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LOW COST CARBON CATHODE FOR NATURAL DYE SENSITIZED SOLAR CELL

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ABSTRACT

Objective: Platinum film on fluorine doped tin oxide (FTO) glass surface has been used commonly in the research of dye sensitized solar cells (DSSCs). However, cost of platinum is too high to fabricate a cost effective ecofriendly DSSC. The current study has been done to replace the high cost platinum counter electrode by low cost carbon electrode.

Material and Method: TiO2 nanoparticles has been synthesized and used to synthesize Photo anode of DSSC on fluorine doped tin oxide (FTO) glass surface. Platinum and Carbon cathodes has been synthesized on fluorine doped tin oxide (FTO) glass surface fabricated and their photovoltaic properties have been compared. Area of the cathode and anode has been maintained 1square centimeter.

Results: Study of DSSCs reveals, carbon cathode can successfully replace the platinum cathode as efficiencies of DSSCs have been found to be more using carbon cathode as compare to the platinum cathode. Ecofriendly Eosin Y dye sensitized TiO_2 nanoparticles photo anode has been used for the fabrication of DSSC.

Conclusions: Investigation leads to the conclusion that carbon cathode can replace the platinum cathode in dye sensitized solar cell.

Keywords: Dye sensitized solar cell, TiO_2 nanoparticles photo anode, carbon cathode, eosin Y dye

INTRODUCTION

Dye sensitized solar cells (DSSC), are the third generation hybrid solar cells offer a particular promise as an efficient, low cost alternative to the silicon semiconductor solar cells. Since the working principle of DSSC is the mimicry of natural photosynthesis process, DSSC is the most promisingly environmental benign solar cells [1]. Unlike the silicon solar cells, DSSC uses sensing dye for light harvesting and electron transport, which allows researchers to fine tune each component separately and to optimize the device performance. Along with environmental friendliness, DSSCs poses the attractive properties like, flexibility, multicolored and hence aesthetics [2].

In a typical DSSC, light photons are absorbed by a sensitizer, which is adsorbed to the surface of wide band gap semiconductor oxide. The sensitized nano particles of semiconductor in combination with the electrolyte and counter electrode produce the regenerative cycle of photo electrochemical cell [3]. Literature study reveals, most often Titanium oxide (TiO_2) photo anode sensitized by ruthenium complex dye and the platinum counter electrode is the typical components of Dye Sensitized Solar Cells (DSSCs) [3]. In our previous studies, Al doped TiO_2 photo anode proved to be fruitful to increment the photovoltaic parameters i.e., photo current and efficiency of the DSSC along with organic Eosin Y dye [4-6]. Eosin Y dye is one of the xanthene dye exhibiting the properties like large absorption and luminescence; low toxicity in-vivo and relatively high solubility in water [7-10].

Counter electrodes (Cathodes) have usually been prepared by depositing a thin layer of platinum (Pt) onto the FTO substrates. The FTO substrate without platinum coating can also work as the counter electrode, however, its charge transfer resistance is very high on the order of mega ohm per square centimeter in iodine-triiodide electrolyte and hence, the platinum layer is deposited on the FTO to work as the catalyst. It reduces the oxidized form of the redox couple in the electrolyte so that the cathode material must be adapted to the redox system in the electrolyte. Although platinum is the most efficient catalyst for counter electrode to date, rarity and high cost of platinum makes it unsuitable for low cost DSSC. Hence, several other materials have also been adopted for the preparation of the counter electrode in DSSCs, such as conducting polymers such as poly (3,4-ethylenedioxythiophene) doped with toluene sulfonate anions, carbon materials and cobalt sulphide, carbon black [8]. Moreover, the platinum being heavy metal costs too high and elevates the overall cost of DSSC [11-12]. Whereas, DSSC comprised of carbon cathode has also found to be exhibiting comparable results to that of the platinum cathode [13-17].

Considering support of these studies, the current study of DSSC comprised of TiO_2 nanoparticles photo anode sensitized by eosin Y dye has been further explored towards the cost effective and environmentally benign DSSC by employing the carbon cathode.

MATERIALS AND METHODS

Materials

Titanium Tetra iso-propoxide (TTIP) (Otto Chemicals, Germany), Eosin Y dye and Chloroplatinic acid (H_2PtCl_6) (Ward Hill, U.S.A.), Aluminium Nitrate ($Al(NO_3)_3$ and Poly-ethylene Glycol (Otto Chemicals, India), Lithium iodide and iodine all reagents were used without further purification.

Synthesis and characterization of TiO_2 nanoparticles

TiO_2 nanoparticles have been synthesized as discribed in previous studies[6] and characterized using FTIR spectra.

DSSC Fabrication and Testing

The DSSCs were assembled as follows: cleaned fluorine-doped tin oxide (FTO, Sigma- Aldrich) conductive glasses of size 2*2 cm^2 have been used as the substrate. The TiO_2 nanoparticles anode has been prepared using doctor blade method and has been sintered at 450ºC for 1 h to enhance the bonding between the semiconductor and the FTO glass. After cooling to 80ºC, the prepared photo anodes have

been immersed into 0.3mM Eosin Y dye solution in ethanol for 24 hours at room temperature (30ºC). The Carbon counter electrode has been produced just by a spattering the HB pencil on 1cm area of FTO glass whereas, Platinum counter electrode was deposited on cleaned FTO glass by drop casting the Cloroplutanic solution. The dye adsorbed photo anodes and counter electrodes have been assembled using Surlyn polymer spacer, crocodile clips and alligator pins. Electrolyte prepared using 0.05mM Iodine and 0.5mM lithium tri-iodide in Acetonitril has been inserted in the space between two electrodes just before connecting for the photovoltaic characterization. The performance of DSSCs was determined by indigenous solar simulator under irradiation of 100mW/cm^2 (Iin). The current density-voltage (J-V) curves have been obtained on source measurement unit (Keithley 4200) to obtain Jsc, Voc, and FF of DSSCs.

RESULTS AND DISCUSSION

Figure 1 shows the FTIR study of TiO_2 nanoparticles which confirms the Ti-O bond formation.

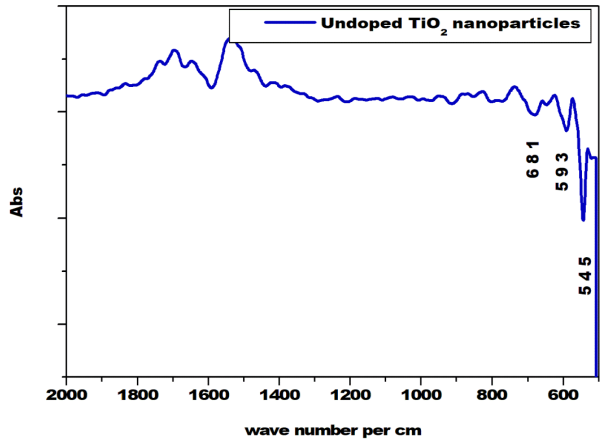

Fig. 1: FTIR spectra of undoped TiO_2 nano particles

Ti-O stretching vibrations are observed at 545 per cm for undoped TiO_2 nanoparticles whereas bending vibrations of Ti-O-Ti have been observed at 681 per cm. Fig. 2 exhibits the comparative study of photovoltaic characteristics of the DSSCs using TiO_2 nanoparticles photo anode and Platinum and Carbon cathode. In the device the photo anode has been sensitized by ecofriendly Eosin Y dye.

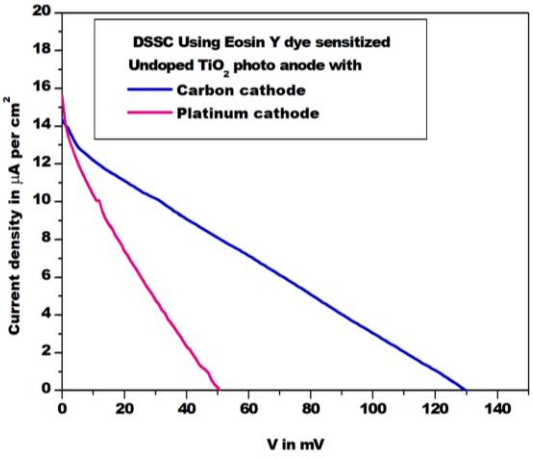

Fig. 2: Photovoltaic characteristics of DSSC- TiO_2 nps photo anode and Platinum and Carbon cathode

It has been observed that the DSSCs using carbon cathode exhibits the excellent result as compare to the Platinum cathode.

Table 1 shows the photovoltaic parameters of the DSSC comprised of TiO_2 nanoparticles photo anode sensitized by Eosin Y dye and Platinum and Carbon coated photo cathodes. In the DSSC, the short circuit current density is 15.8 µAcm^{-2} for DSSC using platinum cathode where as it is 14.2 µAcm^{-2} for the DSSC using Carbon cathode, it has been found to be decreased by 10% for the Carbon cathode DSSC as compare to platinum cathode DSSC. However, for DSSC using carbon cathode open circuit voltage (130 mV) has been found to be increased by 160 % as compared to DSSC using Platinum cathode. The efficiency for DSSC using Carbon cathode has been also increased by 181% as compared to DSSC using platinum cathode. Also, fill factor has been found to be increased comparatively when platinum cathode has been replaced by carbon cathode.

Table 1: Photovoltaic parameters - maximum current density (Im), maximum voltage (Vm), Short circuit current density (Jsc), open circuit voltage (Voc), fill factor (FF), efficiency (η) using Eosin Y and Hibiscus dye

DSSC Fabricated using	Jsc (µAcm^{-2})	Voc(mV)	Im (µAcm^{-2})	Vm(mV)	FF	(%) η
TiO_2 nps photo anodes & Pt cathode	15.8	50	6.38	24	0.19	0.00200
TiO_2 nps photo anode & C cathode	14.2	130	6.64	65	0.23	.00400

CONCLUSIONS

Investigation leads to the conclusions that carbon counter electrode could replace the platinum counter electrode to construct an ecofriendly DSSC using TiO_2 nanoparticles photo anode sensitized by Eosin Y dye which will be a step towards ecofriendly DSSC.

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