International Journal of Scientific Research & Engineering Technology (IJSET)
Vol.7 pp. 33-35

Effect of interface states on CdS/CGS solar cells

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***Abstract*—The aim of this research is to investigate the effect of interface state density on the performance of the CGS solar cell structure. The simulations for this work were done by giving the diode equations and varying interface state density of CdS/CGS . The interface recombination leads to lower values of the open-circuit voltage, short-circuit current density, and fill factor**

Keywords*— *Solar cells; interface state; CdS-CGS; efficiency

I. Introduction

A solar cell is an electronic device which directly converts sunlight into electricity. Light shining on the solar cell produces both a current and a voltage to generate electric power. Thin-film ZnO/CdS/CGS solar cells are especially outstanding due to their low cost [1], radiation hardness [2], long-term stability [3]. CGS is one of most promising materials for thin film photovoltaic devices because of its appropriate band gap and high absorption coefficient for solar radiation.
ZnO/CdS/CuGaSe2 cells, have gained a great deal of interest both in high voltage modules
(as single cells) and in tandem systems (as top cells) [4–7]
The interfaces occur between the different layers, generally play an important role in this film solar cells devices, can cause stresses, defects ,interface states, and surface recombination centers. In this study, we will investigate the effect of the interface states concentration on CGS efficiency. A model is presented for p–n hetero-junction CdS/CuInGaSe2 solar cells in which interface recombination is the dominant diode current transport mechanism.
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II. Model

The band gap diagram of d p–n hetero-junction with interface states is shown in figure (1).
The interface states N_s are assumed to be in the n-region close to the interface.V_{d1}; V_{d2} are the diffusion voltage components in the n- and p-region, respectively.W_1andW_2 are the depletion layer width values in the n- and p-region, respectively. The recombination path way through the interface states is also shown in figure 1

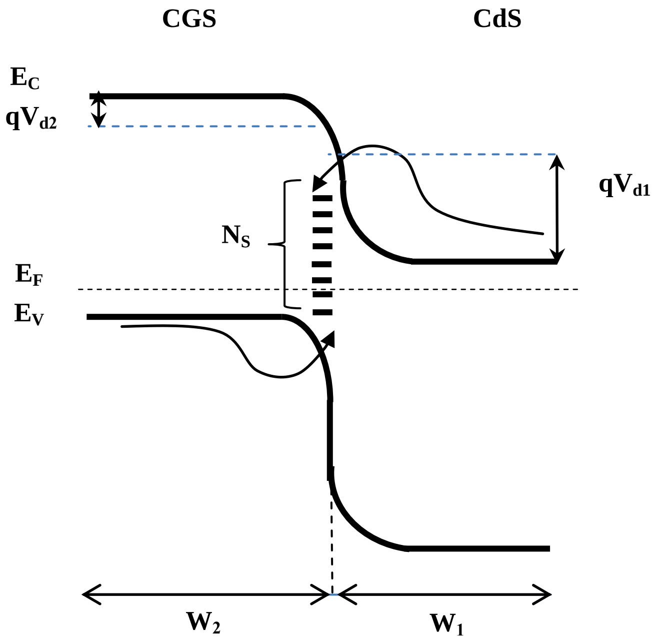

Figure 1 p–n hetero-junction with interface states.

The ideality factor reflects the influence presence of interface states it will be calculated as functions of absorber CIGS doping N_2.

$$n = \frac{V_d}{V_{d2}} \quad (1)$$

Where Vd diffusion voltage is related to energy band gap by

$$V_d = E_{g2} - \delta_n - \delta_p - \Delta E_c \quad (2)$$

Where

$\delta_n = E_c - E_F$ and $E_F - E_c = KT\ln\frac{N_1}{N_{c1}}$ for n type

$\delta_p = E_F - E_v$ an $E_v - E_F = KT\ln\frac{N_2}{N_{v2}}$ for p type

The neutrality of the junction implies between window CdS and absorber CIGS layers with interface state

$$N_1W_1 = N_S + N_2W_2 \quad (3)$$

ISSN 1737-9296

Where N_1 the donor concentration, N_2 the acceptor concentration, $W_1$the depletion layer width in the CdS region,W_2 the depletion layer width in the absorber layer and Ns is the interface states.

Solving the Poisson equation for this system the individual built-in diffusion voltages $Vd_1$and Vd_2 in the n-region and p-region of the junction, respectively

$$V_{d1} = \frac{q}{2\varepsilon_{r1}\varepsilon_0} N_1 W_1^2 \qquad (4)$$

$$V_{d2} = \frac{q}{2\varepsilon_{r2}\varepsilon_0} N_2 W_2^2 \qquad (5)$$

ε_{r1} and ε_{r2} are dielectrics constants of CdS and CIGS respectively, ε_0 is vacum dielectric constant.

The factor n >2 in this case interface recombination becomes the dominant diode current transportmechanism.and the diode parameters will be calculated as functions of N_S (n) [8].
Using the equations (4) and (5), $W_1$and W_2can be given by

$$W_1 = \sqrt{\frac{2\varepsilon_{r1}\varepsilon_0 V_d(n-1)}{qN_1 n}} \qquad (6)$$

$$W_2 = \sqrt{\frac{2\varepsilon_{r2}\varepsilon_0 V_d}{qN_2 n}} \qquad (7)$$

Where $V_d = V_{d1}+V_{d2}$

Using (3), (6) , (7) to find the following equation of N_S

$$N_S = \sqrt{\frac{2\varepsilon_{r1}\varepsilon_0 N_1 V_d}{q}\frac{(n-1)}{n}} - \sqrt{\frac{2\varepsilon_{r2}\varepsilon_0 N_2 V_d}{qn}} \qquad (8)$$

The interface recombination of holes is the dominant diode current, the saturation and current–voltage for a diode can be given respectively [9]

$$j_0 = qv_{th}\sigma_p N_S N_2 \exp\left(\frac{-qV_d}{nKT}\right) \qquad (9)$$

$$j = j_0(e^{\frac{qv}{nkT}} - 1) \qquad (10)$$

Where V_{th} is the thermal velocity, σ_p cross section of hole, KBoltzmann constant, T is the absolute temperature.
The short-circuit current density *Jsc* and open-circuit voltage V_{oc} can be written as [9]

$$j_{sc} = \frac{j_L}{1+\frac{\sigma_p v_{th} N_S \varepsilon_{r1}\varepsilon_0}{qu_1 N_1 W_1}} \qquad (11)$$

$$V_{oc} = \frac{nKT}{q}\ln\left(\frac{I_{sc}}{I_0}+1\right) \qquad (12)$$

III. RESULTS

Under AM1.5 illumination the photovoltaic characteristics is shown in following figures. We draw the these characteristics for different values of N_S corresponding to various value of ideality factor n.
The influence of N_S on the short-circuit current density (Fig.2) is small. However, because of the strong increase of J_0 (eq. 11) the open-circuit voltage decreases with increasing N_S

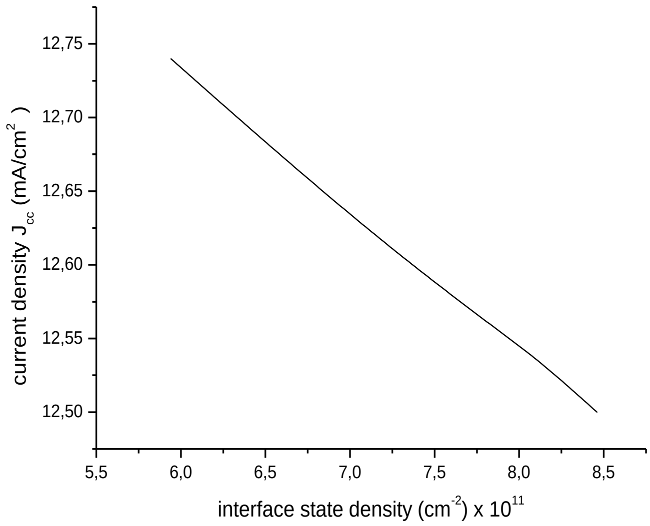

Figure. 2. Open circuit current vs interface state density N_S

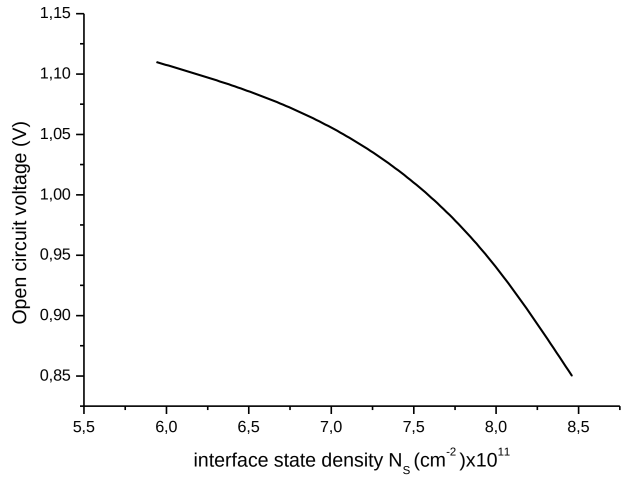

Figure. 3. Photocurrent vs interface state density N_S

Fig.4 shows the dependence of the fill factor on the interface state density. It can be seen that the interface recombination leads to a decrease in the fill factor

ISSN 1737-9296

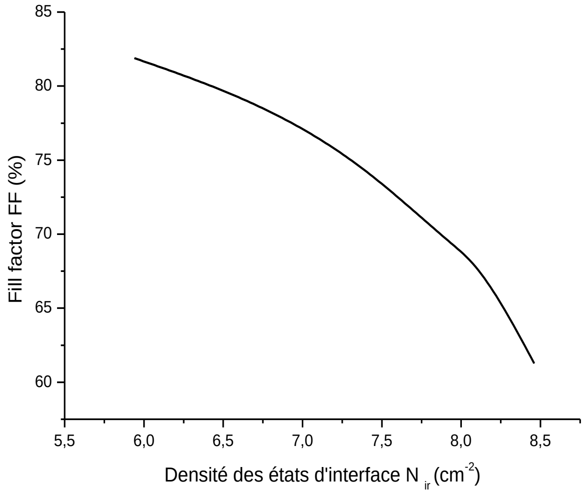

Figure. 4. Fill factor vs. interface state density N_S

Fig.5 shows the variation of the efficiency as a function of interface state density Note that the efficiency decreases with increasing N_S

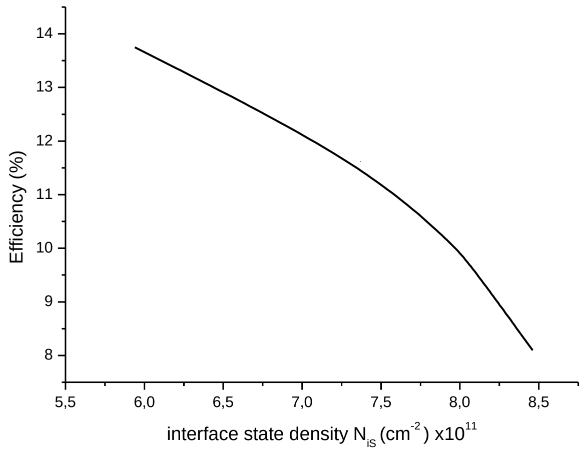

Figure. 5. Efficiency vs interface state density N_S

Conclusion

We have used a simple model to investigate the dependence of interface state of CdS/CGS heterojunction. We have seen that energy conversion efficiency increases with decreasing interface state density. Because the diode ideality factor exceeds 2 and interface recombination becomes the dominant diode current transport mechanism. This can lead to a decrease in the open-circuit voltage, the short-circuit current density and the fill factor.

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ISSN 1737-9296