INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & MANAGEMENT

DETERMINATION OF ENERGY GAPS OF CuO & ZnO SOLAR CELLS USING SPECTRA AND ELECTRIC POWER

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ABSTRACT

The energy gaps for CuO and ZnO are obtained by using optical absorption and transmittance. The optical absorption for CuO and ZnO, shows a peak corresponding to the energy gaps in the ranges (1.3 – 2 eV) and (2.2 – 3.6 eV) respectively. These values are compatible with the observed values 0.2 eV and 3.3 eV for CuO, which acts as a p-type semiconductor, and for ZnO, which acts as an n- type semiconductor. These values measure acceptor and donor levels for CuO and ZnO. However the transmittance spectrum for CuO and ZnO shows band gaps about $E_g \sim 3.7\ eV$, and 3.6 eV. These values measures the energy gap between conduction and valence band for both, respectively. The solar cell fabricated from FTO/ ZnO/ CuO/ Al shows decrease in efficiency as the cross section area increase.

Keywords: Optical absorption, Transmittance, Spectrum, semiconductor.

INTRODUCTION

Energy is the backbone of human life, in industry and everyday life needs [1]. Solar energy is very important, it is available as long as sun is there safe and pollution free [2].The mean problem is fabrication of solar cell is its cost, recently most studies were looking for materials costing reasonable prices. As well known Silicon as semiconductor material is very complex and expensive to fabricate. Copper oxides such as CuO and Cu_2O are one of the candidate materials. The features of copper oxide semiconductors are high optical absorption coefficient and non toxicity and low cost fabrication [3]. CuO and Cu_2O are p-type semiconductors with band gaps of ~1.5 ev and ~2.0 ev, respectively, which are close to the ideal energy gap for solar cells and allows for good solar spectral absorption due to these direct band gap. The highest efficiency of ~2% for Cu_2O solar cells has been obtained by using the high-temperature annealing method and an expensive vacuum evaporation technique. Zinc oxides are also used as n- type material in solar cell. Efficient hetero junction solar cells with p-Cu_2O and n-ZnO fabricated by electro deposition and photochemical deposition methods have been investigated and reported [4,5]. However, the solar cells with a CuO/ZnO structure have not been widely fabricated and examined. Since CuO acts as p- type and ZnO as an n- type therefore it is very interesting to solar cells using them. The purpose of the present work is to fabricate and characterize solar cells with CuO/ZnO structures. This can be done by studying the spectra of CuO and ZnO, beside the study the efficiency of CuO/ZnO as solar cell. The hetero junction solar cells were denoted as CuO/ZnO. ZnO is an n-type semiconductor with a wide band gap of ~3.37 eV, which can be applied to solar cells [3]. This work consists of introduction sections. Section 2 is concerned with materials and methods, while section 3 is devoted from results and discussion. The conclusion is in section 4.

DESCRIPTION OF THE MATERIALS

Zinc oxide (ZnO) is considered as an excellent materials in this work because of it's a wide band gap($\sim 3 - 3.5\ eV$), high free carrier concentrations for electron conduction ($10^{18}\ cm^{-3}$), and very similar electron affinity (4.35 eV) [6].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[7] such that the photo generated electrons (minority carriers) from the absorber can be collected effectively and transported to their respective contacts with minimal current losses. Also the low toxicity and relatively easy processing of ZnO makes it an attractive with other materials. 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 exciting binding energy of (60 m eV) [8].

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 [9]. 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 afavarble material for photovoltage cells [10].

UV –VIS 1240 Spectrophotometer device was used to measure the absorption and the transmission of the solutions and solvents before use in cavity. It is covering a wavelength from 190-1100 nm with auto lamp switch from visible to ultraviolet range. UV-VIS spectrophotometer from SHIMADZU contains a cell of thickness 0.1 mm as a sample holder.

RESULTS AND DISCUSSION

Figure (1) Shows measured optical Absorption of thin films. The CuO thin film shows high optical absorption in the range of 400nm to – 700 nm. This corresponds to an energy band gap (for 800 nm), $E_g \sim 1.3 - 2\ eV$ which is near the known value 1.2 eV.

For ZnO the absorption range is (300 – 550 nm) with energy gap in the range $E_g \sim (2.2 - 3.3\ )eV$.

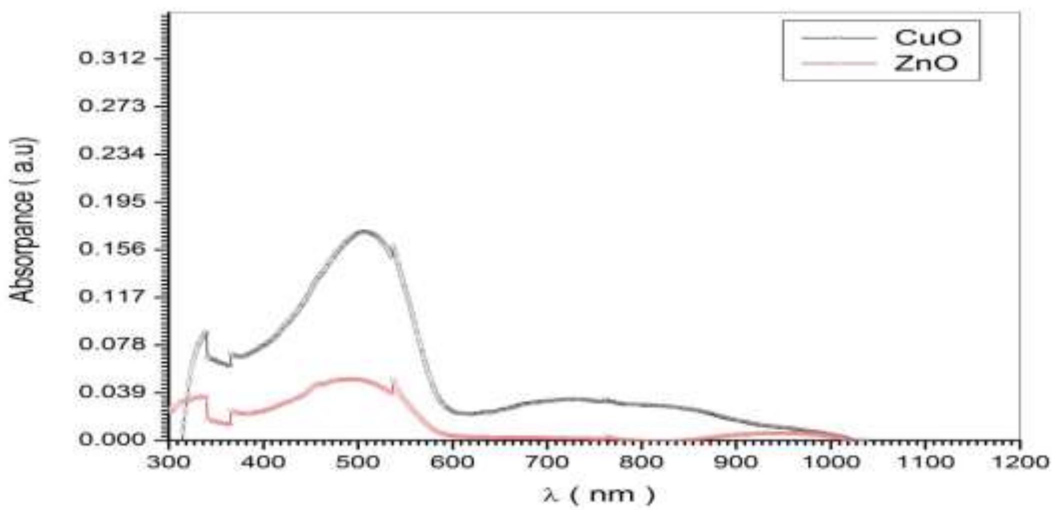

Figure (1) UV – Visible absorption spectra of thin films prepared bay electrode position.

Transmittance spectrum of 0.3 μm thick CuO film, deposited on FTO is presented in Fig(2) and ZnO film in fig(3).

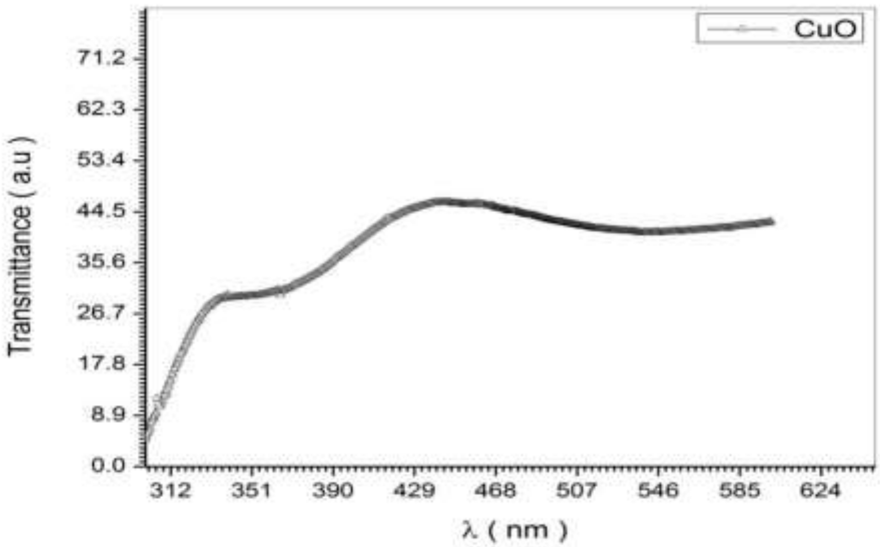

Figure (2) optical transmission spectrum of 0.3 μm thich CuO film

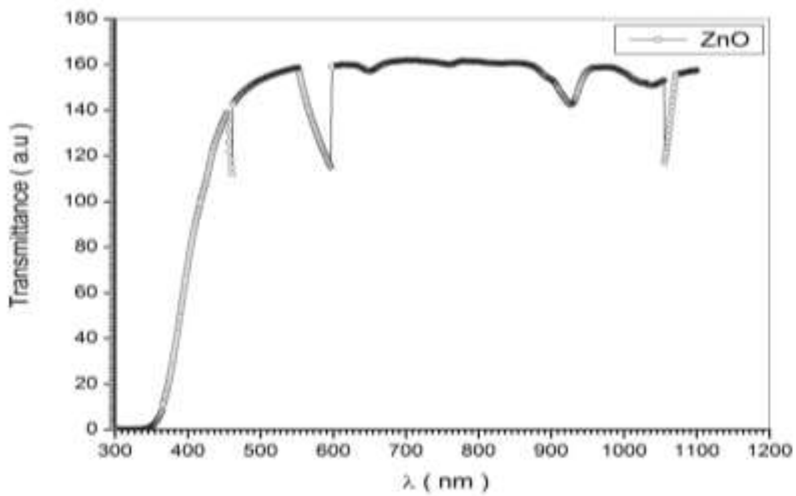

Figure (3) optical transmission spectrum of 0.3 μm thich ZnO film

The transmittance for CuO in figure (2) shows that the transmittance at about 300 nm drops abruptly corresponding to energy gap $E_g \sim 3.7\ eV$ which is apparently in conflict with the real value $E_g(accepor) \sim 1.2\ eV$

This discrepancy can be removed if one bears in mind that $E_g(accepor) \sim 1.2\ eV$ is the energy gap between top valance band and acceptor level. Since acceptor atoms are very few compared to the host CuO atoms. Then one expect radiation absorbed for electron transfer to the acceptor level can be neglected compared to a large amount of radiation absorbed to transfer electron from conduction to valence band of CuO which is as wide as $E_g \sim 3.7\ eV$.

However the situation is different for ZnO which is an n – type Sc, where the donor level is near conduction band. Thus

$$E_g(donor) \sim E_g(cond. valence)$$

Therefore transmittance spectrum in figure (3) shows an energy gap for ($\lambda \sim 300\ nm$) of value, $E_g(cond, valence) \sim 3.6\ eV$ which is near the known value $E_g(donor) \sim 3.3\ eV$. The fact that:

$$E_g(cond. valence) > E_g(donor)$$

Again confirms the fact that ZnO host atoms which have very high concentration absorb radiation more efficient than donors which have very low concentration.

from the spectrum of the optical band gap for CuO can be found . The optical absorption Coefficient (α) of this film it can be determined from the spectral transmittance.

The determination of the optical band gab energy (E_g), for CuO is based on the relation of:

$$\alpha h\upsilon = A(h\upsilon - E_g)^{\frac{n}{2}}$$

where n is a number that depends on the nature of the transition . In this case is value was found to be 1 (which corresponds to direct band to band transition) because that value of n yields the best linear graph of $(\alpha h\upsilon)2$ versushυ. In view of figure (4) the band gap for CuO is which agrees with the range $(1.5 - 2.0\ )eV$.

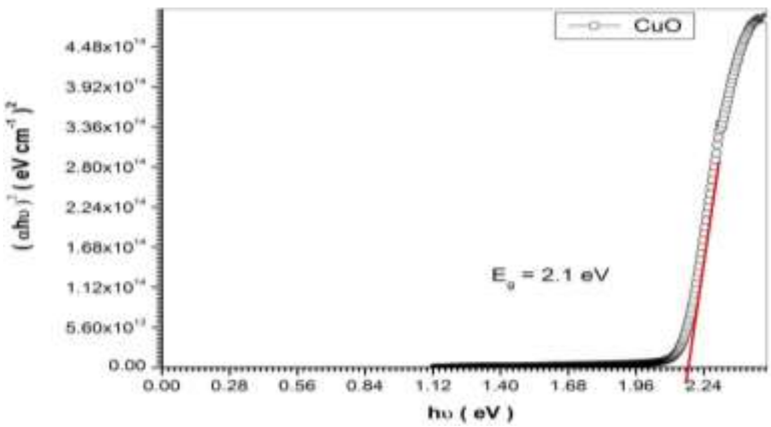

Figure (4) photon energy and absorption Coefficient

The plate shapes of the spectrum for ZnO and CuO in figs (2) and (3) towards longer wave length conforms with fact that low energy photons escape without being absorbed as far as they have no sufficient energies to transfer electrons from valence to conduction band.
It is also observed that for FTO/ ZnO/ CuO/ Al solar cells the area decrease, increases the efficiency and V_{oc}. This may be related to the fact that the V_{oc} is related to the concentration of carriers by treating the terminals of the cell as capacitors of electric field E and potential difference V given by

$$V_{oc} = EL = \frac{\sigma L}{\varepsilon} = \frac{nL}{A\varepsilon}$$

Where L is the length of the cell, A being the cross sectional area. Thus the area decrease increases V_{oc}, which in turn increases the efficiency η.

Table (1) Relation between A, V_{oc} and η

A	V_{oc}	H
1.4	0.214	0.5595×10^{-3}
1.2	0.222	0.6551×10^{-3}
0.8	0.223	0.9790×10^{-3}

CONCLUSION

The optical properties of ZnO and CuO indicates that the optical transmittance spectrum determines the energy band that separates conduction band from the valence band. The small difference between optical band gap for ZnO and the real value confirms the fact that it is an n- type semiconductor. While the large difference for CuO indicates that it is a p- type semiconductor. The absorption spectrum is related to the donor or accepter levels.

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