Influence of Sb doping on $AgAlSe_2$ heterojunction solar cells

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Abstract

This study based on improvement of efficiency for Antimony (Sb) doped AgAlSe2 (AAS) solar cell has been prepared by using vacuum thermal evaporation method on glass and (P-type) single crystal silicon substrates, AgAlSe2 is doped with Sb with different ratios (2% and 4%). Structural and optical characterizations of these samples indicate that the tetragonal chalcopyrite structure nor affects the optical band gap of the parent compound. Different ratios of Sb, found to increase in efficiency of a solar cell the which have an optimal condition thickness t=(0.6)µm and Sb=4% have higher efficiency between other cells (η =1.5). Short circuit current density (J_{sc}) of (19mA/ cm^2) and open circuit voltage (V_{oc}) of (240mVolt).

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1. Introduction

The ternary semiconductor compounds as the formulation AIBIIICVI2 such as AgInS2, AgAlSe2, AgInTe2 have been widely studied because of their potential applications in electrooptic, the chalcopyrite with the series of I−III−VI2 where Cu is involved as a group I element, more studies have been carried out but limited workings have appeared in literature where the group I element is Ag[1].

AIBIIICVI2 semiconductors chalcopyrite have been produced by different methods such spray pyrolysis technique [2], sol–gel spin-coating technique[3], electrodeposition process [4], ultra-high vacuum with laser deposition [5], molecular with beam epitaxial [6], thermal evaporation with annealing treatment [7,8], vertical gradient freezing temperature technique [9] and solid state microwaves irradiations [10] Thermodynamic modeling [11], thermal evaporation of Ag and In elements followed by a heat treatment in selenide atmosphere at different temperatures [12], co-

evaporation[13], the pulse electrodeposition technique[14]. Thermal evaporation[15,16]

Absorber materials in solar cells and optoelectronic devices such as ternary chalcopyrite materials offer numerous possibilities of applications. The Ag-based Chalcopyrite compounds and they can be developed either as p or n type, the optical energy gap Eg can be various from 1.2 eV (AgInSe2) to 3.1 eV (AgAlS2). AAS compound is a promising absorber materials semiconductor and its energy gap about is about 2.55 eV direct gap refractive index n=2.47 and dielectric constant εo =3.89, lattice constants a=5.95, c=11.59 [17]. In this paper, we have prepared AgAlSe2 thin films and solar cell by vacuum thermal evaporation, followed by investigates the influence of a doped with Antimony.

2. *Experimental*

Alloy polycrystalline AgAlSe2 (AAS) was prepared by weighed in stoichiometric proportion (1:1:2) and fusing high purity of the elements Ag, Al and Se in ampule of quartz with pressure of 10^{-3} Toor heated at (1400 K).

Thin films of AAS with thickness (0.6) µm have been deposited on a glass and silicon substrates by vacuum thermal evaporation (E 306 system) with $2.5x10^{-6}$ Toor at ambient temperature with a deposition rate about (1.5 nm/sec). The thin film has been doped with different ratio of (Sb) (2% and 4%) by vacuum evaporation then heated by using electric furnace at 500 K for one hour. All samples pure and doped with (Sb) deposited on glass and silicon substrates to study its structural, optical and solar cell properties. From X-ray diffraction found that the thin films are polycrystalline structure, to calculate the average crystallite size (C_S) of AAS(Sb) it used Scherrer's formula[18,19]. The effect of Sb concentration on direct energy gap value Eg has been calculated from Tauc formula [15]. The Hall measurement showed (n or p) type of AIS(Sb) thin films with Vander Pauw.

By use thermal evaporation technology in vacuum, a solar cell where manufactured from heterojunction (n- AAS(Sb) /p-Si) which achieved by the deposition of the composite alloy thin films (AAS) on a single crystal silicon substrate with direction (111) of the (p-type).

The measurements of I-V for standardized illumination (100mW/cm2) determined by using the using Shockley equation [20].

3.Result and discussion:

To examine the weight ratios and the atomic components of the alloy, it was use the EDX-Energy dispersive of X-rays of the elements (Ag, Al, Se). The results are shown in Figure (1) and it found the weight ratios (1:1:2) for Ag, Al, Se.

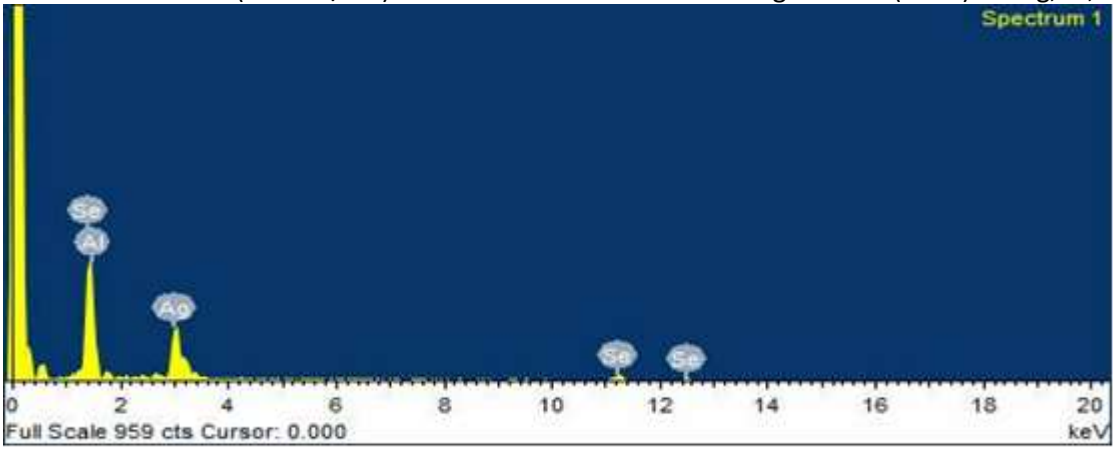

Figure (1) EDS patterns for AgAlSe2 alloy.

Figure (2) show the XRD patterns of AAS thin film pure and doped with Sb ratios (2% and 4%) , it can see from this Figure that the AAS thin films have the polycrystalline type tetragonal structure have many sharp peaks with prefer orientation is (112) this agree with the study[15] , when compared it with the ICDD **00-007-0309** card standard values found very good matched. From the FWHM values and Scherrers equation for the (112) peak we can estimate the crystallite size, it is observed the crystallite size increased when ratios of Sb increase as displays in Tables (1). Note that there is a significant shift in the position of the peaks of the prepared films after the doping process. This is due to the simple stress arising from entering the doped atoms and spreading it in the host material and occupying sites in the AAS crystal lattice, the intensities of the peaks increases by increasing the Sb ratios this gives the probability that the crystallization of the films material increases by increasing the doping ratios, and sometimes crystalline defects are centers for recrystallization [18].

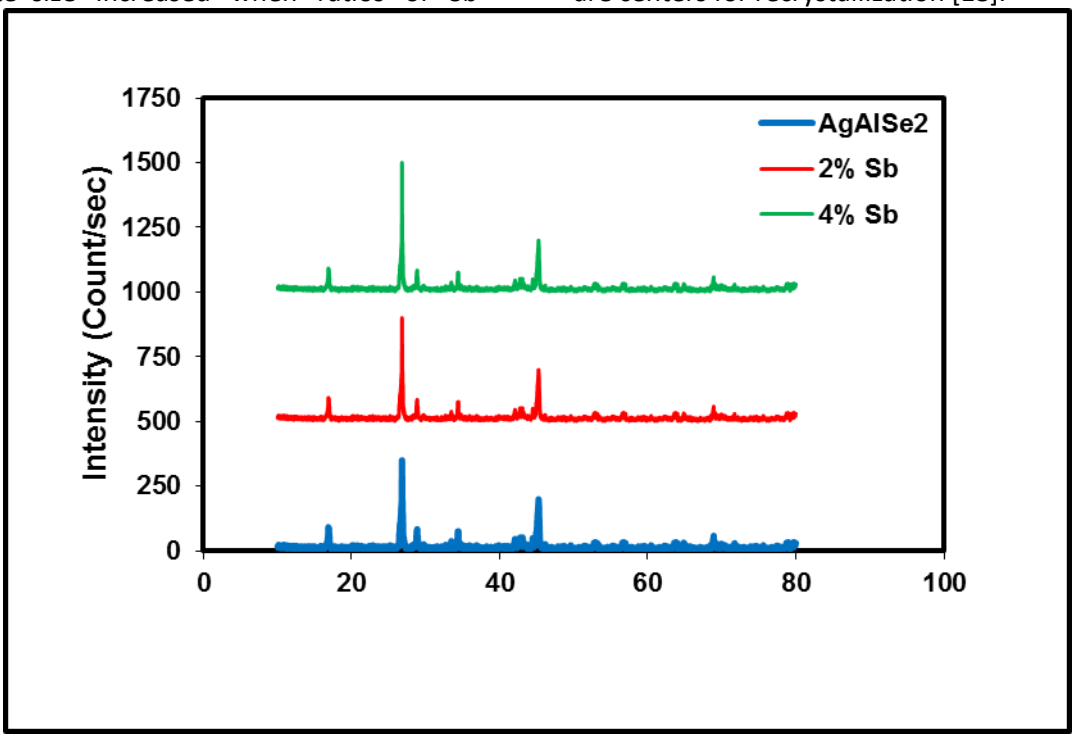

Figure 2: XRD patterns for thin films AgAlSe2 pure, Sb(2% and 4%).

Table (1) XRD Strictures for 112 pure, Sb(2% and 4%).

Thin Film	2θ(Deg.)	hkl	d_{hkl}(Exp.)(Å)	β(Deg.)	C_S(nm)
AgAlSe2 (Pure)	26.8	112	3.32	0.522	16.304
2%Sb	26.71	112	3.33	0.498	17.09
4%Sb	26.69	112	3.34	0.379	22.455

To determine the effect of doping ratios (Sb 2% and 4%) of the optical energy gap 112, Figures (3a) show the decreasing of energy gap from 1.72 to 1.5 eV, this decreases for AgAlSe2 (Sb) due to the growth of grain size as shown in XRD. this result is in agreement with refs. [7,14]. The light transmittance spectrum of AgInSe2 were evaluated as a function of wavelength at AIS pure, Sb(2% and 4%) as in Figure (3b). It is clear from this figure that the light transmittance decreases in the visible wavelength range with increasing of Sb, the behavior of the absorbance is opposite completely to that of the transmittance.

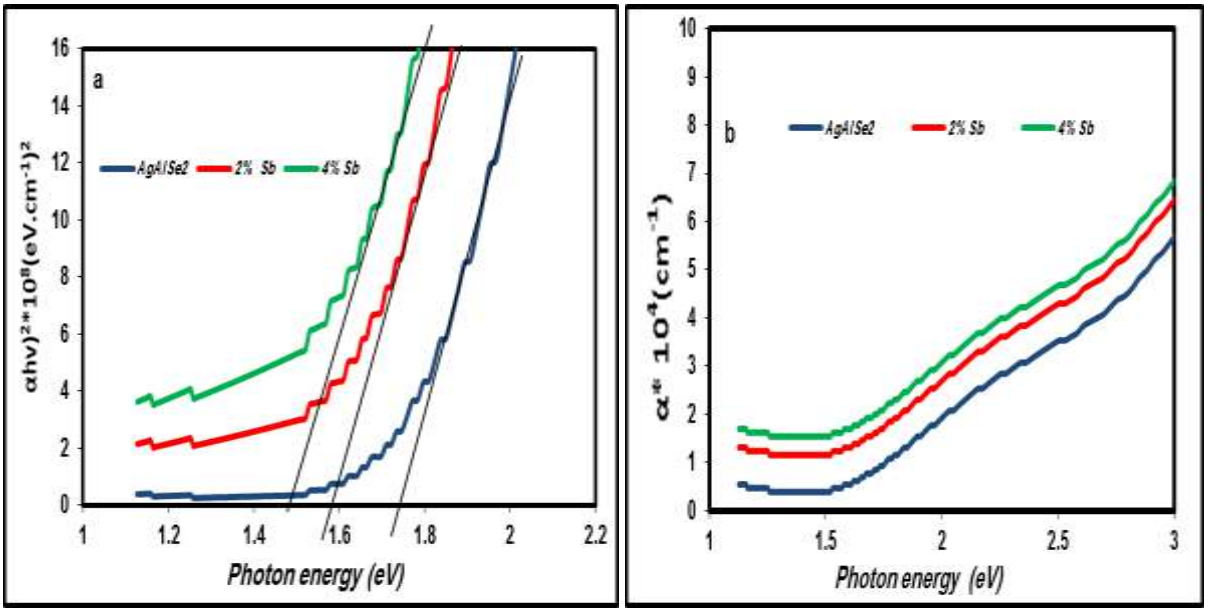

Figure 3. The Energy Gap(a) and Optical Transmittance (b) AgAlSe2 pure, Sb(2% and 4%).

To manufacture the heterojunction we must to know the type of thin film (n or p-type) so the Hall coefficient R_H determined the type of majority carriers for AAS. **Table (2) show** the obtained results for AgAlSe2 and doped Sb thin films, the negative value of the R_H mean the type of thin film is (n-type) as in Table**(2)**. This designates that the carriers are electrons, Our study agrees with the sources [7,11,14].

We can show from Table 2 The increase of Sb in the (AAS) films leads to a decrease in the resistivity and Hole coefficient (R_H) due to an increase in the carrier concentration (N_D) will leads to an increase in the current passing through the films with the voltages and the increase in mobility due to the increased probability of collisions between the carriers. The highest value of the charge carriers was the ratio 4%Sb.

Table (2): Hall parameters for AgAlSe2 pure, Sb(2% and 4%).

Thin Film	AgAlSe2 (Pure)	2%Sb	4%Sb
ρ (Ω.cm)	6.7	2	0.83

μ_H ($cm^2/V.S$)	15.6	36	79
$N_{D*10^{16}}$ (cm^{-3})	6	8.7	9.5
$R_{(H)}$ ($cm^3.C^{-1}$)	-104	-72	-66

The I-V characteristics of manufactured n-AgAlSe2 /p-Si heterojunction with Sb ratios (2% and 4%) in illumination condition that calculated using Shockley equation display in Figure 4 between (voltage V and current density J) of PV solar cell. The results found of this study displayed in Table 3 that observe the current density began to increase with Sb. That is due to the result of increasing the grain size as mentioned in the study of XRD and absorption. However, the increasing in the value of the open circuit voltages V_{OC} that will increase in concentration of carriers as in Hall affects parameters. The solar cell device have Jsc 19 mA/cm^2 and Voc ~ 240 mV, with a conversion efficiency 1.5% when Sb ratio is 4%. The values of solar cell efficiency close to the study [8,14].

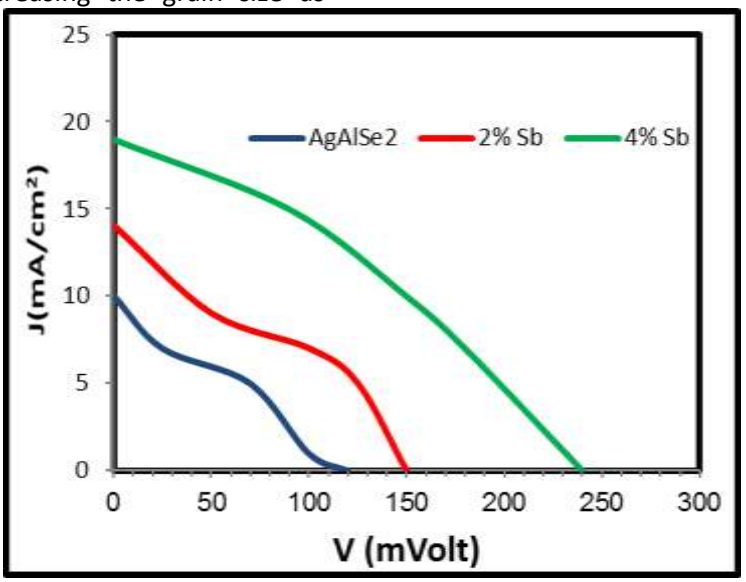

Figure 4. I-V characteristic for AgInSe2 /Si solar cell under illumination with Sb(2% and 4%).

Table (3): The parameters of solar cell for AgAlSe2 pure, Sb(2% and 4%).

Thin Film	AgAlSe2 (Pure)	2%Sb	4%Sb
V_{OC} (mV)	120	150	240
J_{SC}(mA/cm^2)	10	14	19
V_{max} (mV)	70	100	150
J_{max}(mA/cm^2)	5	7	10
FF	0.29	0.33	0.35
η %	0.35	0.7	1.5

Conclusions

Successfully preparation of AgAlSe2 alloy and solar cell, the thin films were deposited by vacuum thermal evaporation with Sb (2% and 4%). EDS show alloy successfully. XRD showed that tetragonal polycrystalline AgAlSe2 (Sb) and

have (112) prefer orientation. Optical properties show the influence of Sb doping on the band gap energy, where the allowed direct optical energy gap decreases as the Sb increased and high absorption in the visible region, The efficiency increases with Sb ratios, the maximum value efficiency were 1.5 where Sb=4%.

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