency FOR ECOLCARB WAS CALCULATED AS:**

 Jmax = 0.39 mAcm-2

 Vmax = 0.41V

 Jsc = 0.62 mAcm-2

 Voc = 0.46V

 $ Fill factor (FF)= \frac{P\_{max}}{V\_{OC}J\_{SC}}= \frac{V\_{max}J\_{max}}{V\_{OC}J\_{SC}}$

 $FF= \frac{0.41×0.39}{0.46×0.62} =\frac{0.16}{0.35}=0. 56$

$η= \frac{FF.V\_{oc}.J\_{sc}}{P\_{in}}$ =$ \frac{0.56×0.46×0.62}{100}×100 =0.$16 %

**MWCNTs:** Current voltage analysis of MWCNTs

Figure 5: Current-voltage Curve for MWCNT

**DSSC Efficiency FOR MWCNTS WAS CALCULATED AS:**

 Jmax = 0.61 mAcm-2

 Vmax = 0.38V

 Jsc = 0.75 mAcm-2

 Voc = 0.46V

 $ Fill factor (FF)= \frac{P\_{max}}{V\_{OC}J\_{SC}}= \frac{V\_{max}J\_{max}}{V\_{OC}J\_{SC}}$

 $FF= \frac{0.38×0.61}{0.46×0.75} =\frac{0.23}{0.35}=0. 66 $

$η= \frac{FF.V\_{oc}.J\_{sc}}{P\_{in}}$ =$ \frac{0.66×0.46×0.75}{100}×100 =0.28\%$

Current voltage analysis of Pt-MWCNT



Figure 6: Current-voltage Curve for Pt-MWCNT

**DSSC Efficiency FOR Pt-MWCNTS WAS CALCULATED AS:**

 Jmax = 0.40 mAcm-2

 Vmax = 0.41V

 Jsc = 0.72 mAcm-2

 Voc = 0.46V

 $ Fill factor (FF)= \frac{P\_{max}}{V\_{OC}J\_{SC}}= \frac{V\_{max}J\_{max}}{V\_{OC}J\_{SC}}$

 $FF= \frac{0.42×0.40}{0.46×0.72} =\frac{1.7}{0.33}.=5.15$

$η= \frac{FF.V\_{oc}.J\_{sc}}{P\_{in}}$ =$ \frac{5.15×0.46×0.72}{100}×100 =1.71 \%$

**Table :** I-V Characterisation Parameters of DSSC with MWCNTs, Pt- MWCNT and Ecocarb

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Counter Electrode | V0C | JSC | FF | $η$ % |
| ECOCALB | 0.46 | 0.62 | 0.16 | 0.16 |
| MWCNTs | 0.46 | 0.62 | 0.66 | 0.28 |
| Pt-MWCNTs | 0.46 | 0.72 | 5.15 | 1-71 |

**SUMMARY: Current-Voltage Analysis**

**Table :** I-V Characterisation Parameters of DSSC with ECOLCARB; MWCNTs, Pt- MWCNT

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