FABRICATION OF Cu_2O BACKWALL SCHOTTKY BARRIER SOLAR CELL

Haruna Ali
Nigerian Defense Academy, Physics Department, P.M.B. 2109, Kaduna, Nigeria.

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Abstract

Simple and less economical method of determing the mass of Cu_2O on Cu as well as the thickness of Cu_2O on Cu was investigated. The variations of open circuit, voltage, V_{oc}, resistivity, and short circuit, current, I_{sc} with the thickness of Cu_2O on Cu were investigated. The best V_{oc} (93.05mV) obtained in this study was for the cell thickness of 14μm and resistivity of 0.26Ωm. The highest value of the I_{sc} obtained in this work is 23μ. Results further show that I_{sc} increases with increasing thickness and resistivity of the cell.

Keywords: Short circuit current, resistivity, fill-factor, and shunt resistance.

Introduction

It has become necessary to look for alternative energy sources since demand for electricity is increasing tremendously. In view of this, scientists have been carrying out researches aimed at solving energy problem, which may emanate in the near future. Among several energy sources, photovoltaic systems have some unique and attractive features. These includes

(i) Reliable and long power supply for both small and large scales for satellites and space vehicles as well as in small-scale terrestrial applications (Martin, 1982).
(ii) Requirement of no moving parts when in operation. This makes for less maintenance cost.
(iii) Non pollution of the environment (Martin, 1982).

Solar cell requires encapsulation not only for mechanical protection but also to provide electrical isolation and a degree of chemical protection. Encapsulation provides mechanical rigidity to support the brittle cells and their flexible interconnections. It also provides protection from mechanical damage as may be caused by hail, birds and objects dropped or thrown onto the modules.

The energy conversion by the use of photovoltaic effect can be observed in nature in a variety of materials, but semiconductor devices have shown the best performance in light (Michael, 1990). When solar energy is incident on a solar cell, some of the photons create electron- hole pairs, which in effect generates a photon current.

Solar cells provide the most reliable, long duration power supply for satellites and space vehicles. It is also used in small-scale terrestrial applications. The solar cells are photovoltaic devices in which photons with energies above a threshold value are absorbed to produce electric excitations and electron-hole pairs as charge carriers. The photovoltaic device does not require intermediate stages of conversion to thermal and mechanical energy prior to conversion to electrical energy. The conversion does not involve any moving parts (Martin, 1982). In a photovoltaic power generation system, the exact photovoltaic conversion device, a semiconductor or array of cells is a modular form and converts solar energy directly into electricity. However, the use of photovoltaic cell is very limited due to the cost of photovoltaic materials.

The potential of Cu_2O to be used in semiconductor devices has been recognized since 1920 (Herion, 1979). Copper (I) oxide has been observed to be one of the earliest known semiconductors. It serves as an alternative starting material for solar cells for low cost terrestrial conversion or solar energy to electricity (Ali, 1998). It is said to be one of the earliest known photovoltaic materials and the first in which the photovoltaic effect was successfully explained (Musa, 1994). However, the performance of Cu_2O solar cell is still poor when compare to more developed types of solar cells like silicon solar cells (Furtine and Sears, 1981). Copper (I) oxide was mentioned as a possible material for photovoltaic solar cell, having direct band gap of 2eV, optimum conversion efficiency of 12% at room temperature (Furtine and Sears, 1981). The primary cause for this apparent efficiency plateau is due to the barrier heights of the range of 0.7-0.9eV.

Preparation of copper (I) oxide has been carried out in various ways yielding reasonable results. One of the widely used methods is thermal oxidation. The oxidation of pure copper requires temperature range from 1000 ^{0}C –1500^{0}C with time ranging from one hour to one and half hours for partial and complete thermal oxidation respectively (Ali, 1998). Fast oxidation at high pressure and temperature has been used to produce Cu_2O/Cu backwall cells with the characteristics comparable and possibly superior to frontwall cells made of monocrystalline Cu_2O (Herion, 1979). Other methods used in preparing copper (I) oxide are electro-deposition and sputtering (Olsen and Brahare, 1979).

Aims/objectives

The aims and objectives of this work are as follows:

- To fabricate Cu_2O solar cell by partial thermal oxidation.
- To study the current voltage characteristics of Cu_2O solar cell.
- To study the variation of current and voltage with the thickness of the cell.

Materials and Method

The materials used in the fabrication of Cu_2O solar cells are: copper foil (99% pure), Sodium Persulphate, $FeCl_2$, HCl, distilled water, NaCl and furnace.

The main steps involved in the preparation of Cu_2O solar cells by thermal oxidation are as follows:

(a) Oxidation of high purity copper sheet by heating in air at 1000°C.

(b) Conversion of Cu_2O to single crystal by annealing at 500°C followed by quenching.

(c) Surface preparation by polishing and etching Musa A1994.).

Thermal oxidation method is used in preparation of Cu_2O. The preparation of the sample started with the cutting of the copper foil into small sizes 6mm by 6mm. After thoroughly cleaning the samples, they were dipped in a solution of 4g of sodium persulphate dissolved in 100ml of distilled water. The samples were dried between tissue paper and placed in crucible and gently inserted into the furnace with the help of tong, when the furnace's temperature reached 1000°C. The furnace cover was closed and oxidized for 3minutes. After the oxidation, the samples were annealed for 1½ hour at the temperature of 500 °C. The annealing process was to improve the conductivity of Cu_2O.

After the oxidation and annealing, chemical etching was performed to remove the unwanted CuO layer from the sample. This was done in two stages:

(i) The samples were dipped into the solution containing 5gm of FeCl, 4gm of NaCl dissolved in 100ml of distilled water, and 20cm^3 of concentrated HCl.

(ii) The samples were further dipped in a solution containing 4gm of sodium persulphate, and cleaned in distilled water. Finally, concentrated nitric acid was used to remove Cu_2O layer from one side of the structure $Cu_2O/Cu/Cu_2O$ to obtain Cu_2O/Cu.

The samples used for the thickness measurement were oxidized at constant temperature but varying time of oxidation. The cell samples used for these measurements were without current collection grids.

The thickness of Cu_2O on Cu was measured by the mass loss of Cu_2O/Cu cell after the Cu_2O layer had been dissolved in concentrated HCl. The procedures are as follows:

(i) The samples were weighed in a digital meter balance to obtain the mass of the cell.

(ii) The samples were then dipped in concentrated HCl to remove Cu_2O layers.

(iii) The samples were again weighed to obtain the mass of Cu_2O dissolved, that is, the mass difference before and after dissolving of Cu_2O.

At every step, the thickness, short circuit current, I_{sc}, and open circuit voltage, V_{oc} were measured. The thickness was measured with micrometer and by the equation: thickness = mass/density x Area, while I_{sc} and V_{oc} were measured with voltmeter. The area of the cell was obtained from the dimensions of length and breath of the cell. The density of Cu_2O is 6.0gmcm^{-3} (Furtine and Sears, 1981).

Results and Discussion

At the end of the oxidation and annealing processes, black substances were observed at the surface of the samples. The black substances signified the presence of copper (II) oxide, CuO. Copper (II) oxide is also a photovoltaic material. It has a band gap of 1.5eV.

After etching, the samples turned reddish brown in colour. The reddish brown colour confirmed the presence of copper (I) oxide, Cu_2O. These results showed that the aims of the oxidation, annealing and etching processes were achieved.

It was observed that temperature and time played important roles in the oxidation process. The higher the oxidation temperature, the more the copper (I) oxide layer deposited on copper and the thicker the copper (I) layer. However, irrespective of the oxidation temperature after the annealing, copper (II) is always formed.

Copper wires were fixed to the cell as positive and negative terminals. The contacts between the terminals and cell were made with the help of silver paste. Silver paste has very low resistivity that will have little or no effects on the performances of the cell.

The short circuit current I_{sc} was measured with the same cell used for the measurement of open circuit voltage V_{oc}, and resistivity It was observed that I_{sc} depended on the thickness of Cu_2O on Cu. While I_{sc} increases from 26μA to 50μA, and later decreases to 23μA, the thickness of the cell decreases from36.50μm to 14μm, (Fig. 1). This increase and decrease in the thickness is due to the in-homogenous nature of Cu_2O layer on Cu during oxidation. During the oxidation process, there is possibility of non-uniformly deposition of Cu_2O on Cu. This resulted in the increase and decrease of I_{sc} as the thickness of the cell decreases as shown on the table.

The increase in I_{sc} with the decreasing thickness of Cu_2O on Cu could also be explained in term of the position of photon-generated charges relative to the location of the electric field of the cell. If more Cu_2O is deposited on Cu, it will become difficult for charge separation at the junction between Cu_2O and Cu to take place. The highest value of the I_{sc} 50μA in this work was obtained for the cell thickness of 23μm.

When sunlight strikes solar cell, the incident energy is converted directly into electricity. Solar cell depends upon the photovoltaic effect for their operation.

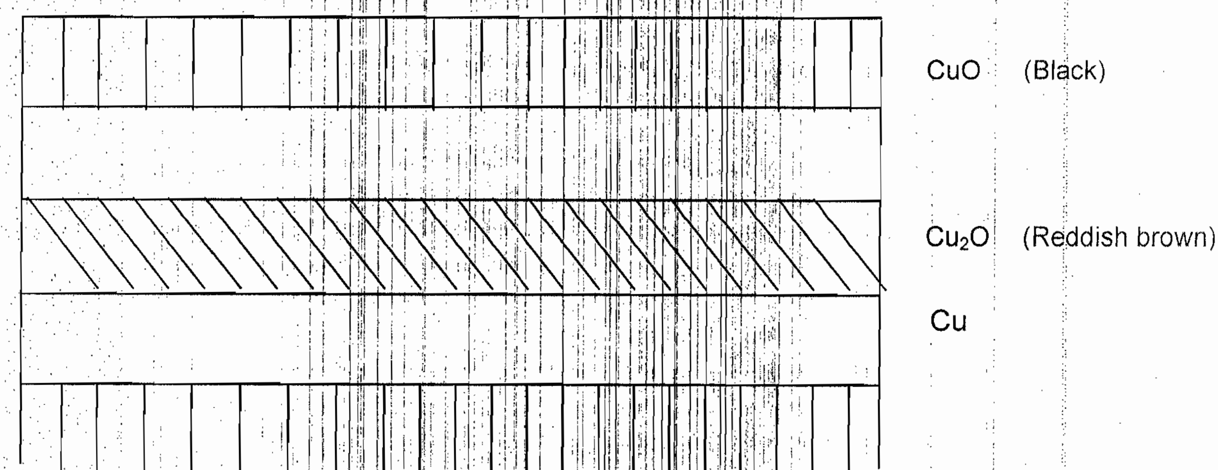


Fig. 1: Sample after oxidation

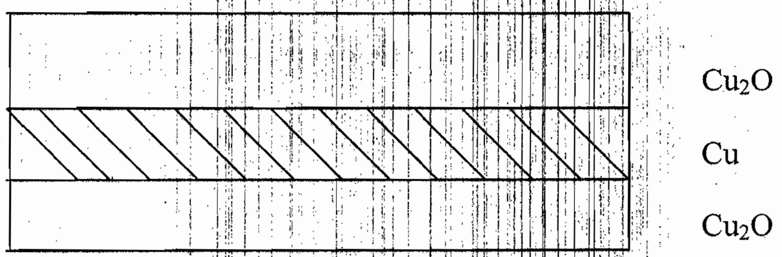


Fig. 2: Simple after etching

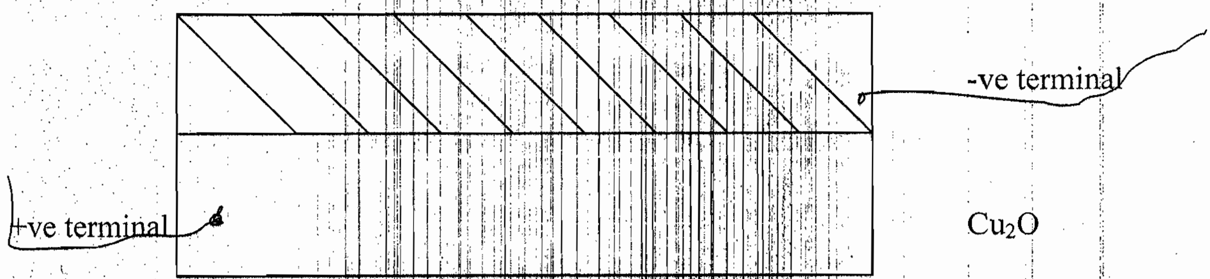


Fig. 3: Completed backwall solar cell

When a ray of monochromatic light is incident on a semiconductor, a certain fraction of the incident power will be reflected and the remainder will be transmitted into the semiconductor. The transmitted light of appropriate energy can be absorbed within the semiconductor and excite electrons from lower energy states to unoccupied higher energy states. Since there are large numbers of occupied states with valence band of a semiconductor separated by the forbidden band from largely unoccupied states in the conduction band, absorption is particularly likely when the energy of the photons making up the light is larger than the forbidden band gap of the semiconductor.

Light of appropriate wavelength shining on the cell creates electron-hole pairs. The concentration of carriers in the illuminated material will therefore be in excess of their values in the dark. If the light is switched off, these concentrations decay back to their equilibrium values. The process by which this decay occurs is known as recombination (Musa, 1994).

The I_{sc} is dependent on the resistivity. As I_{sc} increases from 26μA to 50μA and later decreases to 23μA, resistivity increases from 0.37Ωcm to 0.17 Ωcm and later decreases to 0.26 Ωcm, (Fig. 2). This showed that the thinner the copper (I) oxide layer on copper, the less resistance on photon energy falling on the cell, and therefore the higher the current generated.

The V_{oc} was observed to be linearly dependent on the thickness of Cu_2O on Cu as shown in Table 1 and in Fig. 3.That is, V_{oc} increases from 58mV to 93.10mV as the thickness decreases from 36.50μm to 14μm, higher values of Voc in solar cell are obtained when the thickness of the cell is small. This is because the electric field is situated between Cu_2O and Cu junction in backwall solar cell. It is at this region that carrier separation takes place. The highest V_{oc} (93.05mV) obtained in this work was for the cell thickness of 14μm and resistivity of 0.26 Ωcm.

Solar cells generally have parasitic series, R_S, and shunt resistances, R_{SH}, associated with them. These were obtained from I-V characteristic measured in the dark (Fig. 4a). A series resistance of 689Ω and shunt resistance of 12k Ω were obtained by taking the inverse slope along the straight portion of the I-V characteristic at the forward and reverse bias, respectively.

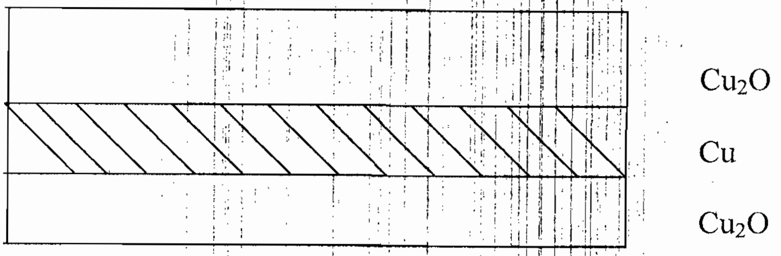
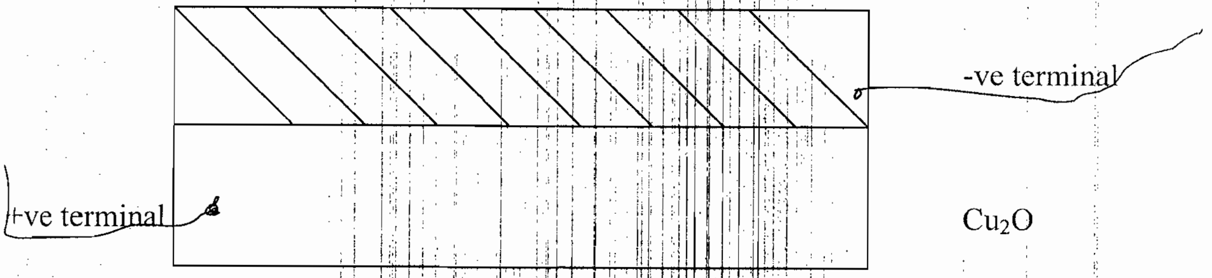


Fig. 2: Simple after etching



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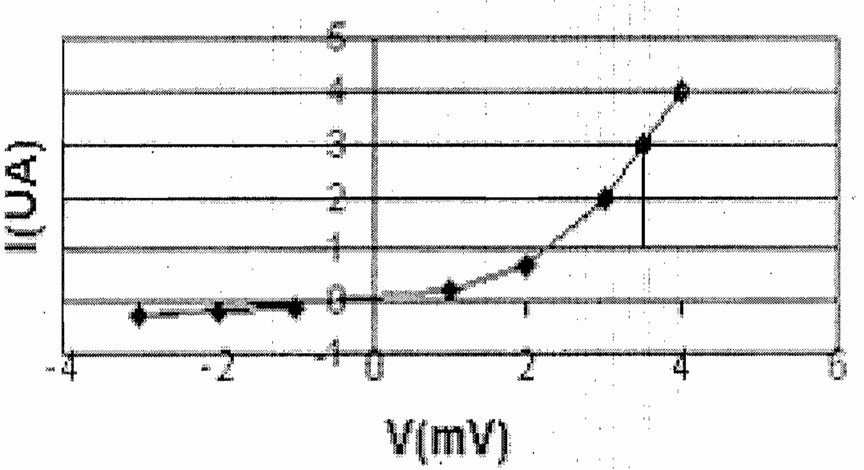
A fill-factor of 0.31, which is the measure of the squareness of I-V characteristic was obtained from the I-V characteristic measured under illumination (Fig. 4b). For better performance of a cell, it is required that R_S should be as close to zero as possible and R_{SH} as close to infinity as possible. These values are good enough to yield high efficiency of the cell performance. The values obtained in this work are in agreement with that obtained in 2000 (Musa and Onimisi 2000). In their work, R_S and R_{SH} obtained are 620Ω and 163k Ω, respectively.

Conclusion

It has been shown that I_{sc} measured changed as the thickness and resistivity of the cell changed and V_{oc} is equally depended on the thickness of Cu_2O on Cu. However, I_{sc} does not completely depend on the thickness of Cu_2O on Cu; as the thickness of Cu_2O becomes very thin, I_{sc} decreases. The deposition of Cu_2O on Cu needs careful attention to avoid too much or less deposition. The thickness of Cu_2O on Cu obtained in this work, that is, 23μm for I_{sc}, 50μA, is of good value for better performance of the cell efficiency.

Table 1: Variation of the thickness of Cu_2O on Cu with I_{sc} resistivity and V_{oc}

I_{sc} (μA)	V_{oc} (mV)	Thickness (μm)	R x 10^3 (Ω)	ρ(Ωcm)
26.00	58.00	36.50	2.23	0.37
35.0	69.00	31.50	1.97	0.28
40.00	70.50	29.50	1.76	0.23
46.00	78.10	27.50	1.70	0.21
50.00	85.00	23.00	1.70	0.17
46.50	87.50	21.50	1.88	0.18
40.00	89.10	18.10	2.23	0.18
30.00	91.50	16.20	3.05	0.22
23.00	93.10	13.50	4.05	0.26



(a)

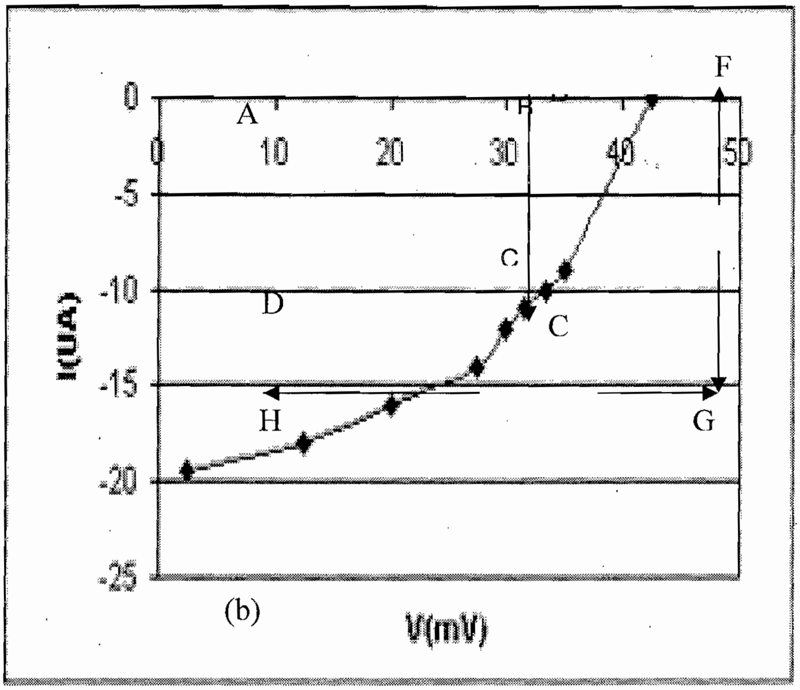


Fig. 4: I – V characteristics (a) in the dark (b) under illumination

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