International Journal of Advanced Research and Review

EFFECT OF VARYING TITANIUM DIOXIDE AND IODINE ON OPEN CIRCUIT VOLTAGE AND SHORT CURRENT DENSITY

[1]**Njoroge David Kimemia; [2]Dr. Walter K. Njoroge; [3]Dr. Isaac W. Mwangi**

Kenyatta University, Kenya

ABSTRACT
The study sought to establish a photo cell which can reduce use of fossil fuels and in turn reduce on air pollution and climate change. The experimental design involved preparation of various ratios of titanium dioxide: graphite /iodine/KI mixtures in each respective layer. Optimization was carried out by varying the mass of the constituents of each layer while maintaining the others constant to obtain the highest current-voltage outputs. The study investigated the effect of the thickness of TiO_2 (the photo active layer) and the electronegative material layers on current-voltage output of the fabricated solar cell. The optimum electricity generation was observed at the ratio of TiO_2/ C_x: I_2: KI as 0.4: 0.3: 0.17: 0.01 g respectively. Results show a very sharp increase in potential from a molar ratio of 0.1g of TiO_2 to 0.4 g producing a voltage of 0.73 V after which there was a steep decrease from 0.73 V to 0.22 V with a short change of 0.1 g. Therefore, the molar ratio of (0.4: 0.2: 0.12) generated a reasonably high voltage of 0.73 V indicating that these values were almost the optimized ratios. There was a linear increase in potential up to a molar ratio of 0.5 g after which a uniform plateau was observed. Finally, the Variation of graphite-C_X molar ratio was investigated at constant iodine (0.1 g) and TiO_2 (0.5 g). The results showed a gradual increase in voltage from a molar ratio of 0.1g to 0.2 g generating a potential of 0.2 V, after which there was a gradual decrease from 0.2 V to 0.09 V with a change 0.2 g of graphite. In conclusion, the results obtained on optimization of a blank cell, the open circuit voltage (V_{OC}) and short circuit current density (J_{SC}) of 0.083 V and 0.33μA were respectively obtained. These values were low confirming that a conducting medium was necessary for the migration of the generated electrons. The research generally recommends that there is need to employ improved technology to reduce presence of air packets which creates air gaps.

Keywords: Varying Titanium Dioxide, Iodine, Open Circuit Voltage, Short Current Density

INTRODUCTION
Coating graphite onto the conductive side is one of the crucial steps for making the dye-sensitized solar cells (DSSC) (Grätzel, 2009). Therefore, the study tested the dependence of the thickness of graphite layer with the performance of the cell. Grätzel (2003) notes that graphite layer has potential influence on the efficiency of the solar cell. The study was conducted using a control experiment. First, solar cell was designed to be a blank experiment, that is, no graphite layer on the conductive side. It has been already known that graphite layer is necessary for cell functioning properly, and it is important to have a complete comparison with this blank control group (O'Regan & Grätzel, 1991). The graphite layer was controlled by manipulating the time over the candle flame. In order to ensure the minimum random error, the candle was used with minimum perturbation. Difference in thickness of graphite can be tracked by the colour of the layer (O'Regan & Grätzel, 1991). However, graphite layer

was necessary for the DSSC to produce voltage and bulky thickness would not improve the efficiency of the solar cell (O'Regan & Grätzel, 1991).

Titanium Dioxide Solar Cell
O'Regan and Grätzel (1991) fabricated titanium dioxide solar cell through a wet chemical process. Thicker layers of titanium dioxide potentially decrease the output of the cell by blocking the photon transfer (Grätzel, 2003). The development of the cell brought about the possibility of having an alternative to silicon based photovoltaic cell (Sundaram, 2009). The Grätzel cell, also referred to as dye-sensitized solar cell (DSSC), is inexpensive and easy to develop and has the highest overall conversion efficiency currently reported at 12%. However, its development has a challenge in that the cell suffers from corrosion due to action of oxygen on the material used (Sundaram, 2009). Thus, the study exploited the same principles of the DSSC but avoided the aqueous media to minimize effects of corrosion.

Migration of Electrons in the Solar Cell
A complex of KI/I_2 conducts well when it dissolves in water (Hebling, 2010). This is because it dissociates into K^+ and I^- ions. These ions are mobile and they support current flow (Kiplagat *et al*., 2011). The mixture of I_2/KI was dispersed in graphite which is a good conductor of electricity. Its conductivity is due to the first electrons delocalized within the carbon layers (Auciello & Krauss, 2005). Structurally, in graphite, the carbon atom has three bonds leaving a delocalized electron available for conduction (Adler, 2011). Sellappan (2013) has noted that graphite prepared using different methods results in different forms and electrical conductivity which strongly affect charge carrier dynamics. Thus there are three carbon electrons used in bonding which leaves the fourth electron to move freely along the layers (Auciello & Krauss, 2005).

The unhybridized p electrons from a delocalized cloud of electron similar to metallic bond enable graphite to conduct electricity (Fungo, 2007). This dispersing media and the electronegative iodine provided a medium for movement of electrons in the study. Combination of materials in photo active layer resulted in a greater efficiency in converting light into electricity (Gűnes & Serdar, 2008). Hence graphite powder was used in the current study to support conduction of electrons. Various parameters of the cell were optimized by obtaining the best ratio from which the most suitable I-V characteristics was observed. Jessica (2009) notes that the cell was dominated by the iodide/iodide process which inhibited the layer of photo active electrode, leading to low conductivity.

In summary, TiO_2 is identified as a non-toxic inorganic material with ability to generate electrons and holes when illuminated with radiation (Sellappan, 2013). The TiO_2 photo active material has been used in electro chromic devices and dye-sensitized solar cells (Caitian *et al*., 2014). It has also been utilized in a photo cell in a wet chemical process. However, that application is associated with a lot of corrosion and emission to the atmosphere (Kamat, 2007). Due to such limitations, and considering the utility of titanium dioxide as a photo catalyst with its subsequent application in oxidation of various species, the study exploited photo generation of electrons and holes on electricity in its solid form upon illumination with a suitable radiation.

This was achieved by use of TiO_2 in its solid form to avert corrosion and reduce pollution to the atmosphere. The generated electrons were replenished by an iodine/iodide complex and their migration was facilitated by graphite. The mixture of those constituents was made into a pellet and photo electric properties were investigated.

MATERIALS AND METHODS

The study adopted an experimental research design to investigate the performance of the fabricated solar cell. It was done by first obtaining the optimal values of the parameters under investigation. The best parameters were obtained by establishing the optimal values of each material constituent of the cell. These were TiO_2, which was the photoactive material, the graphite which was the conducting medium and the Iodine/Iodide mixture which replenished the electrons conducted away after photo excitation. This process employed varying the weights of the component parts, and finally characterization of the fabricated solar cells under constant radiation intensity in clear daylight.

In the study, the following assumptions were made: The solar radiation was assumed to be constant at 100 mW/cm^2 irradiance (Hagfeldt *et al.*, 2010); the solar density on the solar cell was assumed to be uniform, and the voltage drop in the digital meter leads was assumed to be negligible. All reagents were of analytical grade and were sourced from Sigma Aldrich. The titanium dioxide (TiO_2), iodine (I_2), potassium iodide (KI) and graphite (C_X) in their powder form were used.

To fabricate the solar cell, different molar ratios of graphite (C_X) powder, titanium dioxide (TiO_2) powder, potassium iodide (KI) and iodine (I_2) were mixed and compressed to form a Solar Cell. Figure 1 below shows the schematic presentation of the fabricated cell.
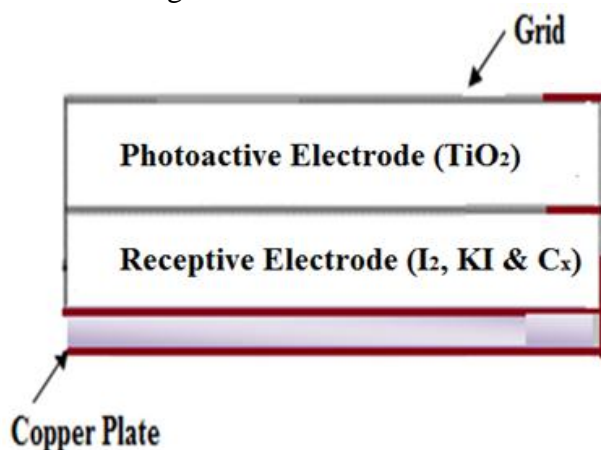

Figure 1: Schematic presentation of the fabricated solar cell

To provide the required dimensions, a copper plate was cut into 2.5 cm by 2.5 cm by the use of metal plate shears. An active cell of Ø 1.3 cm (A=1.327 cm^2)was prepared, laid on the copper plate and covered with a transparent raisin as a copper conductor in contact with the upper electrode was drawn through the raisin for external connection.

The first cell electrode was made by placing the photo active measured sample separately in a circular dice and compressed thoroughly. The second electrode was made by disposing the mixtures of molar ratios of (graphite: iodine: I_2/KI) over the initial layer and the pressing procedure followed. The resultant was a circular pellet which served as the photo active cell. I-V characteristics of each of the resulting cells were monitored. The photo active (cathode) was prepared by varying molar ratios of powdered TiO_2 ranging from (0.2-1) g. These molar ratios were inserted in a moulding dice and pressed into a disc form with a diameter of 1.3 cm to form a circular pellet.

The receptive layer (anode) was prepared by varying molar ratios of finely divided mixtures of molar ratios (graphite: I_2: I_2/KI) ranging from (0.1: 0.1: 0.01) g to (0.6: 0.3: 0.01) g. These

mixtures of molar ratios were then inserted in a moulding dice and pressed into a disc form with a diameter of 1.3 cm to form a circular pellet similar in size to the photoactive layer. The receptive layer (anode) was then placed on photo active (cathode) and pressed further to form a complete assembly of the solar cell. External conductors were then connected to the cell for I-V characterization. Figure 2 shows the schematic cell presentation of the solar cell.
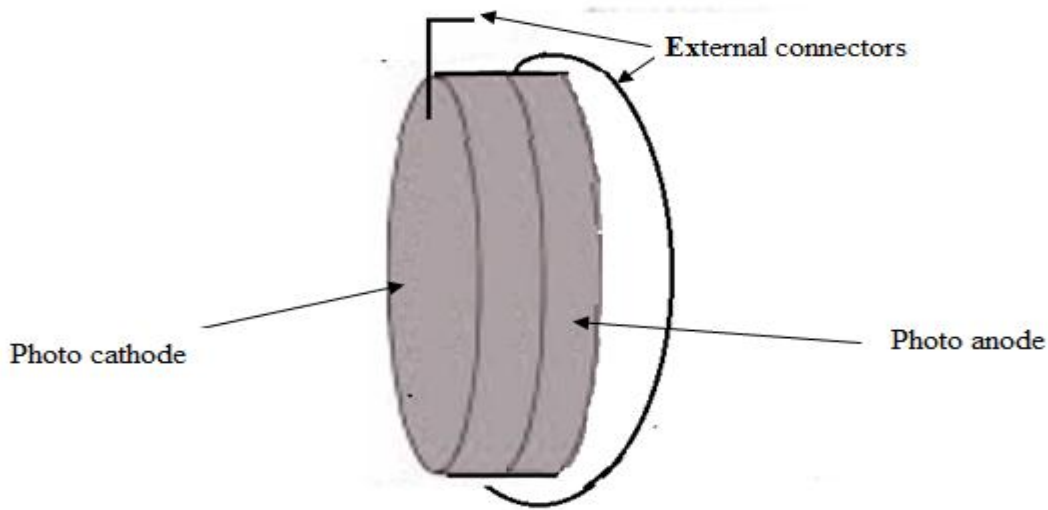

Figure 2: Photo voltaic cell scheme

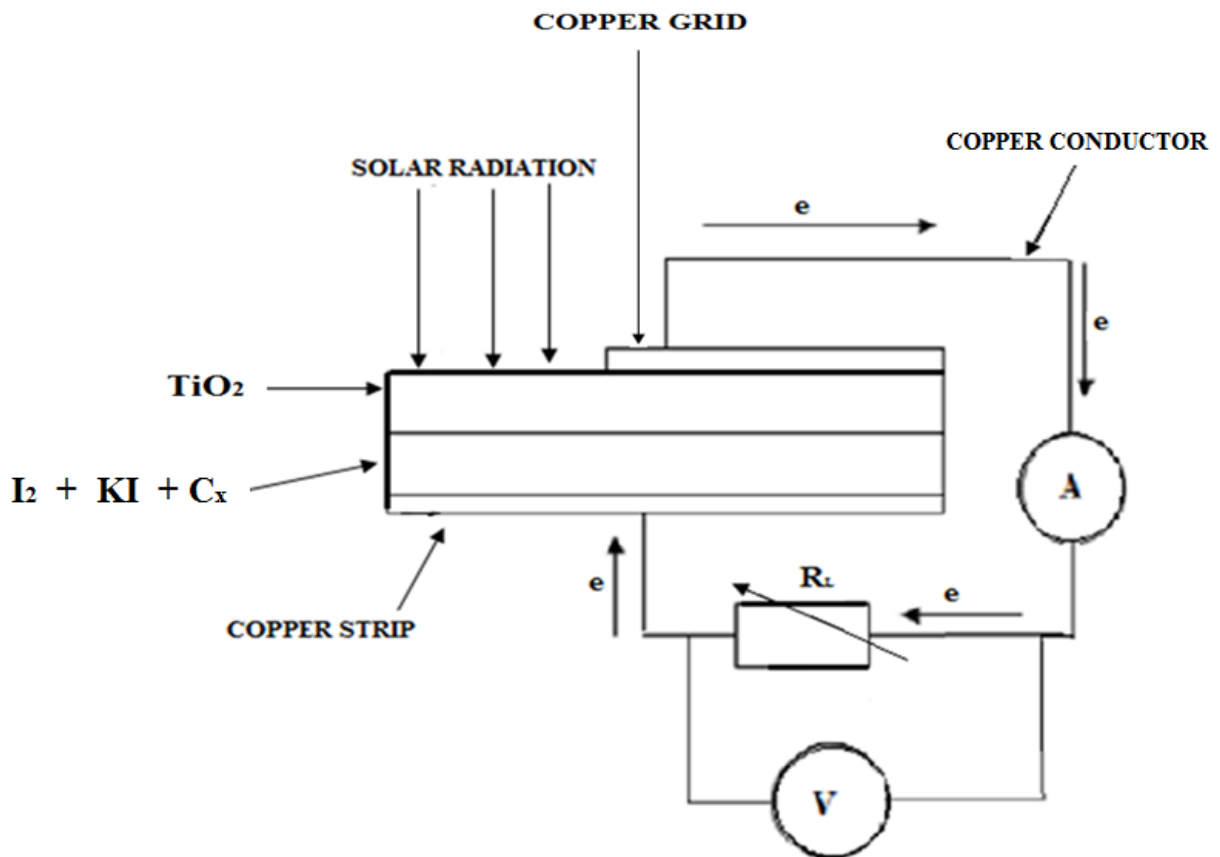The optimum I-V characteristics were established using the circuit diagram of Figure 3.

Figure 3: Assembly of the circuit diagram for the I-V characterization

A high resolution micro-Ammeter (0-100 μA) was connected in series with the fabricated Solar cell to measure the current density output (J_{MP}) resulting from the generated charge carriers which migrated from the photo active cathode layer of the cell through external conductors and back to the cell through the anode. A high resolution galvanometer (0-250 mV) was connected in parallel with the arrangement of the Ø 1.3 cm (A=1.327 cm^2) active solar cell and the micro-Ammeter (0-100 μA) to measure the resulting open circuit voltage (V_{OC}) at the output terminals.

A high resolution graduated variable resistor (Ohmmeter) (0-34 Ω) was connected in series with the micro-Ammeter (μA) and in parallel with the galvanometer (0-250 mV). The variable resistor served the purpose of an external load and the ratio of the generated potential (V_{MP})to the measured resistance at any particular instant, confirmed the amount of the current density (J_{MP}) through the external circuit and this was recorded to determine the maximum power (P_{MAX}) of the solar cell. The short circuit current density (J_{SC}/cm^2) values were determined at zero applied voltage and the open circuit voltage (V_{OC}) values were determined at zero current under solar radiation. The current generated against their corresponding potential for various cells were collected and tabulated. The voltage output for maximum power output (P_{MAX}) were taken at 5 minutes intervals and tabulated for analysis.

The fabricated solar cell parameters were calculated using equations as applied by Adegbenro (2016) while calculating parameters of different shapes and states of solar cells. In his study, the cells were in 1cm^2 squared blocks while the cell in this study had a diameter of (Ø) 1.3 cm giving an area (A) of 1.327 cm^2:

$$V_{MP} = \frac{V_{MAX}}{A} (mV\ cm^{-2}) \tag{1}$$

$$J_{MP} = \frac{I_{MAX}}{A} (\mu Acm^{-2}) \tag{2}$$

$$P_{MAX} = V_{MP} \times J_{MAX} \tag{3}$$

$$J_{SC} = \frac{I_{SC}}{A} (\mu Acm^{-2}) \tag{4}$$

$$V_{OC}/cm^2 = \frac{V_{OC}}{A} (mV/\ cm^2) \tag{5}$$

$$P_T = V_{OC}/cm^2 \times J_{SC}/cm^2 \tag{6}$$

$$Fill\ Factor(FF) = \frac{J_{MP} V_{MP}}{J_{SC} V_{OC}} \tag{7}$$

$$Shunt\ Resistance(R_{SH}) = \frac{\Delta Y}{\Delta X} \tag{8}$$

$$Series\ Resistance\ (R_S) = \frac{\Delta X}{\Delta Y} \tag{9}$$

$$Efficiency\ \eta = \frac{J_{SC} \times FF \times V_{OC}}{p_{in} \times A} \tag{10}$$

'A' is the photoactive area of the cell; A= 1.327 cm^2. In the study, the parameters were obtained by adopting expression 1-10 as applied by Adegbenro (2016) when he characterized different shapes and states of solar cells to obtain their parameter values.

Nikhil (2013) defines the open circuit voltage (V_{OC}) is the voltage delivered by the solar cell when the electrodes are isolated and no current is sourced under infinite load resistance. This

voltage represents the maximum potential energy stored to initiate the flow of electrons which are yet to be dissipated. Nikhil also notes that the voltage of a unit area (V_{OC}/cm^2) delivered by a solar cell when the electrodes are isolated represents the maximum potential energy stored to initiate the flow of electrons which are yet to be dissipated.

RESULTS AND DISCUSSION

Effect of varying TiO_2 and I_2 on V_{OC} and J_{SC}

Variation of TiO_2 molar ratios were investigated at constant molar ratio of iodine (0.12 g) and graphite (C_X)(0.2 g) and the results are as presented in Table 1.

Table 1: Effect of variation of TiO_2 of cells Q, R, S, T and U on V_{OC} and J_{SC}

Cell	Mass (g)				Potential (V)	Short cct current density (μAcm^{-2})
	I_2	KI	C_X	TiO_2	V_{OC} (V)	$J_{SC}(\mu Acm^{-2})$
Q	0.12	0.01	0.2	0.2	0.1	1.35
R	0.12	0.01	0.2	0.4	0.73	9.82
S	0.12	0.01	0.2	0.5	0.22	2.96
T	0.12	0.01	0.2	0.8	0.18	2.42
U	0.12	0.01	0.2	1	0.45	6.05

From the information recorded in Table 1 a graphical presentation of potentials against the masses (TiO_2) was made as shown in Figure 4.
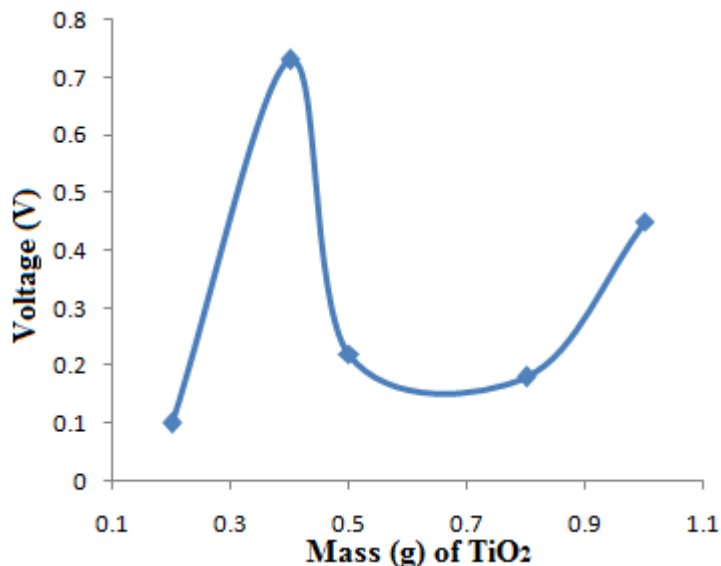

Figure 4: Variation of TiO_2 mass against potential of cells Q, R, S, T and U

Figure 4 shows the composition molar ratios (0.2: 0.2: 0.12), (0.4: 0.2: 0.12), (0.5: 0.2: 0.12), (0.8: 0.2: 0.12) and (1:0.2: 0.12), respectively of TiO_2: graphite: I_2 of cells Q, R, S, T and U.The result of Figure 4 shows a very sharp increase in potential from a mass of 0.1g of TiO_2 to 0.4 g producing a voltage of 0.73 V after which there was a steep decrease from 0.73 V to 0.22 V with a short change of 0.1 g. A uniform plateau was then formed with a further increase of the photo active material TiO_2 from 0.5 g to 0.8 g after which there was a decrease of voltage from 0.22 V to 0.18 V. A further increase in mass of TiO_2 from 0.8 g to 1 g show

some rise in voltage from (0.18 to 0.45) V. This can be attributed to the charged species encountering some regions of non-uniformity in resistance of the cell constituents as they migrated to the external circuit (Imran, 2013). Going by the ratio of TiO_2: C_X: I_2, it implies that the molar ratio of (0.4: 0.2: 0.12) generated a reasonably high voltage of 0.73 V indicating that these values were almost the optimized ratios. Further investigations were done to investigate the effect of the conducting medium on the generated open circuit voltage and the short circuit current of the solar cell.

Effect of Blank (graphite =0g) Conducting Medium on V_{OC} and J_{SC}

The effect of a blank conducting medium mass (graphite-C_X = 0 g) of cells V, W, X and Y was investigated as presented in Table 2 at constant mass of the electronegative material (0.12 g) as the photo active material mass was varied at (0.05, 0.55, 0.65 and 0.95) grams, respectively.

Table 2: Effect of a blank conducting medium (graphite = 0g) of cells V, W, X and Y on V_{OC} and J_{SC}

Cell	Mass (g)				Potential (V)	Short cct current density (μAcm^{-2})
	I_2	KI	C_X	TiO_2	V_{OC} (V)	$J_{SC}(\mu Acm^{-2})$
V	0.12	0.01	0	0.05	0.028	0.26
W	0.12	0.01	0	0.55	0.083	0.21
X	0.12	0.01	0	0.65	0.089	0.14
Y	0.12	0.01	0	0.95	0.091	0.11

From the information recorded in Table 2 a graphical presentation of potentials against the masses of (TiO_2) was made as shown in Figure 5.
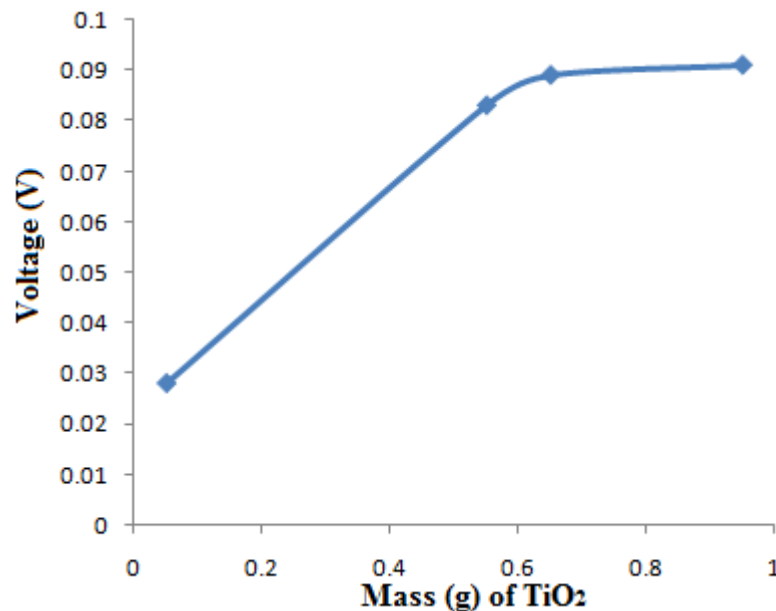

Figure 5: Variation of TiO_2 against potential of cells V, W, X and Y

The composition molar ratios (0.05: 0: 0.12), (0.55: 0: 0.12), (0.65: 0: 0.12) and (0.95: 0: 0.12) respectively of TiO_2: Graphite: I_2 of cells V, W, X and Y were varied. The results shown in Figure 5 give a linear increase in potential up to a mass of 0.5 g after which a uniform plateau was observed. This is a clear indication that without the conducting media, an increase in the photoactive material can produce an increase in the potential but has a limit because of saturation of generated holes and electrons on its surface (Samuel, 2006).

The results from Table 2 shows that a maximum open circuit voltage and short circuit current density of 0.091 V and 0.26μAcm^{-2} were generated by the active cell fabricated from the photo active (TiO_2) and iodine-iodide complex mass values of (0.95) g and (0.12) g respectively. The low potential and the current density generated by the cells V, W, X and Y can be attributed to the lack of conducting medium of the generated charged species as they migrated to the external circuit (Grätzel, 2009). The maximum output parameters of cell Y could only provide a Fill Factor (FF) and efficiency (η) of 0.11 and 0.0003%, respectively.

Effect of varying graphite at constant TiO_2 and I_2 on V_{OC} and J_{SC}

Variation of graphite-C_X masses was investigated at constant iodine (0.1 g) and TiO_2 (0.5 g) and the results are as presented in Table 3.

Table 3: Effect of variation of graphite of cells Z, A^1, B^1 and C^{1}on V_{OC} and J_{SC}

Cell	Mass (g)				Potential (V)	Short cct current density (μAcm^{-2})
	TiO_2	KI	I_2	C_X	Voc(V)	J_{SC}(μAcm^{-2})
Z	0.5	0.01	0.1	0.1	0.07	0.94
A^1	0.5	0.01	0.1	0.2	0.2	2.69
B^1	0.5	0.01	0.1	0.4	0.09	1.21
C^1	0.5	0.01	0.1	0.5	0.08	1.07

From the information recorded in Table 7 a graphical presentation of potentials against the masses of graphite (C_X) was made as shown in Figure 6.
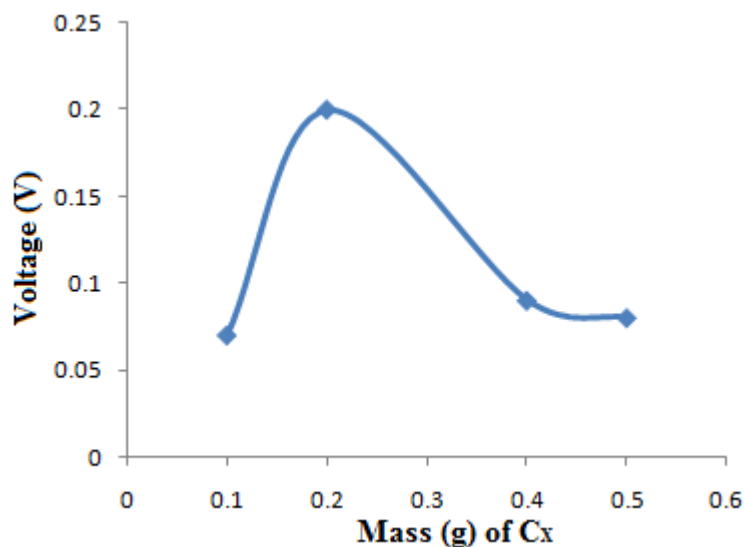

Figure 6: Variation of graphite mass against potential of cells Z, A^1, B^1 and C^1

The composition molar ratios (0.5: 0.1: 0.1), (0.5: 0.2: 0.1), (0.5: 0.4: 0.1) and (0.5: 0.5: 0.1) respectively of TiO_2: graphite: I_2 of cells Z, A^1, B^1, and C^1 were varied. The results of Figure 6 shows a gradual increase in voltage from a mass of 0.1g to 0.2 g generating a potential of 0.2 V, after which there was a gradual decrease from 0.2 V to 0.09 V with a change 0.2 g of graphite. The curve then has a linear profile with a slight change in voltage as the mass of graphite was varied from 0.4g to 0.5 g.

This can be attributed to existence of non-uniformity resistance regions within the cell electrodes (Galymzhan, 2010). The migrating electrons therefore encountered regions of varied resistance resulting to generation of varied potentials as the mass of graphite increases with high parasitic resistance (Galymzhan, 2010). The migrating electrons therefore encountered regions of varied resistance resulting to generation of varied potentials as the mass of graphite increases. Further experiments were carried out on cells fabricated with the mass of conducting medium (graphite-C_X) varied at constant TiO_2 (0.6 g) and iodine (0.1 g) and the results were as presented in Table 3.

Table 3: Effect of a Variation of Graphite of Cells D[1], E1, F[1,] G[1], H1and I[1] on V_{OC} and J_{SC}

Cell	Mass (g)				Potential (V)	Short cct current density(μAcm^{-2})
	TiO2	KI	I_2	C_X	Voc(V)	J_{SC} (μAcm^{-2})
D[1]	0.6	0.01	0.1	0.2	0.35	1.71
E[1]	0.6	0.01	0.1	0.25	0.67	3.45
F[1]	0.6	0.01	0.1	0.3	0.38	1.34
G[1]	0.6	0.01	0.1	0.4	0.26	0.79
H[1]	0.6	0.01	0.1	0.5	0.15	0.64
I[1]	0.6	0.01	0.1	0.6	0.01	0.11

From the information recorded in Table 3, a graphical presentation of potentials against the masses of graphite (C_X) was made as shown in Figure 7.
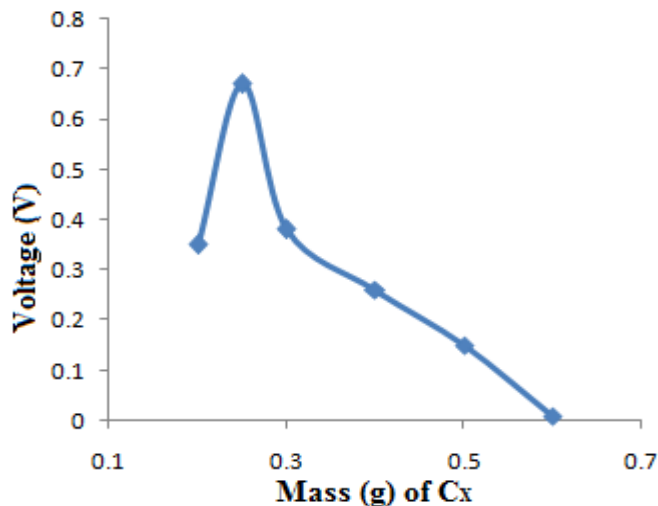

Figure 7: Variation of graphite mass against V_{OC} of cells D[1], E[1], F[1], G[1], H[1] and I[1]

The composition molar ratios (0.6: 0.2: 0.1), (0.6: 0.25: 0.1), (0.6: 0.3: 0.1), (0.6: 0.4: 0.1), (0.6: 0.5: 0.1) and (0.6: 0.6: 0.1) respectively of TiO_2: Graphite: I_2 of cells D[1], E[1], F[1], G[1], H[1] and I[1] were varied.

Figure 7 shows a sharp increase in voltage from a mass of 0.2 g to 0.25 g generating a potential of 0.67 V, after which there was a steep decrease of potential from 0.67 V to 0.38 V with a short change of 0.05 g of graphite. A similar scenario can be seen at 0.3 g to 0.4 g where there was a decrease of voltage from 0.38V to 0.26 V. This is repeated between 0.4 g to 0.5 g as the generated potential decreased further to 0.15 V and finally to 0.01 V when the

mass of graphite was increased by 0.1 g. This can be attributed to larger thickness of graphite in the cell which increased higher resistance to the migrating electrons resulting to lower potential at the cell terminals (O'Regan & Grätzel, 1991).

Further experiments were carried out with cellsJ[1], K[1], L[1], M[1], N[1] and O[1] fabricated with different masses of graphite at constant TiO_2 (0.7 g) and iodine (0.1 g) and the results were presented in Table 4.

Table 4: Effect of a variation of graphite of cells J[1], K[1], L[1], M[1], N[1] and O[1] on V_{OC} and J_{SC}

Cell	Mass (g)				Potential (V)	Short cct current density(μAcm^{-2})
	TiO2	KI	I_2	C_X	Voc(V)	J_{SC} (μAcm^{-2})
J[1]	0.7	0.01	0.1	0.1	0.02	0.27
K[1]	0.7	0.01	0.1	0.2	0.2	0.69
L[1]	0.7	0.01	0.1	0.3	0.5	2.73
M[1]	0.7	0.01	0.1	0.4	0.29	1.94
N[1]	0.7	0.01	0.1	0.5	0.15	0.22
O[1]	0.7	0.01	0.1	0.6	0.03	0.11

A graphical presentation of potentials against the masses of graphite was made as shown in figure 4.9 from the results recorded in Figure8.
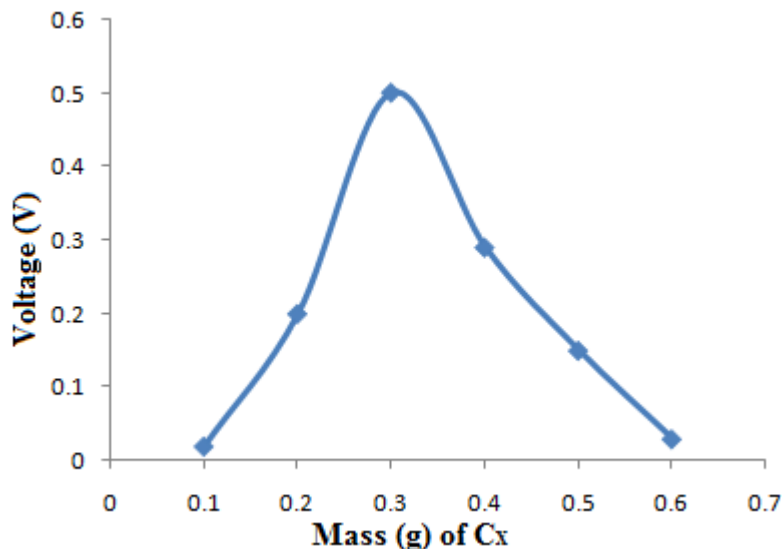

Figure 8: Variation of C_X mass against V_{OC} of cells J[1], K[1], L[1], M[1], N[1] and O[1]

The composition molar ratios (0.7: 0.1: 0.1), (0.7: 0.2: 0.1), (0.7: 0.3: 0.1), (0.7: 0.4: 0.1), (0.7: 0.5: 0.1) and (0.7: 0.6: 0.1) respectively of TiO_2: graphite: I_2 of cells J[1], K[1], L[1], M[1], N[1]and O[1] were varied.

Figure 8 shows a gradual increase in potential difference as the mass of graphite was increased upto an optimal mass of 0.3 g then decreased with increase in mass at almost the same rate. Thus the highest potential difference was observed at a mass of 0.3 g. This can be attributed to the improvement of the proportion of graphite to the other cell parameters (Grätzel, 2003). Further increase of graphite resulted to a gradual decrease in potential from 0.29 V to 0.15 V. This could be as a result of the thickness of the cell. This can be traded to

increase larger thickness of the conducting medium in the cell which increased higher the resistance to the path of migrating electrons resulting to lower potential at the cell terminals (O'Regan & Grätzel, 1991).

Further investigation was done of cells P^1, Q^1 and R^1 fabricated with different masses of graphite at constant TiO_2 (0.8 g) and iodine (0.1 g) and the results were as presented in Table 5.

Table 5: Effect of variation of graphite of cells P^1, Q^1 and R^1 on V_{OC} and J_{SC}

Cell	Mass (g)				Potential (V)	Short cct current density (μAcm^{-2})
	TiO_2	KI	I_2	Graphite-C_X	Voc(V)	J_{SC} (μAcm^{-2})
P^1	0.8	0.01	0.1	0.1	0.05	0.73
Q^1	0.8	0.01	0.1	0.2	0.18	1.42
R^1	0.8	0.01	0.1	0.32	0.223	2.25

From the information recorded in Table 5, a graphical presentation of potentials against the masses of graphite (C_X) was made as shown in Figure 9.
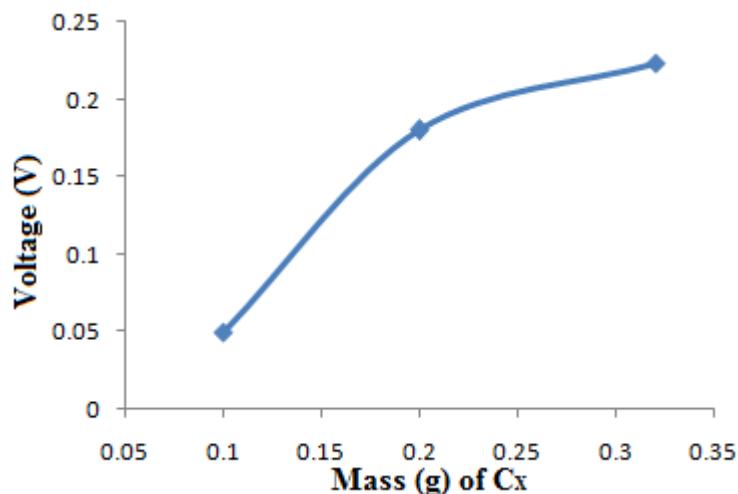

Figure 9: Variation of C_X mass against V_{OC} of cells P^1, Q^1 and R^1

The composition molar ratios (0.8: 0.1: 0.1), (0.8: 0.2: 0.1) and (0.8: 0.32: 0.1) respectively of TiO_2: graphite: I_2 of cells P^1, Q^1 and R^1 were varied.
The results of Figure 9 show a sharp increase in potential up to 0.18 V as the mass of graphite was varied to 0.2 g. A gradual increase in potential was observed up to 0.223 V as the mass of graphite was increased to 0.32 g. This results show that graphite has potential influence on the performance of the solar cell since increase in the potential was proportional the increase in the mass of graphite (Grätzel, 2003). It implies that a molar ratio (0.6: 0.25:0.1) of TiO_2: graphite: I_2 generated the highest output of 0.67V for the cells investigated, for graphite variation.
Going by the ratios of TiO_2: I_2: graphite, it was established that 0.2 g of graphite generated the highest potential of 0.73V. Therefore, our cell for optimum characterization was fabricated at the ass ratios of TiO_2= 0.4 g: graphite = 0.3 g: I_2 = 0.17 g and its I-V characteristic curve was made. Further experiments were carried out on cells with optimized ratios to investigate the effect of thickness on the performance of the optimized solar cell.

CONCLUSION AND RECOMMENDATIONS

In all the cells characterized, even at constant radiation illumination, the V_{oc} was constant but current differed with a factor that could have been contributed by the internal resistance. From the results obtained on optimization of a blank cell, the open circuit voltage (V_{OC}) and short circuit current density (J_{SC}) of 0.083 V and 0.33µA were respectively obtained. These values were low confirming that a conducting medium was necessary for the migration of the generated electrons.

Improved technology needs to be employed to reduce presence of air packets which creates air gaps. These air gaps introduce air capacitance inside the photo active cathode and in between the electrode layers resulting to higher impedance along the electron migrating paths. As a result, few electrons are harvested at the surface of the photo active cathode leading to low photo voltaic and thus low efficiency

REFERENCES

Adegbenro, A. (2016). *Comparison of novel and state of the art solar cells*. University of Kessel, Germany.

Adler, E. (2011). *Semi-conductor photocells and rectifiers; a new cuprous ocide* photocell (Msc Thesis). Columbia University, New York.

Auciello, O., & Krauss, R. (2005). *In situ real-time characterization of thin films.* New York: Wiley.

Caitian, X., Xupeng, L., Zemin, Y., Huigao, Z. E. (2014). *Branched hierarchical photo anode of titanium dioxide nanoneedles on tin dioxide nanofibre network for high performance dye-sensitized solar cells.* Lanzhou University, China.

Fungo, F. (2007). *Photosensitization of Nanocrystalline Semiconductor Film electrodes.* New Jersey: Prentice-Hall, Inc.

Galymzhan, T. K. (2010). *Analysis of Impact of non-uniformities on Thin- film Solar Cells and Modules with 2-d simulations.* Colorado State University Fort Collins, Colorado.

Grätzel, M. (2003). Dye-Sensitized Solar Cells – Science Direct.*Journal ofPhotochemistry and Photobiology,4*(2),145-153.

Grätzel, M. (2009). *Energy Resources through Photochemistry and Catalysis, Technology and Engineering*. New York: Academic Press

Günes, S., & Serdar, S. N. (2008). Hybrid Solar Cells.*Inorganica Chimica Acta,361,*581-588.

Hagfeldt, A. G., Boschloo, L. S., Kloo, L., & Pettersson, H. (2010). Dye-Sensitized Solar cells. *Catalysis, 110,* 6595-6663.

Hebling, G. (2010). Photovoltaic Materials. *Material Science Engineering*, *94*(1), 40-47.

Jessica, C. L. (2009). *The use of nanostructured calcium silicate in solar cells*. Victoria University of Wellington USA.

Kamat, P. (2007). *Actual Applications of Titanium Oxide-Based Photocatalysts.* New York: P-25.

Kiplagat, J. Wang, R.,& Li, T. (2011). Renewable energy in Kenya: *Resource potential and status of exploitation*. Tong University, Shanghai China.

O'Regan, B. & Grätzel, M. (1991). A low cost, high-efficiency solar cell based on dye sensitized colloidal TiO_2 films. *Nature*, *353*, 737-739.

Samuel, H. (2006). *Impact of Back-Contact Materials on Performance and stability of CdS/CdTe Solar Cells*. Xi`an Jiaotong-Liverpool University, Suzhou 215123,Chaina.

Sellappan, R. (2013). *Mechanisms of Enhanced Activity of Model TiO2/Carbon and TiO2/Metal Nanocomposite Photocatalysts*. University of Technology.

Sundaram, K. (2009). *Dye-sensitized solar cells.* London: Taylor & Francis.