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Effect of Annealing Temperature on Structural and Electrical Properties of a-Ga as: Zn Films

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Abstract: *GaAs:Zn films with different thickness (0.25, 0.5, 0.75 and 1.0) μm have been prepared by flash evaporation technique on glass substrate at substrate room temperature under vacuum of 10^{-5} mbar. These films have been annealed at different annealing temperatures Ta (373and 473) K. The d.c. conductivity for all deposited films decreases with increases of annealing temperatures. The electrical activation energies ($Ea_1$and Ea_2) increase with increasing of annealing temperatures. Hall measurements showed that all the films are p-type with carrier's concentration increase with thickness increase and decreases from with increasing of annealing temperature from RT to 473K. Also we observe that the mobility increase with increasing of annealing temperature and decreasing with thickness. the structural characteristic of GaAs:Zn have been studied by using X-ray diffraction which show that the films have amorphous structure for sample annealed at T_a< 473K.The samples were annealed at 473 K showed a polycrystalline with Face-center cubic system preferred orientation along (111).*

I. Introduction

III-V compounds provide the basis materials for number of established commercial technologies, as well as new cutting – edge classes of electronic and optoelectronic devices, which include high electron mobility and hetrostructure bipolar transistor,diode laser, light emitting diodes, photo detector electro-optic modulators, and frequency mixing components [1]. Amorphous III-V compound semiconductors can be obtained in the form of thin films by various methods: vacuum evaporation, cathode sputtering, plasma decomposition …etc. [2]. The conductivity of the amorphous materials is rather intensive to the presence of impurities because of the valence requirements of the impurity atoms are locally satisfied in non- crystalline material [3]. Also preparation conditions play an important role in determining the electrical properties of amorphous Gallium Arsenide (GaAs) [4]. In spite of the efforts to control crystal growth, technically it's impossible to produced GaAs with an impurity concentration lower than 1014 cm^{-3}, because there is no perfect semiconductor material, [5] . islam and mitra[12] and alwahab [13] have studied the structural and electrical properties of thin GaAs films on glass substrates deposited by flash evaporation method .there is however little information available on structural and electrical properties of annealed films of GaAs deposited onto glass substrates. in this paper are studied the effects of annealing in vacuum and doping on structural and electrical properties of thin GaAs:Zn films as deposited by the same way.

II. Experimental

GaAs:Zn films were deposited onto ultrasonically cleaned glass by thermal flash evaporation technique from high purity GaAs powder supplyid from Balzar compeiny.The film thickness in range (0.25-1.0) μm was measured by using weighting method and Michelson interferometr Using He-Ne laser (632.8 nm). with different annealing temperature. The electrical conductivity has been measured as a function of temperature for GaAs:Zn films in the range (298–473) K . The measurements have been done using sensitive digital electrometer type Keithley 616 and electrical oven. The activation energies could be calculated from the plot of Lnσ versus 10^3/T according to equation (1).

$$\sigma = \sigma_o \exp(- E_a / k_B T) \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where σ_o is the minimum electrical conductivity at 0K, Ea is the activation energy
which corresponds to (Eg/2) for intrinsic conduction, T is the temperature and k_B is the Boltzmann's constant [6].

Hall Effect is one of the rich sources of information about the conduction properties of semiconductors. The mobility and carrier concentration can be obtained from the Hall constant in conjunction with the resistivity [7]. Hall Effect measurements have been done by Van der Pauw (Ecopia HMS-3000) Measurements required four Ohmic contacts on the sample;. The principle Hall effect refers to potential difference (Hall voltage) on opposite sides of a thin sheet of conducting or semi-conducting material through which an electric current is flowing, created by a magnetic field (B=0.550 Tesla) applied perpendicular to the Hall element . The Hall coefficient is taken from equation (2) [8].

$$R_H = \frac{V_H}{I} \cdot \frac{t}{B} \qquad (2)$$

The sign of Hall coefficient determines the type of charge carrier. The carrier concentration (n_H) is related to the Hall coefficient which is given by:

$$R_H = \frac{-1}{n \cdot q} \text{ for n-type} \qquad (3)$$

$$R_H = \frac{1}{p \cdot q} \text{ for p-type} \qquad (4)$$

Hall mobility (μ_H) could be calculated simply from the product of the conductivity σ and the Hall coefficient according to equation:

$\mu_H = \sigma|R_H|$ (5)

The structure of the GaAs:Zn films grown on glass substrates and treated at different annealing temperature have been examined by x-ray diffractions using a Philips x-ray diffractometer system which records the intensity as a function of Bragg's angle. The source of radiation was cu(k_α) with wavelength λ=1.5406Å, the current was 30mA and the voltage was 40 kV. The scanning angle 2θ was varied in the range of (20 – 60) degree with speed of (4) deg/min. The interplaner distance d_{hkl} for different planes was determined by using Bragg's law [9]:

$$n\lambda = 2d\sin\theta \qquad \text{……………………………………………….. (6)}$$

Where n is the reflection order. Bragg's law can be used to obtain the lattice spacing of a particular cubic system throughthe following relation:

$$a = d \times (h^2 + k^2 + l^2)^{1/2} \qquad \text{………………………………………(7)}$$

indices of the Bragg plane Where d; the interplanar distance, a; the unit cell distance and l are the Miller

While, the average crystallite size of the GaAs:Zn structures can be estimated by the Scherrer formula using the full width at half-maximum (FWHM) value of the XRD diffraction peaks:

$$D = \frac{0.9\lambda}{\beta \cos} \qquad \text{………………………..…………………… (8) [10]}$$

W are the crystallite size, X-ray wavelength, Bragg diffraction angle, and the parameter (β) can be calculate by the FWHM .

III. Results and Discussion

3-1 D.C. Electrical Conductivity

The variation of electrical conductivity as a function of temperature for different thicknesses and Ta. is shown in Fig.(1). It is clear from this figure that the conductivity for all deposited films increases with thickness Also it is observed that the conductivity of the films decreases with increasing of Ta. from (373 to 473) K. This variation is thought to be due to the changes in the crystallization (reduction of the number of grain boundaries due to the increase of the grain size) of the films. Thin film conductivity measured at room temperature ($\sigma_{R.T}$) was about (2.5×10^{-3}-0.75×10^{-3} and0.33×10^{-3}) $(\Omega.cm)^{-1}$ at RT and annealing temperatures (373 and 473) respectively for thickness equals to 0.25 μm, and (59.3×10^{-3}, 20.0×10^{-3} and 8.46×10^{-3}) $(\Omega.cm)^{-1}$ for thickness equals to 1.0 μm. for all annealing temperatures is given in Table (1). From Fig (1) and Table (1) we can observe that $\sigma_{R.T}$ increases with increasing of thickness but decreases with increasing of annealing temperatures, because of the rearrangement that may occur during annealing at temperatures higher than substrate temperatures which produce an irreversible process in the conductivity [11].

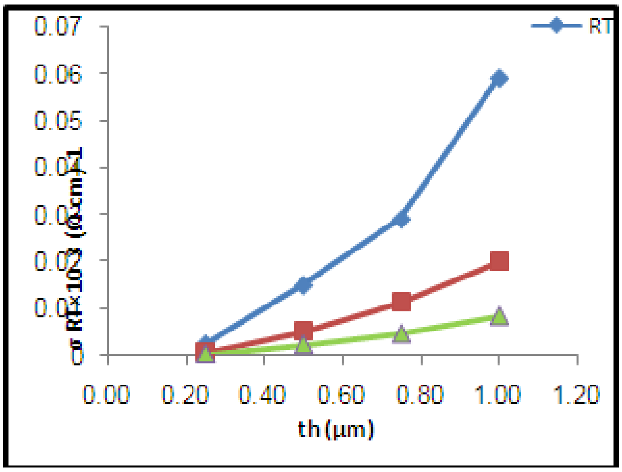

Figure (1): Variation of $\sigma_{R.T}$ versus thickness for a-GaAs:Zn films at different annealing temperatures

The plots of lnσ versus 10^3/T for GaAs films in the range (303-503) K at different thicknesses and annealing temperatures, are shown in Fig.(2). It is clear from this figure that there are two transport mechanisms, giving rise to two activation energies Ea1 and Ea2. The conduction mechanism of the activation energy (Ea2) at the higher temperatures range (403-473) K is due to carrier's excitation into the extended states beyond the mobility edge, and at the lower range of temperatures (298-403) K, the conduction mechanism is due to carrier's excitation into localized state at the edge of the band [13]. Table (1) and Fig.(3) show the effect of thickness and annealing temperature on both activation energies Ea1 and Ea2 for GaAs films. It is clear that the activation energies decrease with increasing of the thickness but increase with increasing of annealing temperatures. These results are in agreement with Islam and Mitra.[12], El-Wahhab [13] .

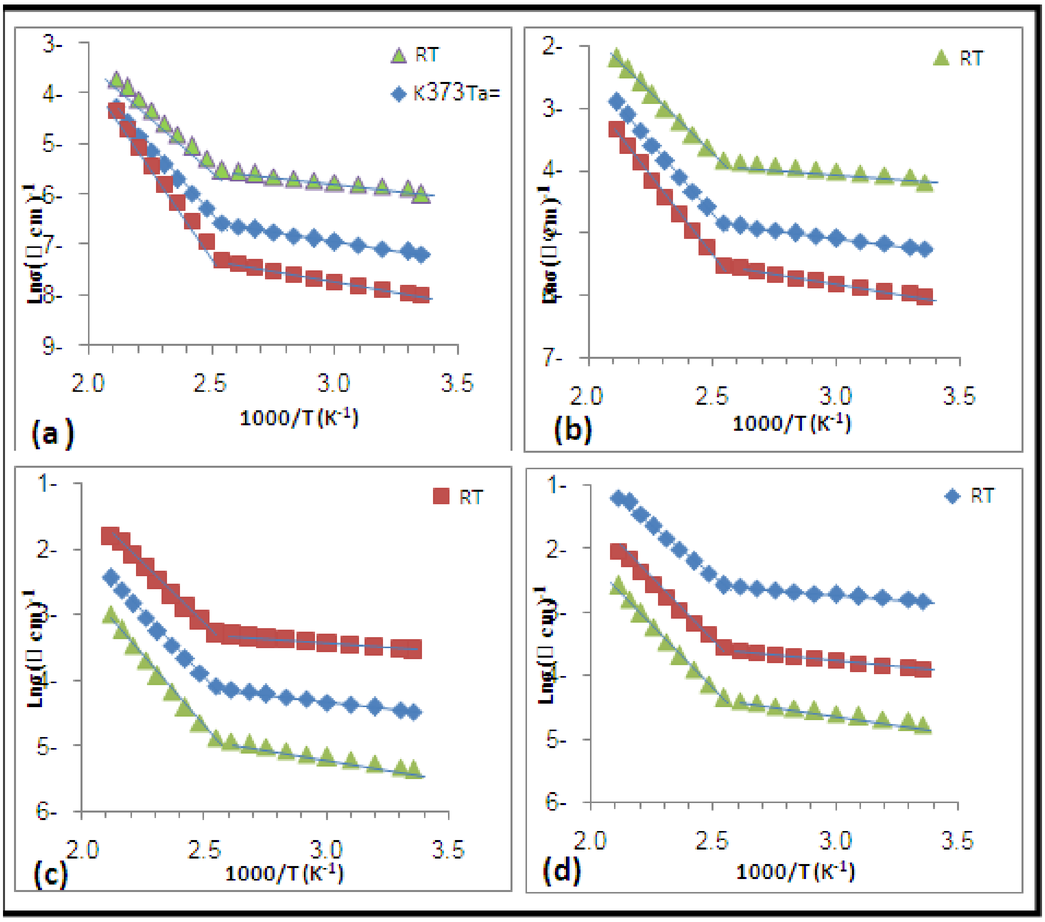

Figure (2): Lnσ versus 1000/T for a-GaAs:Zn films with different thicknesses
(a):0.25 μm,(b): 0.5 μm,(c): 0.75 μm,(d): 1.0μm and annealing temperatures (RT, 373, 473)K

Table (1): D.C conductivity parameters for a-GaAs:Zn films at different thicknesses and annealing temperatures

Thickness (µm)	T_a (K)	(298 – 403)K	(403 – 473)K	$\sigma_{R.T}$ × 10^{-3}
		E_{a1} (eV)	E_{a2} (eV)	$(\Omega.cm)^{-1}$
0.25	R.T	0.052	0.376	2.50
	373	0.074	0.473	0.750
	473	0.089	0.610	0.335
0.5	R.T	0.040	0.341	15.1
	373	0.052	0.400	5.18
	473	0.062	0.449	2.39
0.75	RT	0.034	0.311	29.2
	373	0.048	0.342	11.3
	473	0.058	0.387	4.69
1.0	RT	0.032	0.292	59.3
	373	0.042	0.319	20.0
	473	0.051	0.364	8.46

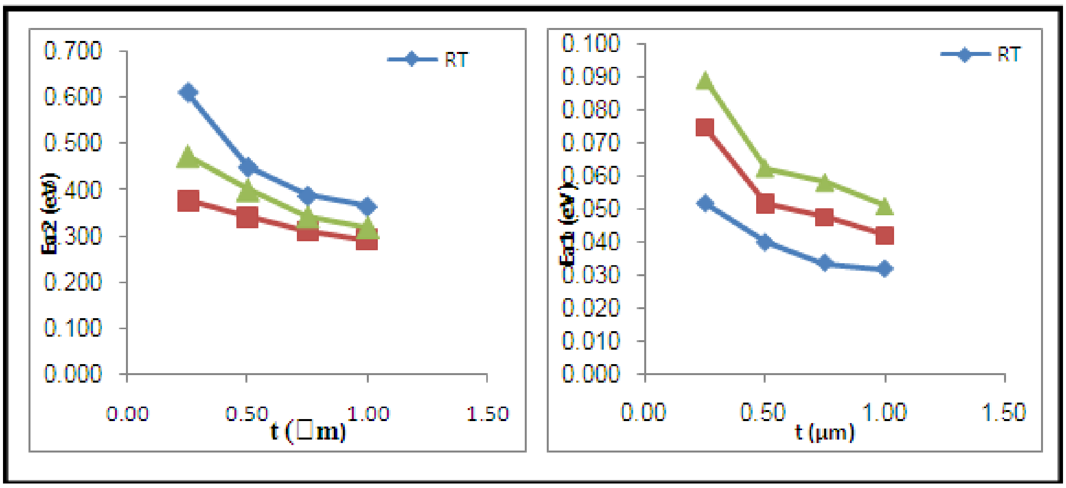

Figure (3): E_{a1} ,E_{a2} as a function of thickness for a-GaAs:Zn films at different annealing temperatures.

3-2 Hall Effect

Carrier concentration and Hall mobility have been determined from Hall measurements a-GaAs:Zn thin films on glass substrate at room temperature R.T for different thicknesses and different annealing temperatures. Hall measurements show that all these films have a positive Hall coefficient (p-type charge carriers). Fig (4) & (5) show the variation of carrier's concentration and Hall mobility as a function thickness with a deference a annealing temperature. It's observed from these figures that the carrier's concentration decreases with increase of annealing temperature while Hall mobility increases. this behavior due to the rearrangement process, which leads to the decrease of defects in the film during the film growth , and consequently a decrease of the carriers scattering at the defect.For that reason the mobility increasing. There is increaseing in the carrier's concentration with increases of thickness due to concentration of the defect in the film increasing with increase thickness led to increase the charge carrier.while decreasing in the Hall mobility with increases of thickness.

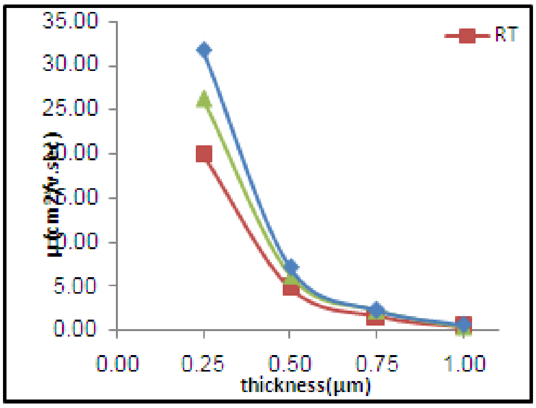

Figure (4): Variation of Hall mobility versus thickness for a-GaAs:Zn films at different annealing temperatures

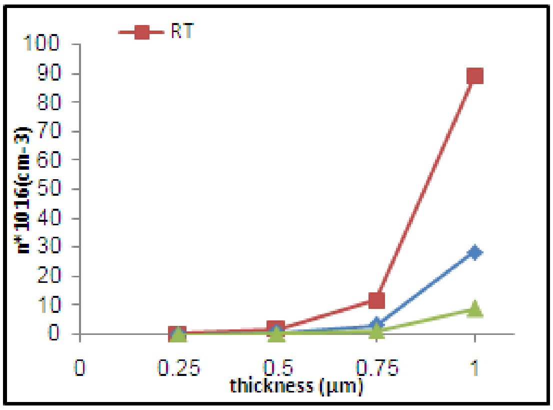

Figure (5): Variation of Hall concentration versus thickness for a-GaAs:Zn films at different annealing temperatures.

Table (2): Values of Carrier Concentration and Hall mobility for a-GaAs:Zn Thin Films .

Thickness (μm)	T_a (K)	n_Hx 10^{16} cm^{-3}	μ_H (cm^2 /V.sec)
0.25	R.T	0.08	20.0
	373	0.02	26.27
	473	0.01	31.69
0.5	R.T	1.95	4.82
	373	0.52	6.21
	473	0.21	7.16
0.75	RT	11.79	1.55
	373	3.13	2.26
	473	1.25	2.35
1.0	RT	89.29	0.42
	373	28.41	0.44
	473	8.74	0.60

3-2 XRD Characteristic of GaAs:Zn Thin Film.

It is possible to find the crystallinity structure of the film and its growth nature through the study of X-Ray diffraction (XRD).The XRD results of GaAs:Zn films prepared on glass substrate at room temperature with thickness 0.5μm at different annealing temperatures (373, 473)K are shown in Fig.(6) This figure shows anon-crystalline structure of the as-deposited films. Upon annealing at temperatures of 373 K,the films appear almost in an amorphous form. Further raise of the annealing temperature At 473K, the crystallinity is improved and peak located at 2θ=27.380 and the oriented in (111) at T_a 473 ,the peaks correspond to the poly-crysalline of tetrahedral structure of fourth column semiconductors. This behavior is in agreement with the results Gheorghiue et al.[2]

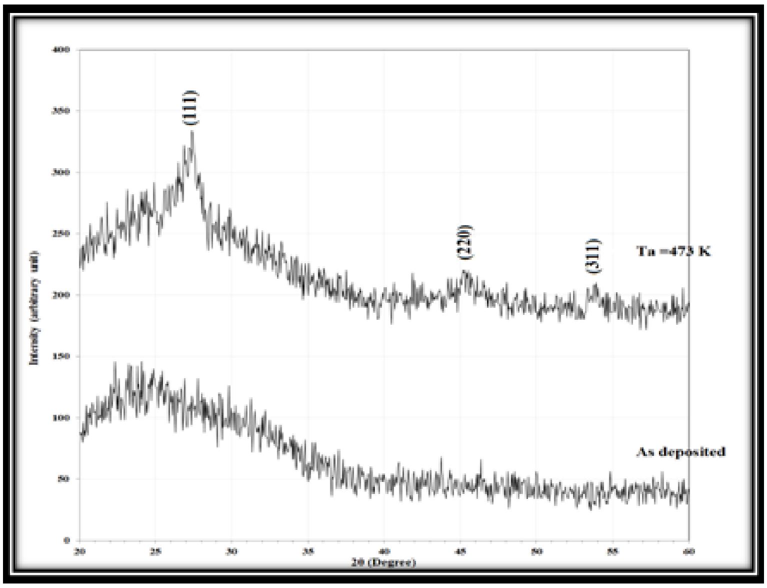

Figure. (6) X-ray diffraction patterns of a-GaAs:Zn film annealed at (373and 473)K.

In addition, The different peaks in the Figure as well as the corresponding values of the inter planar spacing $d_{(hkl)}$ which were calculated from equation (6) and The Crystallite sizes for all films were calculated by using Scherrer equation (8). The variation of the crystallites size for the (111),(220)and (311) planes as a function of annealing temperatureare shown in Table (3) .

Table (3) shows Structural Parameters viz. Inter-planar Spacing, Crystalline Size of as deposited, annealed at 473 GaAs:Zn films.

Ta(K)	2θ (Deg.)	FWHM (Deg.)	d_{hkl} Exp.(Å)	G.S (nm)	d_{hkl} Std. (Å)	hkl
473	27.3805	1.8738	3.2547	4.4	3.2642	(111)
	45.239	1.5679	2.0028	5.5	1.9989	(220)
	53.9197	0.9178	1.6991	9.7	1.7047	(311)

IV. Conclusions

1.Thed.c.conductivityforalldepositedfilmsincreasesasthethicknessincreases,anddecreaseswithincreasingofannealingtemperaturefrom473Kto523K.
2.Therearetwotransportmechanismsofthechargecarriersintherangeoftemperatures(303–503)K.
3.Theactivationenergiesdecreasewithincreasingofthethicknessandincreasewith increasingtheannealingtemperatures.
4.TheHallmeasurementshowedthatallfilmsarep-typewithcarrier'sconcentrationdecreaseswithincreaseofannealingtemperatureandincreasewiththicknesswhileHall mobilityincreaseswithannealingtemperatureanddecreasingwiththickness.
5.AsdepositedthinGaAs:Znfilmisamorphous.butafterannealingat473Kthestructurebecomepolycrystalline.

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