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ORIGINAL STUDY

The Effect of Radiation on the Optical Properties of TiO_2 thin Films as Solar Cell Application

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Abstract

This study investigates the effect of Alpha radiation on dye_sensitized solar cell. The DSSC was manufactured using a TiO_2 thin-layer anode, a conductive glass FTO (Fluorine-Doped Tin Oxide) glass substrate, a counter electrode that was deposited with aluminium (Al)on the FTO glass, and two dyes (a natural dye, blackberry, and a synthetic dye, methylene blue). It was detected that irradiation is positive, as we found that the longer the irradiation time, the higher the efficiency. This research studied the J-V curve and UV−Vis of the cell. The UV−Vis results showed that the energy band gap decreases with increasing irradiation and the energy gaps were (3.01,2.90 and 2.77) eV for (st, 30 min, 60 min) samples respectively. The best result appeared for the cell using the synthetic dye methylene blue; the cell parameters were open circuit voltage (0.69) volt, J_{sc}(5.85 mA/cm^2), FF at (0.15), and efficiency 1c/o. The results showed that DSSC, which uses radiation, is a promising method for future research.

Keywords: Solar cell, Alpha particles, TiO_2, Efficiency, DSSC

1. Introduction

Dye sensitized solar cell (DSSC), a promising alternative candidate to p-n junctions solar cell [1], makes use of Wide-band gap semiconductor materials that have been sensitized [2]. Wide-bandgap semiconductors with strong chemical stability, including SnO_2, TiO_2, or ZnO, are employed in DSSC devices [3]. Together with other organic and inorganic photovoltaic (PV) technologies, DSSC helps somehow in solving the global energy dilemma in addition to the traditional fossil fuel or natural gas-based energy sources [4]. From the initial development of DSSC by O'Regan *et al.* [5], It received a lot of attention from researchers as a cutting-edge, clean, and renewable photon-to-electricity conversion technology. DSSCs make it easier to fabricate Soler Cell since that use readily available, reasonably priced materials that do not require expensive laboratory equipment or highly skilled labour [6]. The way that DSSCs operate differs greatly from that of other traditional semiconductor photovoltaic devices. Typically, the sensitizer in a dye-sensitized solar cell (DSSC) absorbs solar energy to produce excitons. A wide-band gap semiconductor photoanode screen then captures the electrons that the exciton created [7]. A redox pair that bridge the space between the two DSSC electrodes (I_3-/I in an organic solvent, for example), transfer the charge carriers from metal oxide and oxidised dye to electrodes, i.e., the photo-electrode (photoanode) and counter (working) electrode [8]. Due to its potential for use in energy production and environmental protection, titanium dioxide (TiO_2) has gasped recently interest from researchers all over the world. Because of its high surface area for dye adsorption and nanocrystalline mesoporous nature, TiO_2 has been primarily used in dye-sensitive solar cells (DSSCs) [9]. The solar energy can then excite the dye molecules that have been absorbed, creating electron−hole pairs that are then separated and moved within the TiO_2 lattice. The dye's anchoring to the TiO_2 surface and its absorption spectrum are crucial factors in determining the cell's effectiveness. The dye has received a great attention since it is crucial for absorbing visible light and converting photon energy into electricity [10]. A. Sikder *et al.* In this research, used (FTO,TiO_2,I_3,

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Graphite). The highest solar-to-electric PCE of 1.09% was achieved by the DSSC made with jamun dye, which also had an FF (fill factor) of 0.31, an I_{sc} of 7.84 mA/cm^2, and a V_{oc} of 0.45 V. Blackberry and BlackPlum dyes. On the other hand, it had low efficiency; their calculated values were 0.38% and 0.55%, respectively. The power conversion efficiency (PCE) of the blackberry dye was 0.38% [11]. N. I. A. Shukor *et al.*, investigated the use of mulberries and blueberries natural dyes as environment friendly substitutes in solar cells (DSSCs). The research concentrated on a fully "green" approach, utilizing eco-friendly materials for every component of the DSSC. The best-performing dye was mulberry, which produced 13.79 μW of power output outside and 0.122 μW of power production indoors. These results point to the potential of natural fruit dyes for DSSCs, especially in educational contexts and the development of sustainable technologies [12]. J. Safaei-Ghomi, *et al.* used the dye-sensitized TiO_2 photoanodes, an I-/I_3- electrolyte, and a graphite counter electrode were used to manufacture the DSSCs. There was some amount of photoconversion efficiency demonstrated by all of the natural dyes. With a PCE of 1.76%, the beetroot dye produced the highest yield, followed by the dyes for red cabbage (1.31%), blackberries (0.99%), and grapes (0.51%). The DSSCs' V_{oc} values varied from 0.45 V to 0.56 V. The DSSCs' J_{sc} values varied from 4.80 mA/cm^2 to 7.84 mA/cm^2. The DSSCs' FF values varied from 0.49 to 0.69 [13]. The aim of the study is to investigate the effect of radiation on dye solar cells using an synthetic dye (methylene blue) and a natural extract (blackberry).

2. Experimental details

FTO conductive glass with the dimensions of (75*75 × 1.1) mm and a resistance of 15Ω as the basis. Titanium dioxide consists of TiO_2 powder (HImedIa company). Acetone and ethanol were used to clean the FTO glass. Natural dyes (blackberries, Methylene blue) were used at room temperature in a commercial juicer. The dye was extracted from the fruits, and the juice extracted from the solid parts of the fruit was used as a dye. The counter electrode was used where aluminium as deposited on the conductive side of the FTO at the University of Babylon to be used as a counter electrode. The FTO was cleaned with deionized water and an ethanol for 5 min and then dried well. TiO_2 was prepared as 3 g of TiO_2 powder was mixed with 5 ml diluted nitric acid and a drop of ethylene glycol to stick to form a dough. It was applied to the conductive side of the FTO glass and placed in an oven at 450 °C for 30 min then cooled naturally. The cooled TiO_2 film was immersed in the dye, and was extracted overnight and then washed with ethanol. The electrolyte was prepared by mixing (0.127 g of iodine with 0.83 g of potassium iodide in 10 ml ethylene glycol). The voltage and current were measured using a Keithley 2400 device, and the characteristics of the solar cell manufactured from J_V were measured without irradiation and measurement of UV_Vis (Ultraviolet–Visible Spectrometer). The samples were exposed to irradiation from the base source for 30 and 60 min.

3. Results and discussion

Alpha radiation (^{241}Am) is a high-energy particle that can seriously damage materials and has a limited range [14]. In this work, the effect of alpha radiation on TiO_2 was studied over different time periods using Alpha radiation released from an ^{241}Am source. To discuss the results of the UV and J-V optical properties of the samples, Fig. (1) shows the comparison of optical absorbance properties of stander (without radiation), 30, 60 samples. The measurements were carried out in the wavelength range of 300 nm–800 nm. It can be observed from Fig. (1) that the pure TiO_2 has a low absorption because the density of the atoms is relatively small, which means that there are few atoms that can interact with the radiation photons [15], and the increase in the absorption value of TiO_2 caused by radiation with alpha particles that break the covalent bonds between atoms [14]. It could be observe from theFig. (1) that the highest absorption value was at 60 min.

Tauc formula [16] that connects the absorption coefficient, the Planck constant h (6.63*10^{-34} J.s),

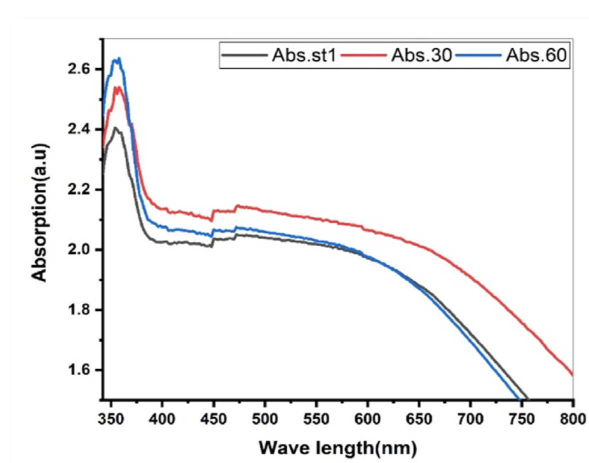

Fig. 1. The comparison of optical absorbance properties of st,30,60 samples.

the energy band Eg gap, the radiation frequency, and a constant A [17] for many kinds of transition materials, n has a distinct value. TiO_2 is a material that is transmitted directly, hence, the value of n in the formula is assumed to be 1/2. Plotting $(\alpha h\nu)^2$ against hv yielded the optical band gap, as seen in Fig. (2). The optical band gap was then calculated by extending the linear section of the curve to the

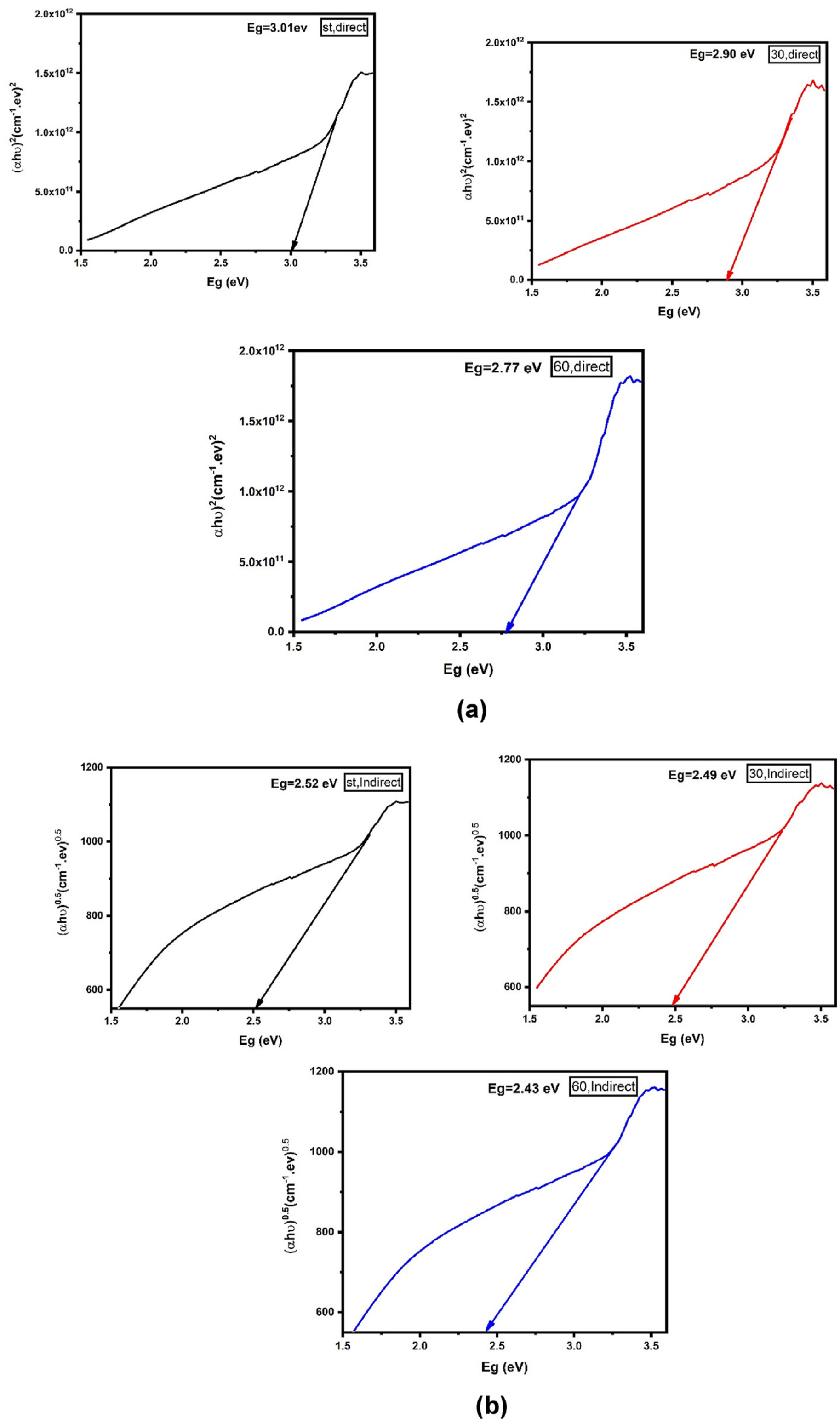

Fig. 2. (a)Tauc plot $(\alpha h\nu)^2$ corresponds to the energy gap (hν) of the TiO_2 film for stander sample, 30 min, 60 min. (b) Tauc plot $(\alpha h\nu)^{0.5}$ corresponds to the. energy gap (hν) of the TiO_2 film for stander sample.

Table 1. Displays the direct and indirect energy gaps for TiO_2 films at irradiation periods.

The irradiation times (min)	Dir. (ev)	Indir. (ev)
Stander (0)	3.01	2.52
30	2.90	2.49
60	2.77	2.43

x-axis of the $(\alpha h\nu)^2$ vs. hν plot. The optical band gap (Eg) was estimated as (3.01, 2.90 and 2.77) eV sample respectively. Each sample (st, 30, 60) shows wide_bandgaps which their values are very close to ideal bandgap of TiO_2 at about 3.2 eV [3,4].

$$(\alpha hv)^{1/n} = A(hv - Eg) \quad (1)$$

According to Table (1), as the irradiation time increases, the energy band gap decreases, Radiation disrupts the Ti−O bonds, exposing the TiO_2 network to the defects and vacancies, which in turn increase the defect and decrease the energy gap [18].

The photocell used in the assembly of a dye-sensitized solar cell (DSSC) were ($FTO/TiO_2/MB/AL$) and (FTO/TiO_2/Blackberry/AL) computed, and the efficiency of the manufactured DSSC modules at 50 mW/cm^2 using current density -voltage (J-V) curves was investigated. Fig. (3) display the (J-V) characteristics under various irradiation times with alpha particles radiation.

Table 2 indicates that the efficiency increases as the irradiation time increases, with the best results of the efficiency achieved. When using dye (Methylene blue) at an irradiation time of 60 min.

4. Conclusion

The fabrication of dye of solar cells in this study was with low-cost and environmentally friendly, In the J-V curve and UV−Vis characteristics investigations, the cells were manufactured from FTO conductive glass substrates, TiO_2 was deposited on them using a doctor's blade method, and were affected by alpha rays. Two dyes were used (blackberry natural dye and methylene blue synthetic dye), and the counter electrode-of aluminium, was deposited on the FTO, which had the best result. When using synthetic dye, it reached 1% at an irradiation time of 60 min, V_{oc} = 0.69 V, J_{sc} = 5.85 mA/cm^2, FF = 0.15, Rs = 1 mΩ, R_{sh} = 11 mΩ because the synthetic dye is free of impurities. The energy band gap decreased with increasing irradiation (3.01, 2.90, and 2.77) eV for the

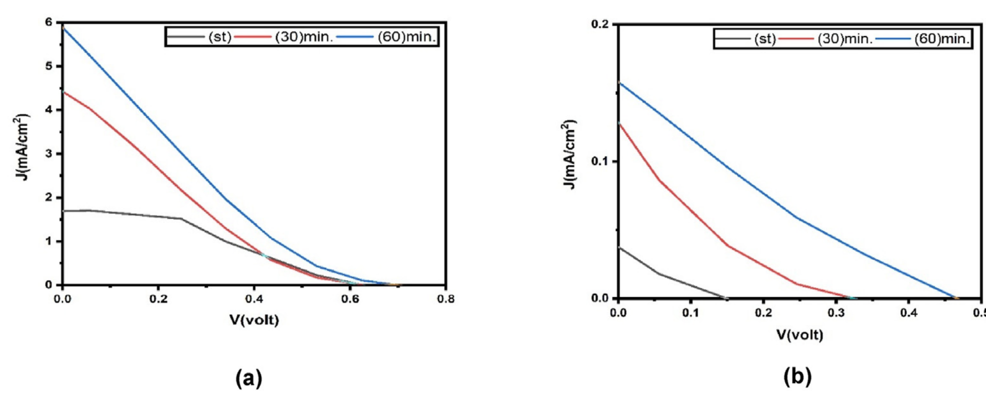

Fig. 3. J-V characteristics of DSSC in the light Standard Sample, 30 min, 60 min for dye (a) methylene blue (b) blackberry.

Table 2. The electrical parameters properties of the solar cell show the open circuit voltage, short circuit current density, fill factor, and efficiency of the TiO_2 film solar cell for Dye MB, BlackBerry.

MB Dye	V_{oc}(V)	J ($mA.cm^{-2}$)	P_{max} (mw)	$R_{shm\Omega}$	$R_{sm\Omega}$	FF	η%
Stander (0)	0.62	1.6	0.36	0.94	2	0.34	0.7
30	0.63	4.41	0.47	9.6	1.7	0.17	0.9
60	0.69	5.85	0.61	11	1	0.15	1
Dye blackberry	V_{oc}(V)	J ($mA.cm^{-2}$)	P_{max} (mw)	$R_{shm\Omega}$	$R_{sm\Omega}$	FF	η%
Stander (0)	0.15	0.04	0.001	0.27	1.82	0.15	0.002
30	0.32	0.13	0.004	0.76	0.13	0.15	0.01
60	0.46	0.15	0.01	1	0.1	0.17	0.02

sample (st, 30, 60) respectively. This study also observed that the increased the radiation time, the increased the efficiency.

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