Optical Materials 79 (2018) 296–301

Contents lists available at ScienceDirect

Optical Materials

journal homepage: www.elsevier.com/locate/optmat

Fabrication and characterization of mixed dye: Natural and synthetic organic dye

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ARTICLE INFO

Keywords:
Dye sensitized solar cell
Natural dyes
Organic dyes
TiO_2 film

ABSTRACT

Mixed dye from hibiscus sabdariffa and eosin Y was employed in the fabrication of dye sensitized solar cell (DSSC). Nanostructured mesoporous film was prepared from the titanium dioxide (TiO_2). The energy conversion efficiency of hibiscus, eosin Y and mixed dye was obtained as 0.41%, 1.53% and 2.02% respectively. Mixed DSSC has shown improvement in the performance of the cell as compared to hibiscus and eosin Y dye due to addition of synthetic organic dye. This illustrates the effect of synthetic organic dyes in performance enhancement of natural dyes. It has been credited to the improved absorption of light mainly in higher energy state (λ = 440–560 nm) when two dyes were employed simultaneously as was obvious from the absorption spectra of dyes adsorbed onto TiO_2 electrode. The cell with TiO_2 electrode sensitized by mixed dye gives short circuit current density (Jsc) = 4.01 mA/cm^2, open circuit voltage (Voc) = 0.67 V, fill factor (FF) = 0.60 and energy conversion efficiency (η) of 2.02%.

1. Introduction

The importance of creature is reliant on energy sources that are susceptible unless clean and renewable sources of energy are produced in the future. Research is only aimed to obtain environmental friendly energy sources. Regan and Gratzel introduced first dye sensitized solar cell having attributes of less exorbitant, effective and environment friendly [1]. Basically, DSSC consists of a dye adsorbed photosensitive working electrode (semiconductor), a counter electrode and an electrolyte filled between two electrodes as shown in Fig. 1.

When the sunlight strikes on to the dye molecules that adsorbed on the surface of TiO_2 coated working substrates. The dye molecules accumulate photons and generate excited electrons into the TiO_2 conduction band. The electron goes through working substrate and reaches to the load thus delivers electrical energy as shown in Fig. 2. After work done electrons reach the carbon coated electrode and thus complete the function. Generally, the working electrode of dye solar cell is made up of transparent conductive oxide glass sheet. Indium doped tin oxide and fluorine doped tin oxide are used as transparent conductive oxide. FTO is more favorable choice due to stability and low sheet resistance. A semiconductor layer usually TiO_2 is sintered on the conductive side of FTO. A layer of dye molecules is deposited onto TiO_2 electrode. A counter electrode consists of a layer of catalytic material to inject electrons into electrolyte solution. The electrolyte transfer electrons between working electrode and counter electrode.

In these cells, dye is the main component that is responsible for finding the photovoltaic conversion efficiency of the DSSC and therefore a lot research has been carried out in exploring of efficient dyes. Fig. 3 Shows three varieties of dyes used in DSSCs, metal complex (synthetic), metal free complex (synthetic organic) and natural dyes [2].

A variety of metal complexes and organic sensitizers have been used for DSSCs. Ruthenium complexes achieved 11–12% efficiency of the cell [3]. However, less accessibility, uneconomical and toxicity are the demerits of such complexes. The metal free organic sensitizer plays an important role in the field of DSSC. Various metal free dyes, as an alternative, have been observed as dyes for DSSCs which includes eosin Y, aniline blue, bromophenol blue, carbol fuchsin [4]. Eosin Y organic dye is more common dye having high absorbance, economical and has shown an efficiency of 0.55% with different thickness of photo-anode [5]. A power conversion efficiency of 2.16% was reported using eosin Y dye adsorb on ZnO [6]. Also, conversion efficiency 2.4% was observed using eosin Y dye [7].

Natural dyes are extracted from natural resources (leaves, flowers, fruits, roots, barks) using simple extraction methodology. The non-poisonous and less expensive qualities are the fore most fundamental points of interest of natural dyes. Therefore, a lot of natural dyes have been extracted for DSSCs such as hibiscus sabdariffa, bixa, bougainvillea, begonia, petinua, rose etc [8]. Hibiscus is liable for red to pink colors range as a result of existence of anthocyanin. A conversion

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https://doi.org/10.1016/j.optmat.2018.03.056
Received 4 March 2018; Received in revised form 20 March 2018; Accepted 27 March 2018
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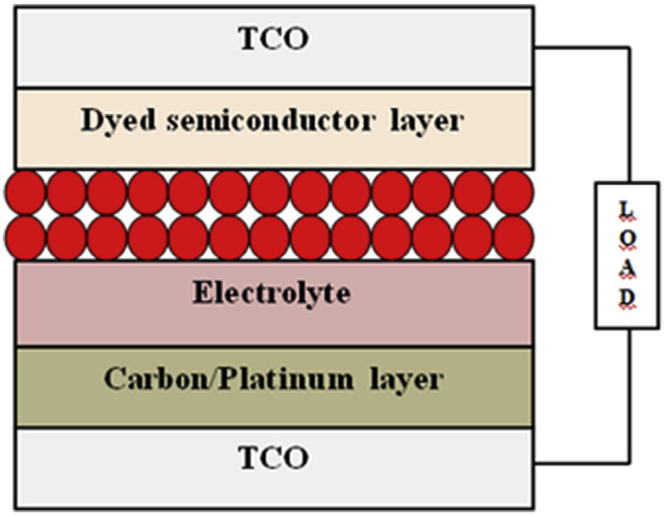

Fig. 1. Structure of DSSC.

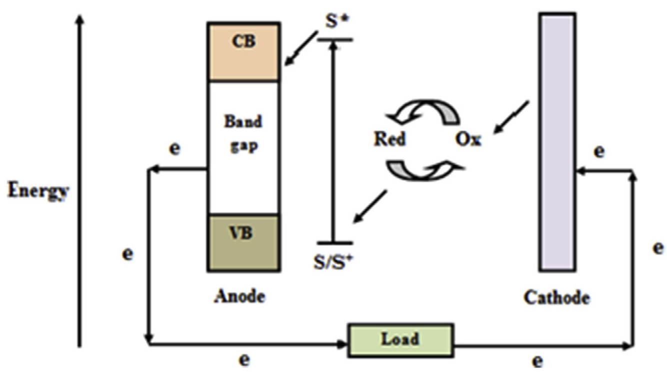

Fig. 2. Energy diagram of DSSC.

efficiency of 0.09% was reported using radish as natural dye [9]. The extracts of siahkooti showed an efficiency of 0.32% with fill factor of 0.73% [10]. Moreover, mixer of shisonin and chlorophyll pigments revealed increment in conversion efficiency of 1.31% [11]. Table 1 shows the performance parameters of different types of dyes.

Looking after all the above cited discussion it was decided for this work, first to select most suitable synthetic organic and natural dyes and observe their performance for TiO_2 semiconductor electrode. Secondly, to study mixed dye characteristics either it would be worthwhile for dyes application, taken to gether or using separately. The mixed dye has been indicated a wide absorbance in UV Visible region of the solar spectrum that shows transition of electron charges. Thus by analyzing all the factors, eosin Y (synthetic organic dye) and hibiscus (natural dye) were chosen and photovoltaic performance was observed by taking individual dyes and mixed dye.

Table 1
Performance parameters of different types of dyes.

Variety of Dyes	Names of dyes	V_{oc} (V)	J_{sc} (mA/cm^2)	FF	η (%)	Reference
Synthetic dyes	RuLo (ortho/Ru derivative)	0.534	0.76	0.55	0.22	[12]
	RuLm (meta/Ru derivative)	0.52	1.39	0.58	0.42	
	RuLp (para/Ru derivative)	0.56	2.28	0.63	0.80	
	Ru-9AA	0.58	3.54	0.46	0.95	[13]
	N3	0.71	12.59	0.64	5.65	
Synthetic organic	Eosin Y	0.35	1.55	0.46	0.28	[3]
	Eosin Y	0.54	4.329	0.39	0.93	[4]
	Phloxine Blue	0.52	4.64	0.46	0.81	[14]
	Bromophenol Blue	0.64	2.21	0.49	0.51	
	Eosin Y	0.58	1.57	0.50	1.518	[15]
	Bromophenol	17.3	0.650	0.4178	1.0	[16]
Natural dye	Turmeric (Curcuma longa L.)	0.57	0.65	0.44	0.16	[17]
	C. haematocephata	0.37	0.25	0.70	0.06	[18]
	Bougainvillea spectabilis	0.5	1.11	0.58	0.325	[19]
	Mangosteen	0.67	2.69	0.63	1.17	[20]
	Haematococcus pluvialis	0.313	0.499	0.72	0.10	[21]
	Maqui berry	0.37	0.43	0.49	0.14	[22]
	Amarnath leaves	1.31	0.582	0.69	0.53	[23]

2. Materials and methods

2.1. Materials and instruments

Ethanol was employed for the extraction of dyes. Polyethylene gycol 400 {HO (C_2H_4O)}, and titanium dioxide were purchased from Solaronix company (Switzerland). Eosin Y dye was bought by JwalaaTraders (India). All the chemicals employed in this study were analytic grade and used without further purification. Fluorine doped tin oxide (FTO) conductive glass slides bought from Solaronix Switzerland, were employed as TiO_2 working electrode and carbon counter electrode as substrates. Electrolyte (Idoloyte) used to provide conductivity between the substrates was purchased from Solaronix Switzerland. X-Ray diffractometer (Co.Bruker) is used to study structural properties of TiO_2 by obtaining X Ray diffraction (XRD) patterns. The surface morphological structure of TiO_2 information was obtained using scanning electron microscope (JEOL/JSM-6390 A). Energy dispersive spectroscopy (EDS) of TiO_2 was done (JEOL/JSM-6390 A). Absorption spectra of dyes were examined using UV Vis spectrometer. The electrochemical impedance analysis was determined using impedance analyzer.

2.2. Fabrication of DSSC

The fluorine doped tin oxide conducting transparent glass used to prepare the working electrode. The FTO was cleaned using ultrasonic bath and then rinsed with distilled water and then left to dry. The titanium dioxide paste was prepared by adding titanium dioxide in

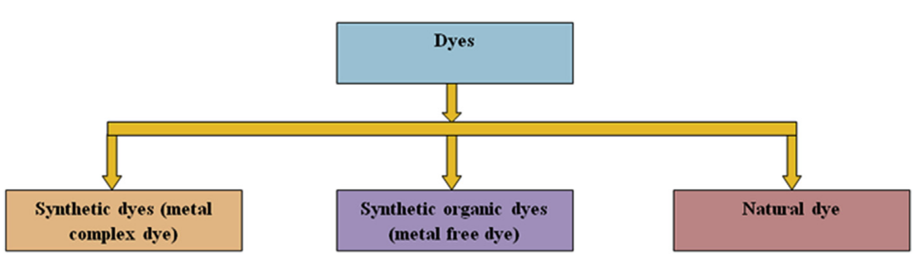

Fig. 3. Varieties of DSSCs.