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GROWTH AND OPTOELECTRONIC PROPERTIES OF p-CuO:Al/n-Si HETEROJUNCTION

B. K. H. AL-MAIYALY, B. H. HUSSEIN*, H. K. HASSUN
Department of Physics, College of Education for Pure Science / Ibn Al-Haitham, University of Baghdad, Baghdad, Iraq

A thin films of CuO and CuO:Al as well as p-CuO:Al/n-Si heterojunction with different Al ratios (0,1,2,3)%wt has been successfully fabricated by thermal oxidation with exist oxygen. The energy gap for thin films was calculated from optical properties. The capacitance was calculated as a function of voltage at reverse bias, and it demonstrate that these heterojunctions are abrupt. The capacitance values decreases with increasing the reverse bias while it increases with increasing Al ratio. The results indicated that the width of depletion layers and highest built in potential values decreases as Al concentration increases. The difference between reverse and forward current with applied voltage confirm for p-CuO /n-Si and p-CuO:Al/n-Si that the heterojunction have a high rectification characteristic.

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1. Introduction

During the past years, scientists have high attention to the group transition metal oxide thin films due to their unique properties which good promising applications in the field of nanotechnology [1].

Copper Oxide (CuO) among different transition metal oxide thin films have been investigated for photo-thermal and photoconductive applications, these films have monoclinic structure, high optical absorption, a narrow band gap (1.5 -2.1 eV) and p-type conductivity in common which suitable for fabrication junction devices such as pn junction diodes and solar cell [2, 3,4]. It exhibits many properties such as stability, non-toxic nature, high thermal conductivity, low cost production processing, reasonably good electrical and optical properties and photovoltaic performance [5,4].

These properties makes CuO have a wide range of application including constructing of optoelectronic devices [6]. Lithium ion electrochemical cell, selective gas sensors [7], field emission devices, heterogeneous catalysts [8], solar cells [9,10], basis of high-T_C super conducting materials, nanofluid, nano-devices for catalysis and giant magneto resistance materials [11]. Also can be used Copper Oxides nanowires in p-type field effect transistors [12].

Undoped and aluminum doped CuO nanocrystalline materials is ready by composite-hydroxide mediated approach[13]. Different physical and chemical methods of deposition practices have been used to synthesize Copper Oxide thin films, for example sol- gel techniques [14], pulsed laser deposition [15], low temperature microwave

Annealing [4], chemical spray pyrolysis [16], composite hydroxide- mediated approach [13], cost-efficient and facile Successive Ionic Layer Adsorption and Reaction method [1], and electro deposition [3],etc.

The aim of the current research is to fabricate CuO:Al/Si heterojunction (HJ) after preparation (Cu) thin films by thermal evaporation technique and oxidation these films with exist

* Corresponding author: bushrahhz@yahoo.com

oxygen . As well as studying the Al ratios effect on it is optical and photovoltaic heterojunction properties.

2. Experimental

Cu thin films have been prepared by thermal evaporation method in a high vacuum system of ($3x10^{-6}$) torr on glass and Si substrate from boat of molybdenum using Edward coating unit model (E-306), with (0.4)μm thickness and (1 nm/sec) deposition rate ,the distance between the substrate and boat was about 16 cm. The thin film has been oxidation by heat treatment using electric furnace at 773 K for one hour with exist oxygen gas flow. Then doped with different ratio of Al (0.01, 0.02 and 0.03). UV/Visible 1800 spectrophotometer used to study the optical properties for films deposited on glass substrates from (300- 1100) nm. The effect of Al concentration on energy gap value Eg has been calculated from Tauc formula [17,18].

To determine the type of the heterojunction (abrupt or graded), the width of junction, built-in potential (V_{bi}) and concentration, C-V characteristics have been investigated by using LCR meters, the capacitance of p-CuO:Al/n-Si hetrojunction with different Al ratio was examined as a function for the reverse bias voltage at high frequency (100 KHz) within the range (0 to -3) Volt

(I-V) Current voltage measurements for p-CuO:Al/n-Si hetrojunction were investagated at reverse and forward bias voltages under dark case at the range (0-3) Volt by using voltmeter and D.C power supply model Dazheng: PS-303D, Keithley 616 digital electrometer.

3. Results and discussion

The Copper Oxide (CuO) films deposited using thermal evaporation with different Al concentration (0,1,2,3)%wt were described by UV–Visible spectrophotometer to determine the optical properties. To examine the transmittance properties and determine the energy gap energies of the produced films, Figure 1 displays the spectra of transmittance in the evaluating range between 400 to 1100nm. The CuO and CuO:Al films have a small transmittance around 10% between 400 and 800 nm. When the wavelengths lower than 800 nm the transmittance decreasing this mean high absorption for CuO and CuO:Al in the visible range because the electronic transition between the valance and conduction Band[16]. The highest values of absorbance of CuO:Al at high ratios (3%) Tauc equation [17,19] used to calculate band gap of CuO and CuO:Al samples, the band gap energy is estimated from and the absorption coefficient by lambert law[20]. The valued energy gap for undoped CuO is 1.5 eV and for 1%, 2% and 3%, Al doped CuO is 1.4, 1.3 and 1.2 eV. Figure 2 presented the evaluated values of energy gap. It is obviously that with increasing in Al ratios energy gap is decreased which mean there is shift toward red in absorption edge. The observed red shift in energy gap can be attributed to the combination of Cu+2 ions by Al+3 ions resulting an increase of defects due to the difference in ionic radii[13]. Therefore, our CuO and CuO:Al thin films good material choice in solar cells.

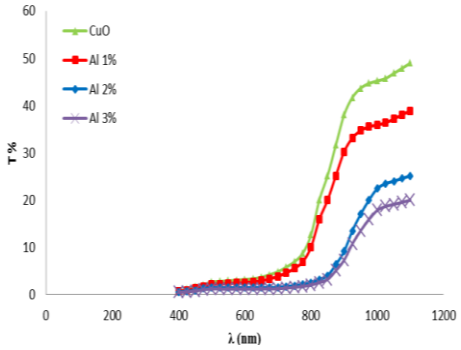

Fig. 1. Transmittance spectra with wave length for thin films CuO for Al (0,1,2,3)%.

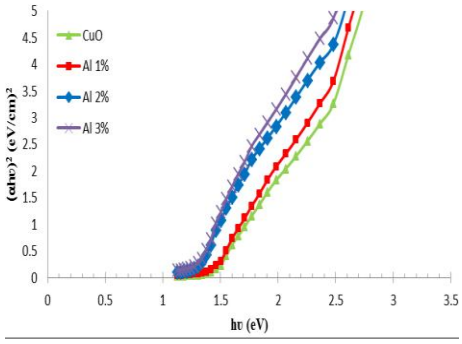

Fig. 2. $(\alpha h\upsilon)^2$ verse with photon energy of thin films CuO for Al (0,1,2,3)%.

The **p-CuO** /n-Si heterojunction with different Al concentration as shown in Fig. 3.

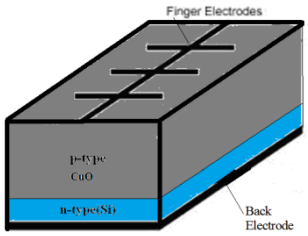

Fig. 3. Schematic represent the p- CuO /n-Si heterojunction.

The capacitance-voltage C-V measurement go to calculate different factors for example built-in potential, junction capacitances, and depletion widths. Figure 4 shows the relation between $1/C^2$ and V at different Al ratios (0,1,2,3)%wt. From Fig. 4 and Table 1, it can be concluded that junction capacitance is inversely proportional to the bias voltage for all films that related to expansion of depletion layer with the built-in potential, the decreases the capacitance at zero bias voltage (C_o) of CuO:Al thin films when the increase of Al concentration.

The depletion layer width increases with increasing Al concentration that is due to the increasing in the carrier ratios which leads to reduce of the capacitance as presented in Table 1. The relationship between ($1/C^2$) and a reverse bias of voltage is lined that is mean the heterojunction of abrupt type. When $1/C^2$ equal zero we can found the built-in voltage of the device [21], as in Table 1.

Table 1. Values of C_o, W, and V_{bi} for CuO /Si heterojunction for different Al concentration.

Al concentration	**C_o(nf/cm^2)**	**W=$\varepsilon_{(s)}/C_0$ (nm)**	**V_{bi}(Volt)**
CuO (Pure)	47.14	63.64	0.7
CuO:Al (1%)	42.25	71.00	0.5
CuO:Al (2%)	36.51	82.16	0.3
CuO:Al (3%)	32.44	94.47	0.2

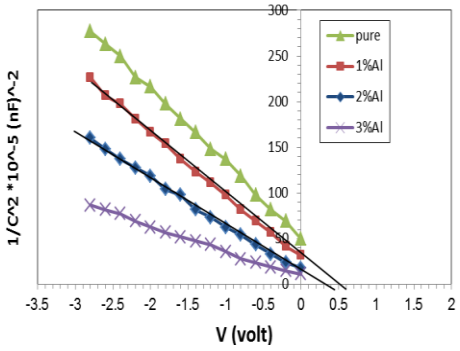

Fig. 4. Relation between $1/C^2$ and reverse bias voltage for CuO /Si heterojunction with different Al (0,1,2,3)%.

Fig. 5 show the (I-V) characteristics of synthetic CuO /Si and CuO:Al /Si HJ at both reverse and forward biases voltage for different Al ratios (0,1,2,3)% with illumination condition that calculated using equation Shockley [20]. When the forward bias the value current is increases with increasing of Al ratios, which refer to increase in the absorption and decrease in transmittance (as we see in Transmittance spectra), and to improve in crystal structure by increasing Al concentration. Because the increasing of Al ratios will cause decrease the dangling bond and a rearrangement the interface atoms and which pointers to develop the junction characteristics[13].

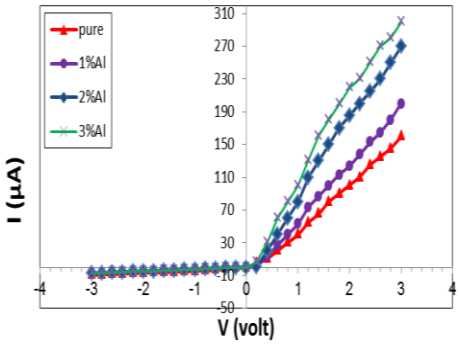

Fig. 5. I-V characteristic for p- CuO /n-Si heterojunction with different Al (0,1,2,3)%.

5. Conclusions

CuO /Si and CuO:Al/Si HJ have been fabricated successfully by depositing a p-type CuO and CuO:Al film (0,1,2,3)%Al on a n-type single-crystalline Si using vacuum evaporation method. The band gap energy was shift to red with increased of Al doped. It is observed that the capacitance decreases with increasing the reverse bias, the depletion layer width increases and the value of V_{bi} is in general decreases with increasing Al ratios. The straight line relationship of (C-V) which means that the HJ an abrupt type. From (I-V) plot the current increases with increasing Al ratios. The CuO and CuO:Al is good to be used in solar cell applications.

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