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Comparative study of the photovoltaic behavior of ruthenium and the other organic and inorganic Dye-Sensitized Solar Cells (DSSC)

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ABSTRACT

This paper gives a detailed description of the design and synthesis of some organic and inorganic sensitizers for DSSC's. Five organic and inorganic dyes were used as sensitizers to fabricate DSSC's. Fresh extracts of different organic and inorganic materials were used as sensitizers in the DSSC's. The organic and inorganic dyes which are used are Beet Root, Fig, Ruthenium, Ruthenium Chloride and Blue Dye. The photo-electrochemical measurements for these DSSC's indicate the variation in open circuit voltage (V_{OC}) from 400 mV to 621 mV, and that in short circuit current density (J_{SC}) ranges from 1.312 mA/cm^2 to 12 mA/cm^2. Ruthenium sensitizer shows maximum value of V_{OC} (621 mV). The photo-to-electric conversion efficiency of Ruthenium based DSSC is found to be 3.86%.

1. Introduction

The global energy consumption is increasing year by year. It was 12.7TW in 1998, but it is predicted to be approximately 26.4–32.9 in 2050 and in 2100 it will boost to 46.3–58.7 TW [1]. There is a continuous consumption of energy which is even increasing exponentially with successive year. However, the rate of reinstating the resources like coal, oil and natural gas is very slow as compared with intake rate. Therefore, it is obvious that the mankind will suffer from the lake of energy resources. In this scenario, the search of such technology which employs the sustainable energy resources like water and sun is very important. The solar energy is the most suitable option to reach the exploding requirement of energy [1]. The first achievement in harvesting the sunlight for electrical energy was made in 1941 by Russell Ohl by invention of semiconductor based solar cells which incorporate the bandgap engineering of silicon PN junction [3]. The second major goal was achieved in 1991 by B. O'Regan and M. Grätzel [4] by fabricating a cheap high-efficiency solar cell based on dye sensitized colloidal TiO_2 film in a simple process.

Recently, due to the emergent pertinence in environmental safety and energy origination, the titanium dioxide (TiO_2) has captivated consideration from researcher throughout the world [5]. The nano crystalline *meso*-porous structure of TiO_2 has a large surface area for dye adsorption which eventually enhances the exposure of sensitizer to the light. After the absorption of sun light the dye molecules become excited and eject the electrons in the electrolyte that are correspondingly scattered

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and transport inside the structure of TiO_2 [2]. The efficiency of the DSSC is significantly dependent on the deposition of the dye molecules on TiO_2 [6]. Many researchers have been working on the search of suitable dye with enhanced light harvesting capability which eventually improves the efficiency of a DSSC [7].

The main feature of the DSSC is its low cost manufacturing which include the use of naturally occurring dyes for harvesting of sun light [8,9]. However, the power conversion efficiency of the of such DSSC's is very low as compare to polycrystalline silicon solar cells ($\eta \sim 20\%$) [9] and even Ruthenium Complexes dyes ($\eta \sim 11\%$) [10]. In search of suitable organic dyes with reasonable power conversion efficiency, many researchers worked in the past few years. Hamadanian et al. [11] showed that among the *Reseda luteola, Berberis integerrima, Panica granatum Pleniflora, Consolida orientalis, Reseda gredensis, Clemetis orientalis, Adonis flammea, Salvia sclarea, and Consolida ajacis* dyes, the last one showed the enhanced photovoltaic properties. Desalegn *etal* [12]. manufactured the DSSC by using the dyes extracted from the flowers of natural dyes extracted from flowers of *Amaranthus caudatus, Bougainvillea spectabilis, Delonix regia, Nerium oleander and Spathodea companulata*. They found that the *Amaranthus caudatus* flower exhibit an enhanced power conversion efficiency of 0.61%. Cerda et al. [13] used *maqui, black myrtle, spinach* and found that myrtle showed better performance. Ruthenium based sensitizers are extensively practiced because of their good adaptability and high constancy. However, these are costly and not environment friendly [10]. Therefore, we choose to use natural colorants as sensitizers. In contrary to artificial dyes, natural dyes are easily achievable, easy to formulate, non-toxic, biodegradable and low cost [14]. These strongly colored fruits, flowers and leaves are accomplished of adhere to TiO_2 surface and inject an electron into the conduction band of TiO_2. In this paper, three inorganic *(Ruthenium, Ruthenium Chloride and Blue Dye)* and two organic dyes *(Fig and Beet Root)* which are belongs to anthocyanin family are used as a sensitizer. The DSSC's employing these dyes are investigated by UV–vis absorption spectra. The open circuit voltage and the short circuit current are also measured to examine the power conversion efficiency of these DSSC's.

2. Experimental procedure

2.1. Experimental setup

The chemicals used in this work include Iodine solution, Platinum, Titanium dioxide (TiO_2) anatase phase, Superglue, Ethanol and the sensitizing dyes which includes ruthenium, ruthenium chloride, blue dye, fig and beet root were used. Manufacturing of DSSC includes the preparation of TCO glass, preparation of the cathode electrode (TiO_2 photo electrode), preparation of the anode electrode (platinum counter electrode), preparation of the dye-sensitized solution and staining the titanium dioxide.

2.2. Preparation method

Squares of TCO glass were prepared with dimensions of 5×5 mm. The glass plates were cleaned before deposition with acetone and methanol using ultrasonic bath which dissolved the undesired substances. The cleaned substrates were than heated for 15 min at 90 °C so that the solvents are vaporized. After the identification of TCO layer the glass substrates were put on a cleaned hot plate by keeping TCO side up. After heating for 10 min Titanium dioxide (TiO_2) was deposited on the TCO by RF Magnetron Sputtering. When the deposition process was completed the samples of Titania (TiO_2) were anneal in a furnace at 450 °C for 30 min under vacuum toimprove the electrical conductivity of films. Platinum counter electrode was used due to its better reflectivity and conductivity.

For preparation of inorganic dyes (Ruthenium, Ruthenium Chloride and Blue dye) we took 25 ml of ethanol in a 100 ml beaker and putted 10 mg of inorganic in a beaker and stirred for 5 min to ensure complete dissolution. The beaker were sealed and placed in a dark room for 6 h. Organic dye, frozen figs and beet root are crushed in a container to get a juice and this juice were used as organic dye material. For staining, the Titania (TiO_2) coated glass is slowly immersed into the staining bath so as to avoid damage to the glass plate; the Titania coated side of the glass is facing upwards. Beaker was sealed and placed into the dye solution for 6 h at room temperature in a dark room. After the allotted time, the glass plates were taken out ofthe staining solution andplaced on a piece oftissue to dry.

2.3. Measurements

The UV–vis spectra from DSSC's having different dyes as sensitizer were collected by UV–vis spectrometer in the wavelength ranging from 200 nm to 800 nm. The measuring wave length was set from 200 nm to 800 nm [15]. The light source for this experiment has an intensity of 1 SUN (100 mW/cm^2) having a target size of 0.25 cm^2 and an Air mass 1.5G (AM 1.5G) filter for simulation. The temperature was set at 25 °C. The voltage range for IV measurements was from −1 V to 1 V with a step size of 0.1 V.