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Fabrication of p-Cu_2O/n-Cu_2O for Photovoltaic Applications

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Abstract

This work presents n-Cu_2O/p-Cu_2O device for photovoltaic application. The n-type cuprous oxide layer is formed by heating copper foil in 0.1M Cu_2SO_4 at 80℃ for one hour and the p-Cu_2O layer is formed by thermal oxidation of copper foil at 930℃. Both the n-Cu_2O and the p-Cu_2O layers were analyzed by scanning electron microscope SEM and X-ray diffractormeter. The SEM micrographs show that the n-Cu_2O layer is composed of smaller grains of different sizes and bigger grains of different orientation for the p- Cu_2O samples annealed at 250℃. The XRD spectra shows that the n-layer is composed of Cu_2O prominent reflections along (111) plane at $2\theta = 36.4^o$ and other smaller reflections along (110) plane at 2θ=29.5^o, (200) plane at 2θ=42.3^o and (220) plane at 2θ=61.3^o. And the p-layer is composed of prominent reflections of Cu_2O along (111) plane at $2\theta = 36.5^o$, (110) plane at 2θ=30^o, (200) plane at 2θ=42.5^o and (220) plane at 2θ=62^o and also there is CuO reflection along (221) plane at 2θ=74^o. Moreover the device shows photoresponse with values of I_{sc} and V_{oc} as recorded in a daylight as, I_{sc}=21μA and V_{oc}=60mV for the cell without annealing and I_{sc}=17 μA and V_{oc}=47mV for the annealed cell which is possibly as a result of effect of annealing on the junction.

1.0 Introduction

With the recent rise in energy demand and cost, and the world's major energy sources are non-renewable taken from sources like wood, coal, petrol and gas, which are available on the earth's surface in limited quantity and may likely finish in the near future. These sources mainly of fossil nature emit greenhouse gasses, mainly carbon dioxide as a result of burning of fossil fuel which contributes tremendously to the increase in the average measured temperature of the earth near the surface, leading to the global warming[1-5]. The sun is outstanding amongst the potentially new sources of energy because of its abundant and widely distributed and non-polluting. The direct conversion of solar energy to electricity using photovoltaic (PV) cells is likely to be a good solution to the global energy problems; especially if practical economic means of direct conversion can be developed. Photovoltaic (PV) systems have several advantages; they are cost effective alternatives in areas where extending utility power lines is very expensive, they have no moving parts and require little maintenance and produce electricity without polluting the environment. Presently, there are few PV cells that are widely used in commercial quantities; these are; silicon p-n junction solar cells, cadmium sulphide/copper sulphide (CdS/Cu_2S). Gallium arsenide (GaAs), and amorphous silicon (a-Si) solar cells. But their future development is predictably going to be lowered by high cost of material. Cuprous oxide is a good candidate for photovoltaic solar cell applications, due to its low cost, abundance of the starting material (Cu) on earth, nontoxicity, cheap and simple processing technique, fairly high minority carrier diffusion lengths, high absorption coefficient in the visible region, and large exciting binding energy with a direct energy gap of 2.1eV and optimum theoretical efficiency of over 20% [6-14].

Several methods have been employed by various researchers to fabricate Cu_2O based solar cells of reasonable efficiencies as schoktty barrier[18-20], heterojunction[3, 9, 21-26] and recently homojunctions[11, 28, 29] were also developed but yielded a disappointing result in most cases due to reaction problems, low mechanical stability, high series resistance, poor barrier characteristics, low morphology, inability to control conductivity type and other problems associated with the deposition conditions like non-simplicity and cost of the procedure (sophisticated and costly equipment) and lack of control on deposition conditions (Temperature, pH, concentration and potential/current) [2, 12,15-17, 21, 31].

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Considering the above listed problems, this paper presents the n-type cuprous oxide/p-cuprous oxide solar cell techniques for photovoltaic applications;p-Cu_2O was produced by thermal oxidation followed by n-Cu_2O by chemical method.

2.0 Experimental Procedure

For the purpose of this deposition the following materials are needed;copper foil, nitric acid, ionized water, tissue paper, anhydrous copper (II) sulphate of 99% purity (BDH-GPR) of molecular weight 159.60, distilled water, melter B154 analytical balance, jenway electronics PH meter, water bath, beaker and sodium per sulphate($Na_2S_2O_8$) .

2.1 Copper Preparation

To prepare good quality Cu_2O material on Cu, the copper surface condition is very important especially for thin oxide. The copper foil was streghtenned and folish this eliminate any grease or dirty from the surface of the copper foil. High purity sheet (0.1mm thickness and 99.99% purity) were cut sample of 1cm × 2cm size and were polished afterwards. The copper sheets were then diffed into the solution of sodium per sulphate ($Na_2S_2O_8$) and washed for three minutes then latter rinsed in distilled water for 20 seconds several times and finally dried between tissue papers and finally in air.

2.2 Solution Preparation

Anhydros copper (II) sulphate of purity 99.0% (BDH-GPR) of molecular weight 156.60 was used to make $CuSO_4$ solution of 0.1M concentration. A melter AR214 analytical balance was used to weight 3.990g of copper (II) sulphate and dissolve in 250cm^3 of distilled water and stirred untill a uniform solution was obtained.

2.3 p- Cu_2Odeposition

This was achieved by oxidizing a purified copper sample in a furnace at 935℃ for 10minutes and quenched in cold distilled water. Followed by annealing the sample at 250℃ for 2 hours then etching the unwanted CuO layer in a solution of 4g of NaCl, 5g of $FeCl_2$ and 20cm^3 of conc. HCl in 100ml of cold distilled water for 20minutes.

2.4 Fabrication of p-Cu_2O/n-Cu_2O Solar Cell.

During this deposition some portion of p-Cu_2O produced abovewas washed away using conc. nitric acid until copper (Cu) layer was exposed then washed in the solution of sodium per sulphate ($Na_2S_2O_8$) for 20 seconds and rinsed with distilled water several times and dried between tissue paper followed by the growth of n-Cu_2O.During this deposition 100cm^3 of 0.1M $CuSO_4$ solution was taken in a beaker and its PH was measured as 4.62 using PHS-25 pH meter, the beaker containing the solution was taken to water bath and heated to 80℃, the sample was then dipped in to the heated solution and heated for about one hour, the sample was then removed rinse in distilled water and dried between tissue paper then in air. The structure of the form p-**Cu_2O/n-Cu_2O** was formed at the surface after the deposition process. as shown in Fig. 1

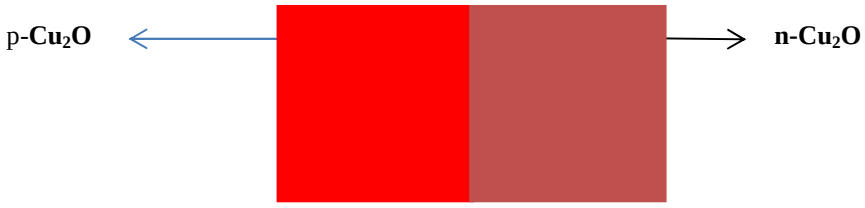


Figure 1: -p-Cu_2O/n-Cu_2O structure.

2.5 SEM, XRD and Photoresponse Study.

The surface morpholgical analysis of the deposited n-Cu_2O, p- Cu_2O and p- Cu_2O/n- Cu_2O solar cell, was studied using Scanning Electron Microscope (SEM) model phenom (Pro X) at Umaru Musa yar'aduwa University Katsina State in Biology research Lab. And the phase and crystalline structure of the deposited films by X-ray Diffractometer (XRD) model Empyrean difractometer DY 674 (2010) at National Geosciences Research Lab NGRL Kaduna.

The cell photoresponce, the open circuit voltage V_{oc} and the short circuit current I_{sc} was analysed by Illuminating the cell on solar radiation at no load condition as shown in the Fig.2a

Result and discussion

3.0 SEM Analysis

The surface morphology of the n and p cuprous oxide layer as observed by Scanning Electron Microscope model (Pro X) shows that the n-cuprous oxide layer is composed of smaller grains of different sizes and the p-cuprous oxide is composed of bigger grains of different sizes and orientation with some black spots of cupric oxide as shown in Fig. 3 a and b. And the p-n-Cu_2O solar cell appears with n-layer darker than the p-layer as shown in Fig 2a.

3.1 XRD Crystal Structural Analysis of n-Cu_2O.

The structural and phase identification for the depositedCu_2O layers were studied with XRD model Empyrean diffractor meter DY 674 (2010) using scherrered equation.

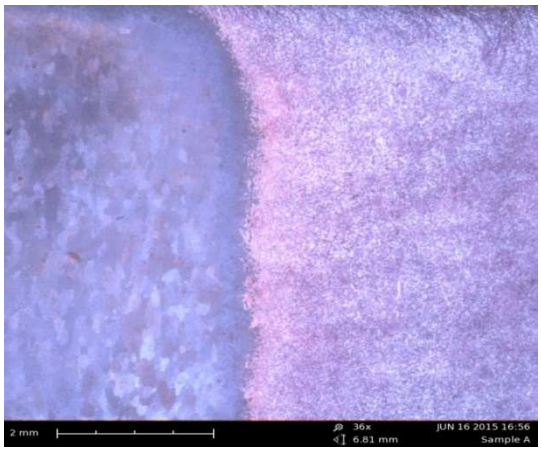
$$D = \frac{K\lambda}{\beta cos\theta} \qquad (1)$$

Where, D is the grain size, K is a dimensionless shape factor with a value (0.9) which varies with the actual shape of the crystallite, λ is the wavelength of the X-ray used (1.5402A). $\beta$is the full width of the half maximum of the most intense peak, θ is the Bragg angle corresponding to maximum X-ray diffraction peak.

The angle of diffraction (2θ) is varied from 05-75^o as shown in the Fig. 4 a and bthe XRD pattern of n-Cu_2O shows Cu_2O prominent reflections along (111) plane at $2\theta = 36.4^o$ and other reflections along (110) plane at 2θ=29.5^o, (200) plane at 2θ=42.3^o and (220) plane at 2θ=61.3^o The presence of these planes ensures the true deposition of Cu_2O layer without CuO impurities. And that of p-Cu_2O layershows prominent reflections of Cu_2O along (111) plane at $2\theta = 36.5^o$ apart from this reflection other reflections along (110) plane at 2θ=30^o, (200) plane at 2θ=42.5^o and (220) plane at 2θ=62^o are also seen, Moreover there is CuO reflection along (221) plane at 2θ=74^o. The presence of these planes ensures the true deposition of Cu_2O layer with CuO as impurity.

4.0 Conclusion

A p-n- cuprous oxide solar cell have been fabricated which gives an I_{sc}=21μA and V_{oc}=60mV for the cell without annealing and I_{sc}=17μA and V_{oc}=47mV for the annealed cell. And can be improved if a careful method of removing p-Cu_2O layer can be developed to minimize the effect of conc.HNO_3 on weakening the layer and by applying grids on the surface of the layer. The method is a low cost, low temperate, simple, requires no sophisticated set up.



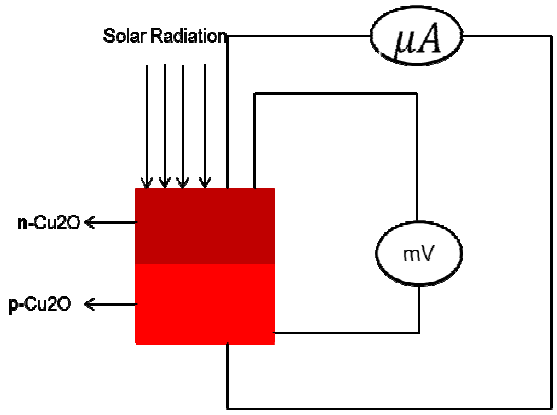
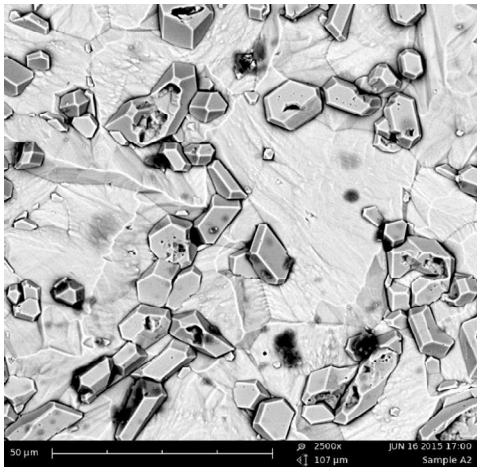


Fig. 2 (a) p-**Cu_2O/n-Cu_2O structure by SEM** **(b) photo responds circuit**



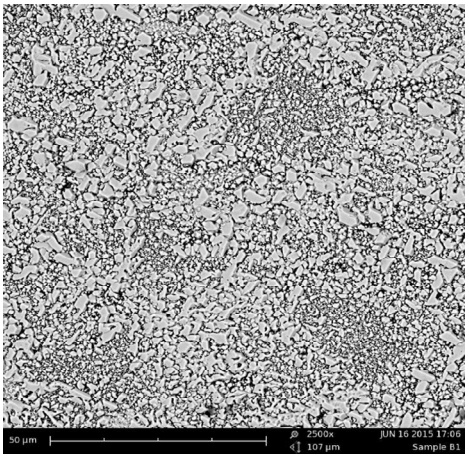


Fig. 3 SEM micrographs (a) p-**Cu_2O** **(b) n-Cu_2O**

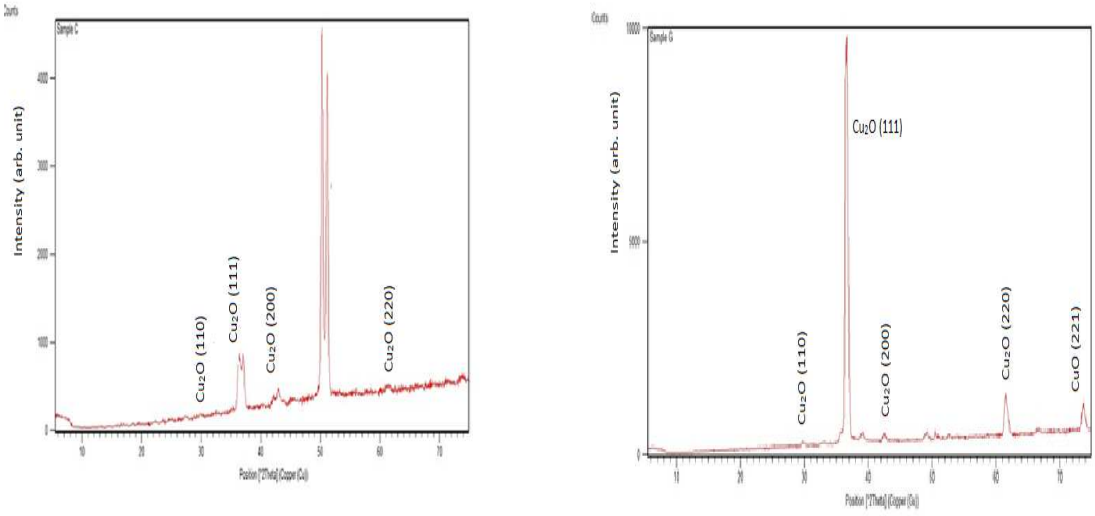


Fig. 4 XRD micrographs (a) n-**Cu_2O (b)p-Cu_2O**

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