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EFFICIENCY ENHANCEMENT OF DYE SENSITIZED SOLAR CELLS WITH A LOW C CO-ADSORBANT IN N719 DYE

Ramshah Ahmad Toor[1]† **--- Muhammad Hassan Sayyad**[2] **--- Nazia Nasr**[3] **--- Sarah Sajjad**[4] **--- Syed Afaq Ali Shah**[5] **--- Tehreem Manzoor**[6]
[1,2,3,4,5,6]*Faculty of Engineering Sciences, GIK Institute, Pakistan*

ABSTRACT

Sunlight is a limitless form of renewable and clean energy which is amply accessible. Economic consumption of solar energy can boundlessly fulfil the energy demand. Dye-sensitized solar cells (DSSCs) are acknowledged as third generation solar cell technology because of their environmental friendliness, cost effectiveness, simple fabrication and capability to be manufactured on huge substrates. The prospective for development of various Dye sensitized solar cell components is massive. We have under taken a series of investigations on the photovoltaic performance enhancement of DSSCs. In this work, effect of chenodeoxycholic acid (CDCA) in N719 dye solution as a co-adsorbent and low cost additive was investigated. The cells were fabricated with and without the addition of CDCA. The co-adsorbent significantly improved the photovoltage open circuit (V_{oc}), photocurrent density (J_{sc}) and the solar energy power conversion efficiency (η). The impedance spectroscopy is also discussed in the paper.

Keywords: Chenodeoxycholic acid, N719, Low cost performance efficiency of DSSC, DSSCs, CV measurement of DSSC, Addive in N719 dye.

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Contribution/ Originality

This study is one of very few studies which have investigated the effect of CDCA additive on ruthenium dye. The paper compares the results from existing data and shows an enhancement in the photovoltaic properties in the results section. The impedance spectroscopy included is studied for the first time for the dye with chenodeoxycholic acid.

1. INTRODUCTION

Dye sensitized photovoltaic technology substitute to thin-film and silicon-based solar cells, are important for the large scale fabrication of low-cost photovoltaic cells that can be developed commercially sustainable. DSSCs was first introduced by O'Regan and Gratzel in 1991, gained significant interest of researchers and acknowledged as third generation cells subjected to their low cost manufacturing process, simple and easy fabrication process, abundant options of efficiency enhancement and capability to be fabricated on large-area flexible substrates (O'Regan and Grätzel, 1991; Kay and Gräetzel, 1993; Grätzel, 2005; Ardo and Meyer, 2009; Sudhan *et al.*, 2015). Its structural configuration is comprised of a photoanode-dye attached , redox electrolyte (I^-/I_3^-) along with a cathode as shown in figure 1. The photoanode is a dye sensitized mesoporous film of semiconductor oxide mostly titanium dioxide, which is sputtered on fluorine-doped tin dioxide (FTO) glass. The summary of chemical reactions taking place in a DSSC is shown in table 1.

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† *Corresponding author*

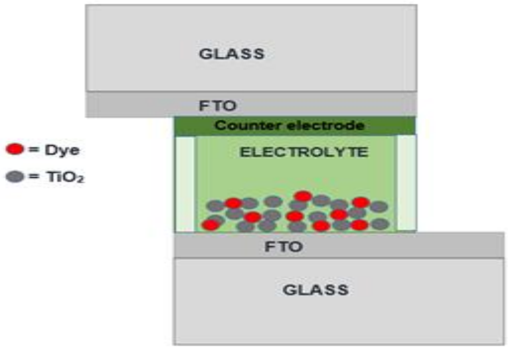


Figure-1. Structure of DSSC

The cathode is platinum or other metals which are also coated on FTO glass, the purpose is to congregate electrons through outer circuit and catalyze the iodide oxidation/reduction process in electrolyte. As soon as DSSC is exposed to sunlight, dye molecules absorbs this light and their electrons gets excited. These excited electrons are drifted to the conduction band (ECB) of Titania, from where they are transferred to FTO by the diffusion process, after that it streams through external circuit to counter electrode. The dye becomes positively charged after giving an electron to the TiO2. Positive charge dye becomes neutral as soon as it accepts an electron from iodide ion in electrolyte. The oxidized triiodide spreads over the counter electrode and convert back into the iodide as a result of gaining an electron. Hence, completing the current loop. The different stages of charge excitation, charge injections,

charge separation and oxidation/reduction steps taking place in the operation of DSSC as shown in figure 2 are:

Table-1. Summary of chemical reactions taking place in a DSSC

Reactants	Product
Photons + Dye	Dye*
Dye*	Dye + e^-
3I^-	I_3^- + 2e^-
Dye^+ + e^-	Dye
I_3^- + 2e^-	3I^-

The photosensitizer has a significant role in evaluating the stability, light absorption and also the price of DSSCs. Improvement in solar energy absorption can be achieved, developing broad absorbing dyes, enhancing the attachment of dyes to the semiconductor nanoparticles or reducing dye aggregation. Currently, photosensitizers employed for the fabrication of higher efficiency of DSSCs are Ruthenium Dyes, which includes mostly N719, Black Dye, N3 (Nazeeruddin *et al.*, 1993; Sudhan *et al.*, 2015) etc.

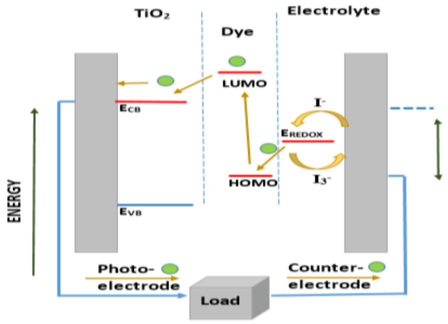
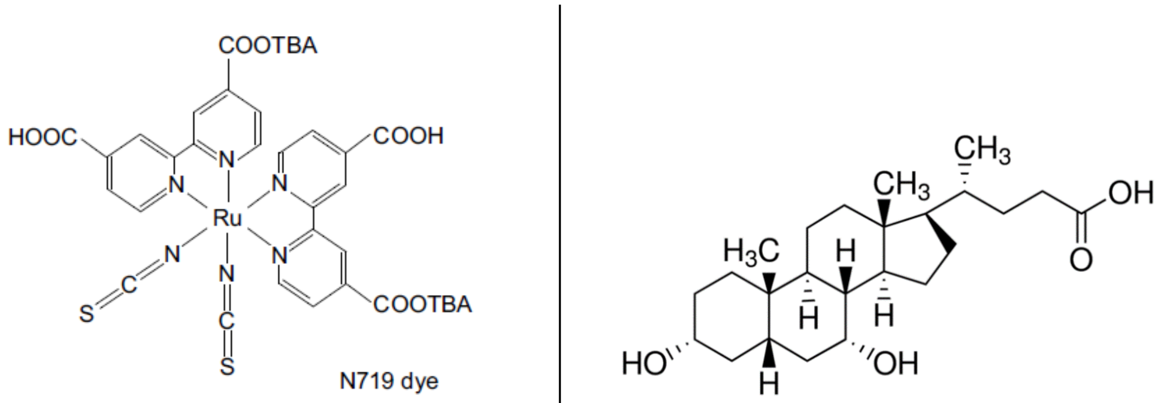


Figure-2. Different stages of charge excitation, charge injections,charge separtions and oxidation/reduction steps taking place in the operation of DSSC

Chenodeoxycholic acid (CDCA) is an organic compound having two significant features. Firstly it is cost effective in nature and secondly it has the ability to strongly gets attached to the mesoporous nanostructured TiO_2, hindering the formation of dye accumulation, and transfers the dye molecules on surface of the semiconductor (Yum *et al.*, 2008; Jing *et al.*, 2011). It is reported to increase DSSC efficiency because of its inhibition of dye collection, subsequently enhancing electron transfer efficiency, therefore results in enhancement of the cell performance. Additionally, the existence of CDCA results in an enhancement in photovoltage that is credited to the reduction of recombination of charges. In this work, DSSCs have been fabricated with Ruthenizer 535-bisTBA (N-719 dye) as sensitizer without and with CDCA as a co-absorbent additive. Further the photovoltaic measurement has been investigated in the presence of considered additive.

2. EXPERIMENTAL

The mesoporous titania electrodes at about 80 °C were dipped in solutions of Ruthenizer 535-bisTBA (N-719) with and without the CDCA as additive, then allowed to stain overnight for about 14 h. The stained TiO_2 photoanode was rinsed thoroughly with methanol and dried in nitrogen gas immediately after taking out from dye. Then a portion of gasket was positioned on upper side of anode over the titania area, a conductive side of Pt counter-electrode was placed over the gasket and heated up to 100 ℃ to ensure perfect sealing. After sealing, through the drilled hole, an iodide based electrolyte was injected in the counter electrode. To avoid photo-bleaching of the dye molecules prior to electrolyte injection, all assembly works were performed in a dark room. 0.36 cm^2 was calculated to be the active area of the cells. The structural formulas of Ruthenizer 535-bisTBA (N-719 dye), and chenodeoxycholic acid (CDCA) are shown in figure 3.



(a) Ruthenium dye [1]

(b) Chenodeoxycholic Acid[2]

Figure-3. Chemical structure of N719 and additive

3. RESULTS AND DISCUSSION

The UV -Vis absorption spectrum of N719 dye with and without the additive can be compared in figure 4. It can be clearly seen that the addition of Chenodeoxycholic acid has resulted in the increase of absorption. Similar increase in absorption has also been observed for some organic dyes (Jing *et al.*, 2011).

The J–V measurements of cells measured in AM 1.5 simulated illumination are exhibited in figure 5. Comparison of the parameters of the cells is given in table 1. The performance efficiency, symbolized as η, of a cell is defined as the ratio between the output power and the input power and is expressed as:

$$\eta = \frac{P_{max}}{P_{in}} \times 100 = \frac{J_{sc} \times V_{oc} \times FF}{P_{in}} \times 100 \qquad (1)$$

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[1] M. Ryan, "PGM Highlights: ruthenium complexes for dye sensitised solar cells," Platinum Metals Review, vol. 53, pp. 216-218, 2009.

[2] http://www.sigmaaldrich.com/catalog/product/sigma/c9377?lang=en&region=PK

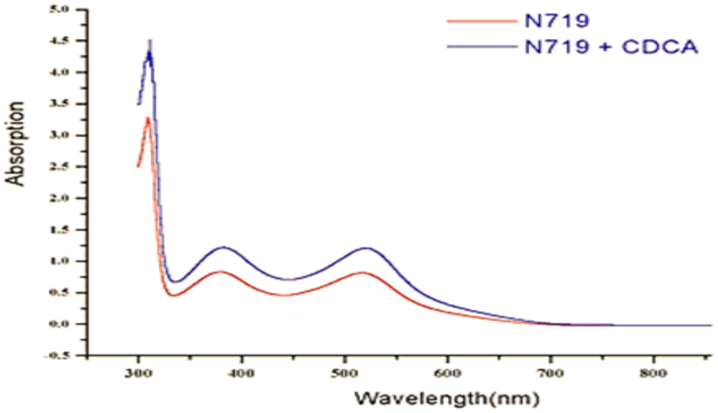

Figure-4. Absorption spectrum of N719 and N719+CDCA

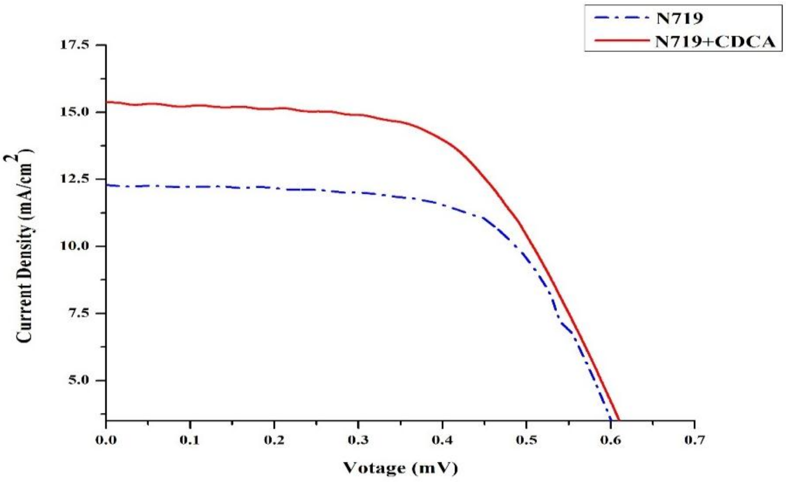

Figure-5. JV measurement of N719 and N719+ additive

Compared with the DSSC fabricated without the additive, open-circuit voltage (V_{OC}), the current density (J_{sc}) and power conversion efficiency (η) of the device fabricated with the CDCA as additive is increased by 3.12% , 24.98 %, 14.46 %, respectively. In an earlier study reported (Jing *et al.*, 2011) the conversion efficiencies of 3.61 % and 4.42 % were obtained for P1- and P2-sensitized dyes. In this study carried out on the N719 sensitized DSSC with CDCA as additive, the conversion efficiency is 57.89 %, 28.96 % higher, respectively. The increase in efficiency is due to the fact that additive helps in prevention of dye aggregation, which results in high absorption of light.

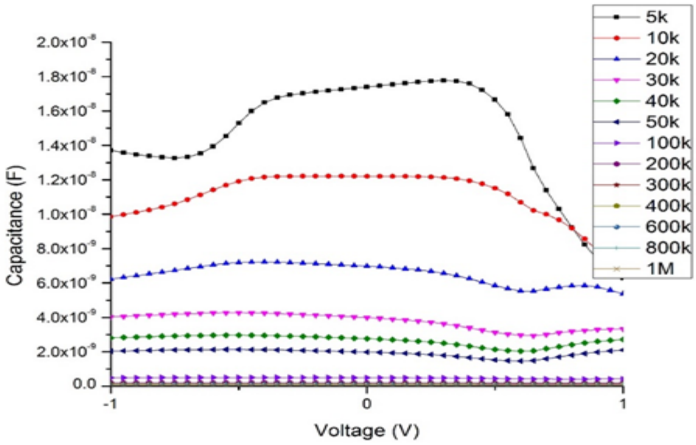

Figure-6. CV measurement of N719 + additive

Impedance spectroscopy was performed on the cell with ruthenium and additive as depicted in fig 6. It shows capacitance vs voltage at different frequencies. At low frequency, a trend is observed in which at low voltage the charge accumulates and then depletes. At higher frequencies capacitance remains constant.

4. CONCLUSION

UV -Vis absorption spectrum of N719 with and without additive is observed and it showed an overall increase in the absorption spectrum with addition of additive. The DSSCs were fabricated using N719 dye as sensitizer, without and with a low cost CDCA as additive. The device fabricated from dye with CDCA as a low cost additive has shown better photovoltaic performance with 14.45% enhancement in efficiency. CV measurement was made and showed for cell with N719 + additive. It is proposed that CDCA can be used as an additive for the fabrication of lower cost and higher efficiency of DSSCs. For further enhancement, the additive is to be tested on different dyes other than N719.

Dye	**J_{sc} (mA/cm^2)**	**V_{oc}(mV)**	**FF**	**η.**
DSSC with N719	12.29	0.640	0.63	4.98%
DSSC with N719+ Additive	15.36	0.660	0.56	5.70%

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Competing Interests: The authors declare that they have no competing interests.

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