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Research Article

The Effect of Exchanging the ZnO and CnO Layers on Their Performance

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Abstract

In this work two solar cell types were fabricated. The first type is FTO/ CuO/ ZnO/ Al and the second type is FTO/ ZnO/ CuO/ Al. Six samples were prepared from each type. The efficiency for each type was obtained. It was found that the efficiency of FTO/ ZnO/ CuO/ Al is in the range $\sim 0.6 \times 10^{-3}$ *, while the efficiency of FTO/ CuO/ ZnO/ Al is in the range* $\sim 2 \times 10^{-3}$ *. The difference may be attributed to the fact that FTO and CnO acts as p- type semiconductor, while ZnO act an n- type semiconductor. Thus the first type acts as pnp component thus have low efficiency, while the second type acts ppn component and have relatively high efficiency*

Keywords: *solar cell, fabricated, efficiency, semiconductor.*

1. Introduction

Energy is very important for civilization. It is important for industry telecommunication, and transportation. There are energy sources, among them; solar energy looks a more convenient for human needs. This is since it is renewable, neat & pollution free (D.A. Neamen *et al*, 2007). Solar energy can be converted into useful energy forms (Li, B.Wang *et al*, 2008). The most popular conversion is to convert solar light energy into electrical one. This is because electricity is widely used and can be converted to other energy forms (S.M. Sze, *et al*, 2009).

Solar cells fabricated from silicon are widely used now. But unfortunately its fabrication is complex and expensive. This forces scientists to search for alternative cheap materials that can be used to fabricate solar cells easily. Among these ZnO and CuO play an important role as cheap alternatives. Zinc oxide (ZnO) is a wide-band gap II-VI compound semiconductor with a direct band gap of 3.37 eV at room temperature. With an electron binding energy of 60 meV

(H. Kidowaki, *et al* 2012) and the superior properties such as anti-oxidation and chemical stability, ZnO is a promising optoelectronic material with great potential in the applications for optical detector, gas sensor, solar cell, short-wavelength UV laser, and blue or green optoelectronic devices (H. S. Rauschenbusch 2012). In the present time, the synthesis of ZnO with novel shapes (e.g. wire, rod, lamina, and tube) has attracted wide spread attention (H. Kidowaki *et al* 2012). The cost reduction of the solar cells is one of the most important issues.

Therefore Oxide semiconductors are one of the alternatives to silicon solar cells, and copper oxides such as CuO and Cu_2O are one of the candidate materials. The features of copper oxide semiconductors are relatively higher optical absorption, low cost of raw materials and non-to xicite. CuO and Cu_2O are p-type semiconductors with band gap energies of 1.5 eV and 2.0 eV, respectively, which are close to the ideal energy gap of 1.4 eV for solar cells and allows for good solar spectral absorption (Li, B., Wang *et al* 2008). The highest efficiency of ~2 % for Cu2O solar cells has been obtained by using the high temperature annealing method. Cu_2O/ZnO thin film solar cells have also been studied and reported. However, the solar cells with a CuO/ZnO structure have not widely fabricated and studied. The purpose of the present work is to fabricate and characterize solar cells with CuO/ZnO structures. The band gap energy of CuO is ~1.5 eV, which is closer to the ideal band gap of 1.4 eV. Zinc oxide (ZnO) is an n-type semiconductor with a wide band gap of ~3.37 eV, which can be applied to solar cells.

(H. Kidowaki *et al* 2012).A part from introduction in sections 1, Section 2 is concerned with materials and methods, while section 3 is devoted for results and discussion. The conclusion is in section 4.

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2. Materials and Methods

2.1 Description of the Materials

Zinc oxide (ZnO) is considered as an excellent materials in this study because of it's a wide band gap($\sim 3-3.5eV$), high free carrier concentrations for electron conduction (10^{18} cm^{-3}), and very similar electron affinity (4.35eV) .These properties suggest minimal voltage loose during charge transport across the interface. The oxide has been shown to form a chemically stable p-n hetero junction (B Ghoch, M.Dos *et al* 2013). As n-type metal oxide semiconductors zinc oxide (ZnO) has attracted intensive research attention owing to its diverse interesting properties such as electro-optical, piezo electronic, and magnetic properties, with a direct band gap and relatively large exaction binding energy of (60 meV). Also the low toxicity and relatively easy processing of ZnO make it an attractive with other materials. As n-type metal oxide semiconductors (Kamat, P.V., *et al* 2014) (P. Würfel, *et al* 2014)

Cupric oxide (CuO) is anther metal oxide material that has been substantially explored for furious fields of applications. As a p-type semiconductor having a narrow band gab of (1.35 eV), CuO has great potential as a field emitter, catalyst and as a gas sensing medium The physiochemical properties of CuO such as the photoconductivity and the photochemistry can be tailored for fabricating optical switches and solar cells.

As a solar material, cuprous oxide Cu_2O has the advantages of low cost, great availability, non-toxic nature for use in thin film solar cells, a theoretical solar efficiency of about 9-11% an abundance of copper and the simple and inexpensive process for semiconductor layer formation. In addition to everything else, cuprous oxide has band gab of 2.0 eV which is within the acceptable range for solar energy conversion, because all semiconductors with band gab between 1 eV and 2 eV are favorable material for photo voltage cells (Werfel. P *et al* 2009)(V.D. Mihailetchi *et al* 2010)

2.2 Set up

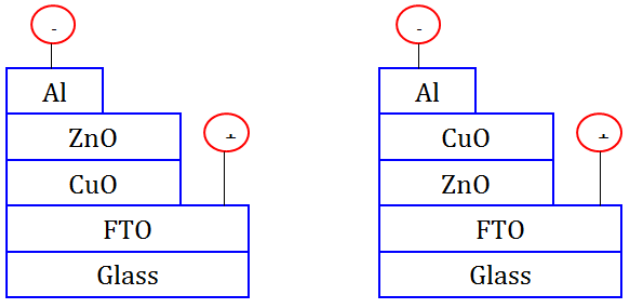

Figure 1: structure of (a) FTO/CuO/ZnO/Al and (b) FTO/ZnO/CuO/Al solar cell

Table 1: FTO/ ZnO/ CuO/ Al Solar cells performance

Structure	(V_{oc})V	Jsc (mA cm^{-2})	FF	η%
(1)	0.221	2.858×10^{-3}	0.99	6.24×10^{-4}
(2)	0.220	2.908×10^{-3}	0.98	6.32×10^{-4}
(3)	0.221	2.931×10^{-3}	0.99	6.45×10^{-4}
(4)	0.223	4.462×10^{-3}	0.98	9.79×10^{-4}
(5)	0.222	3.003×10^{-3}	0.98	6.55×10^{-4}
(6)	0.214	2.688×10^{-3}	0.97	5.59×10^{-4}

Avery simple apparatus was used for electro deposition its consisted of CuO layers were prepared on pre-cleaned fluorine –doped tin oxide (FTO) glass plate by electro deposition using platinum counter electrode. Two electrodes (cathode and anode) and a standard electrical circuit for electrolysis.

The deposition solution contained copper sulfate ($CuSO_4$) 0.4 mol/l, wako 97.5%) and lactic acid ($C_3H_6O_3$)(3mol/l wako) were dissolved in to distilled water. PH of the electrolyte solution was adjusted to 12.5 by adding NaOH. The temperature of electrolyte solution was kept at 650°C during electro deposing. Preparations of CuO layer were carried out at voltage of +0.70V and quantity of electric charge of 2.2C cm^{-2}. After the deposition, the sample was rinsed with water and transferred in to the ZnO electro deposition bath. ZnO layers were electrodeposited from 0.025M aqueous solution of Zn (NO_3) of the FTO/CuO substrate. Finally, the substrate were rinsed with water, dried we use the spin coating and quickly transferred in to a thermal evaporator for the vacuum deposition of the aluminum (Al) back contact.

The structure of hetro junction solar cells were denoted as: FTO/CuO/ZnO/Al (six samples from 1-6) and FTO/ZnO/CuO/Al also (six samples from 7-12) with a schematic illustration as shown in figure (3-4 set up).

3. Result and discussion

The objective of this work is to develop a low cost, easy to manufacture, cuprous oxide (CuO) - based solar cells with zinc oxide (ZnO) to be fabricated on Fluorine - doped tin oxide (FTO) by an electrode position. The performances of the solar cells with FTO/CuO/ZnO/Al and FTO/ZnO/CuO/Al structures were investigated.

Measurements of the CuO/ZnO and ZnO/CuO hetero junction light current- voltage characteristics

were done. The optical absorption of thin film were also measured, beside determination of the optical band gap energy (E_g).

The FTO / ZnO / CuO / Al sample (1) , (2) , (3) , (4) , (5) and (6) structure showed characteristic curves with short – circuit current and open circuit voltage . Table (1) Shows measured parameters of ZnO / CuO – based solar cells.

The figures below, shows V – I characteristics for ZnO/ CuO Sample (1), (2), (3), (4), (5), and (6) of ZnO /CuO solar cells.

The FTO/ CuO / ZnO (Al) , stricture (7), (8) , (9), (10), (11) and (12) showed characteristic current with short – circuit current density (J_{sc}) and open – circuit voltage (Voc), fill factor (FF) and provided a power conversion efficiency (η) Table (2) shows measured parameters of CuO/ZnO – based solar cells

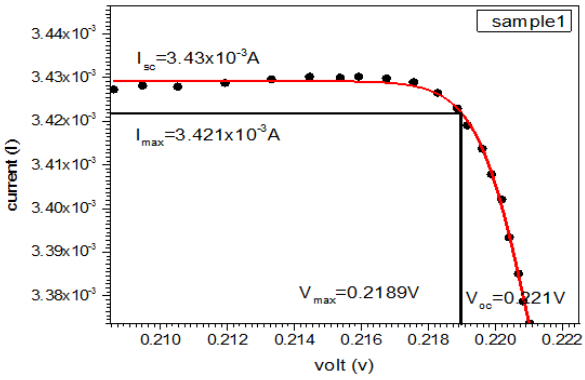

Figure 2: V – I characteristics for sample1

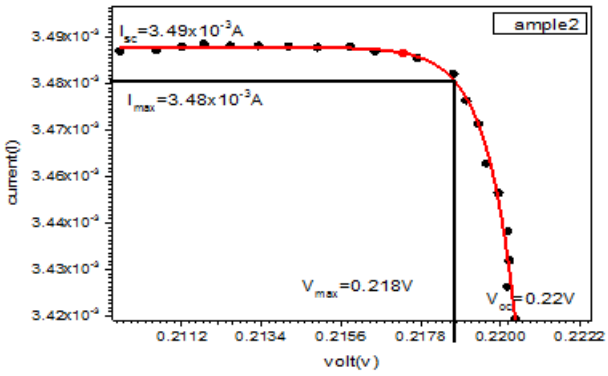

Figure 3: V – I characteristics for sample2

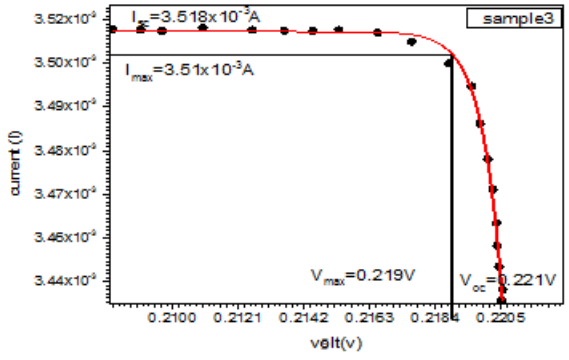

Figure 4: V – I characteristics for sample3

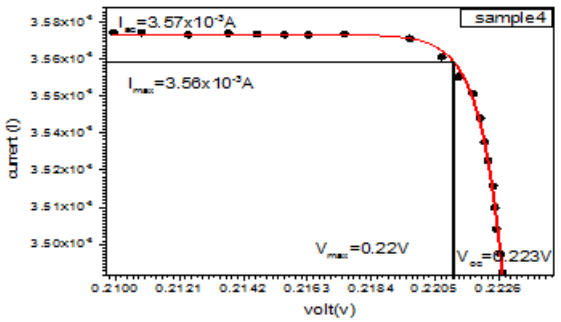

Figure 5: V – I characteristics for sample 4

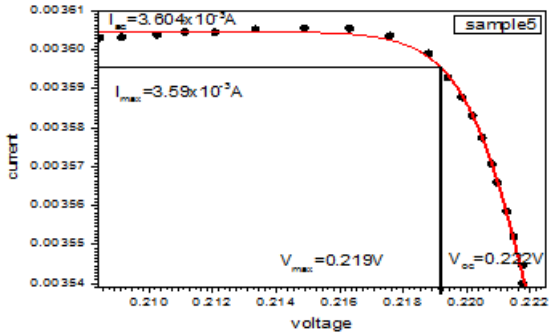

Figure 6: V – I characteristics for sample 5

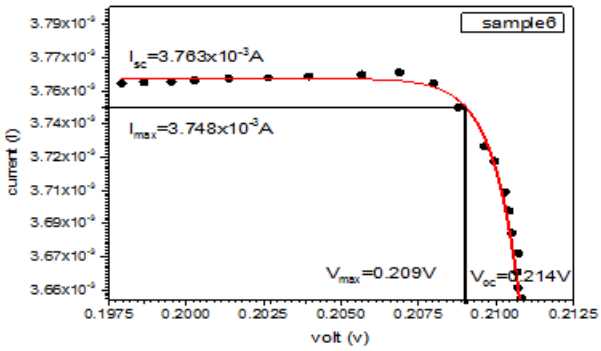

Figure 7: V – I characteristics for sample 6

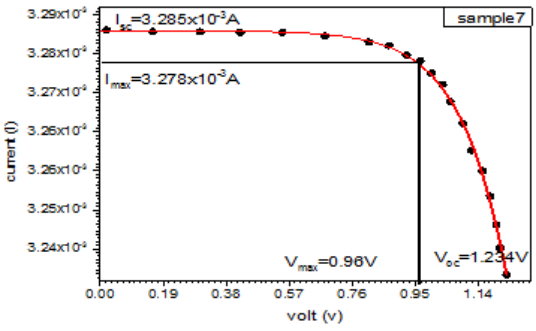

Figure 8: V – I characteristics for sample 7

In view of tables (1) for FTO/ ZnO/ CuO/ Al solar cell the average efficiency is about $\sim 0.65 \times 10^{-3}$. While the average efficiency for FTO/ CuO/ ZnO/ Al is about $\eta \sim 2 \times 10^{-3}$ the efficiency of FTO/ ZnO/ CuO is lower than FTO/ CuO/ ZnO type.

Table 2: FTO/ CuO/ ZnO/Al Solar cells performance

Structure	(V_{oc})V	J_{sc}(mAcm^{-2})×10^{-3}	FF	η%
(7)	1.23	2.74	0.787	2.62×10-3
(8)	1.14	2.75	0.763	2.39×10-3
(9)	1.13	3.30	0.821	3.06×10-3
(10)	0.875	2.767	0.904	2.188×10-3
(11)	0.220	2.86	1.18	7.303×10-4
(12)	0.898	2.81667	0.85	2.14×10-3

This may be related to the fact that FTO act as a p- type Sc since F acts as an accepter, which is well known in the literature. ZnO act a n- type while CuO is a p- type Semiconductor.

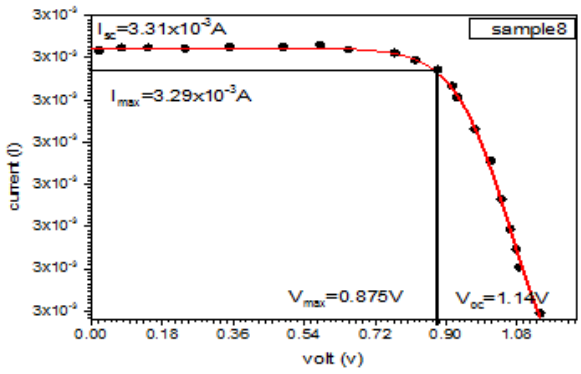

Figure 9: V – I characteristics for sample 8

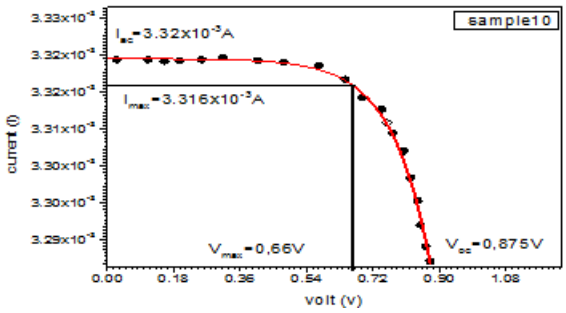

Figure 11: V – I characteristics for sample 9

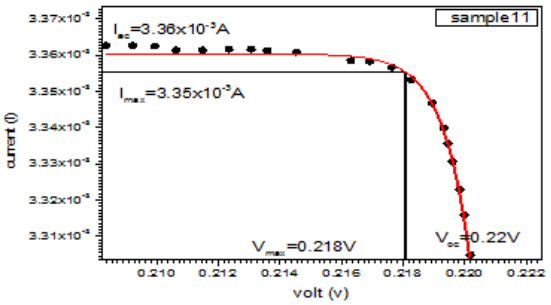

Figure 12: V – I characteristics for sample 11

Thus the first cells act as pnp Semiconductor therefor the free electrons amount in ZnO diffusing to the negative electrode were lowered appreciably by CuO holes, since these electrons passes through their ways to the negative electrode. However, the situation is different for the second cell which act as a ppn Semiconductor. For such cell the ZnO free electron transfer directly to the negative electrode, while CuO and FTO holes diffuse to the positive electrode thus increases electric potential difference appreciably.

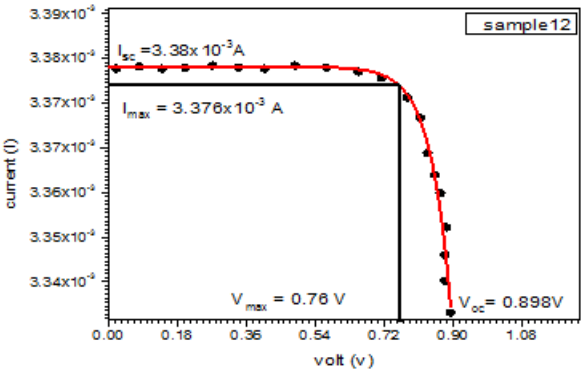

Figure13: V – I characteristics for sample 12

Conclusions

The solar cell which is formed from FTO/ CuO/ ZnO/ Al respectively is more efficient and has good performance compared to FTO/ ZnO/ CuO/ Al solar cell. The efficiency can be increased considerably by adding donors to ZnO and acceptors to CuO.

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