Enhancement of Carriers Density in GeAs Films by Alpha Particles Irradiation

Mohammed Hameed Hussein
Kerbala University

Abstract

A lightly doped GcAs (0.1%As) films were prepared by thermal co-evaporation at a temperature of 373K under vacuum ()1, 10^{-6} Torr. The irradiation has been performed by a normal (^{226}Ra) source, which emits alpha particle of fluency up to 10^9 particles/ cm^2.

X-ray diffraction indicates that the Films were elf an armorphous nature. By using J-V characteristic (current density & voltage density) it was shown that the values of threshold voltage, damage coefficient, initial & final resistivities, current density and resistively variations percentages decrease alter first stage of irradiation & atmospheric exposure.

It was noted that the irradiation. b^y alpha particles increases the density of. carriers in the investigated films.

1- Introduction

One of the basic processing techniques for thin film technology is the fabrication of (p& n-type)-semiconductor resistor, deposited by thermal co-deposition on a glass substrate(Doyle, 1966). The core of complex defects such as point defects, dislocations, cracks have generated(Frided, 1989) when the material is exposed to radiation.

Ishnio and Matsutani, (1978) have irradiated specimen of-small rectangular wafers of' As or Sb doped Ge to form n-type, by fast neutrons with (2-5x 10^{14} n/ cm^2) doses. They have studied the resistivity before and after irradiation at (R.Tr) & 4.6K.

Mchardy and Fitzgerald, (1985) have Studied the effect of electron irradiation on GeAs films deposited on Galcogenides (Si, Se, Te) covering with silver.

Fukuoka, *et al*., (1992) have measured resistivity of single germanium crystal after irradiation with neutron to produce radiation defects.

Al-Bassam, (1998) has studied the environmental and radiation tolerance of lightly doped Ge with Al.

2- Experimental Details

The thermal co-evaporation processes were performed using two types of coating units (E601&El2E2) with glass substrate (2cm, 2.5cm, 1 mm) at temperature (80°C) to obtain homogeneous films (Ge, 99.9%) and (As, 0.1%) under vacuum (10^{-6} mbar). The rate of deposition was about 6A'/ see and the thickness not more than (350±10) rim. The heat treatment applied 373K for 30 min, by using digital thermometer (±5K). After that the films were irradiated by (^{226}Ra) source with 4.68 MeV alpha particles, the distance between the source and the glass substrate was 0.2cm.

The other specimens Were exposed to atmosphere. Measurements of D.C. electrical characteristic were performed on irradiated films.

The prepared films were investigated by X-ray analysis before and after irradiation, The rate of counts activity of the source was determined by Silicon surface barrier layer detector , so it was equal to 1443 counts/ sec.

The thin film thickness can he estimated by the equation(Sasuki, 1976):

$$t = \frac{m}{2\pi^2 \rho} \qquad \textbf{...(1)}$$

Where m (gm) & ρ (gm/cm^3) are the mass and the density of material respectively, r (cm) is the distance between the Source and the glass substrate.

3- Theoretical Calculations

The flux of radiation $\Phi(\frac{\text{particle}}{\text{m}^2.\text{sec}})$ is determined from the Equation:

$$\Phi = \frac{\text{No.ofparticle/sec}}{\Omega \text{As}} \qquad \text{...(2)}$$

where As is the source area, and Ω is the solid angle which can be calculated from the equation:-

$$\Omega = \frac{1}{2}(1 - \frac{\text{d}}{\sqrt{\text{d}^2 + \text{a}^2}}) \qquad \text{...(3)}$$

where a is the radius of the irradiation areas, d is the distance between the source and irradiated area

The resistivity (Ω cm) is given by(Herbert, 1971): -

$$\rho = \frac{\Delta \text{V}}{\Delta \text{J}}(\frac{1}{1}) \qquad \text{...(4)}$$

where I is the length of the film, Δ V & ΔJ are the variations in voltage and current density respectively.

The equation used to find the damage coefficient D (A.sec/m. particle) (Fretwarst *et al.*, 1992).

$$\frac{\Delta \text{I}}{\text{V}} = \text{D}\Phi \qquad \text{...(5)}$$

where V is the volume of the irradiated region. Δ I is the variation in current.

For alpha particles, the range in air at normal temp, and pressure is given by (Nicholas, 1983).

R(mm) =: (0.05T+2.85) $T^{3/2.}$ (MeV) (4<T< 15 (MeV)) ...(6)

where T is the kinetic energy, and by applying the Bragg- Kleeman rule for one material(Nicholas, 1983).

$$\frac{\text{R}_1}{\text{R}_2} = \frac{\rho_2}{\rho_1}\sqrt{\frac{\text{A}_1}{\text{A}_2}} \qquad \text{...(7)}$$

where ρ_1, & A_1 are the density & molecular weight respectively, of material i and then the effective molecular weight was used from the equation (Nicholas, 1983):-

$$\sqrt{\text{A}_{\text{eff}}} = (\sum_{i=i}^{L} \frac{\text{W}_i}{\sqrt{\text{A}_i}}) \qquad \text{...(8)}$$

where L is the no. of elements & W is the concentration of element.

4-Results

The fig.1 shows that the current density obviously increases after two days of irradiation, while it remains almost constant after that. However, the lines appear to shift up, as a result of exposure to atmosphere as shown in fig. (2). The initial & final resistivities of the films decrease after first stage of irradiation, but remains almost constant after other stages as well as the atmospheric exposure as shown in fig. (3) & (4).

Moreover ρ_i was greater than ρ_f after the threshold voltages with respect to alpha & atmospheric exposure. Also the value of Vth decrease after first stage of atmosphere, but shows variation in values as result to alpha particles as shown in fig. (5) &(6). Also table (1) shows that the variations of current density & resistivity percentages decrease with increasing fluence and the value of Damage coefficient decreases with exposure time of film to radiation. X-ray diffraction indicate, that the light doped Ge film with As has an amorphous nature before and after irradiation. From calculations the range of alpha particle was (3.238 cm) in air and (16567 A) in the prepared films.

5- Discussion and Conclusion

It is shown that the contribution of donors increases when the film exposed to alpha particles, by displacing the germanium atoms into interstitial sites. This means the radiation damage causes an increase of production rate of compensating point defects with the levels in the higher half of the forbidden gap and the Fermi level is shifted to another level. Also the atmospheric exposure cause, a small increasing of donor concentration of oxygen (oxygen is donor type)(Schaltz *et al.*, 1988)

The entered particles in the film become embedded and they're changing the chemical composition of the film, and continuous surf-ace layer is formed. The arsenic atom transfers to another position and contributes with negative carriers in addition to generate defects.

Also the composition of the films has modified by doping against irradiation. The conductivity of the film increases after first stage of alpha effect, and remains almost constant after exposure intervals because the generated defects remain in their sites even after irradiated stages.

This has enhanced the density of carriers of the films.

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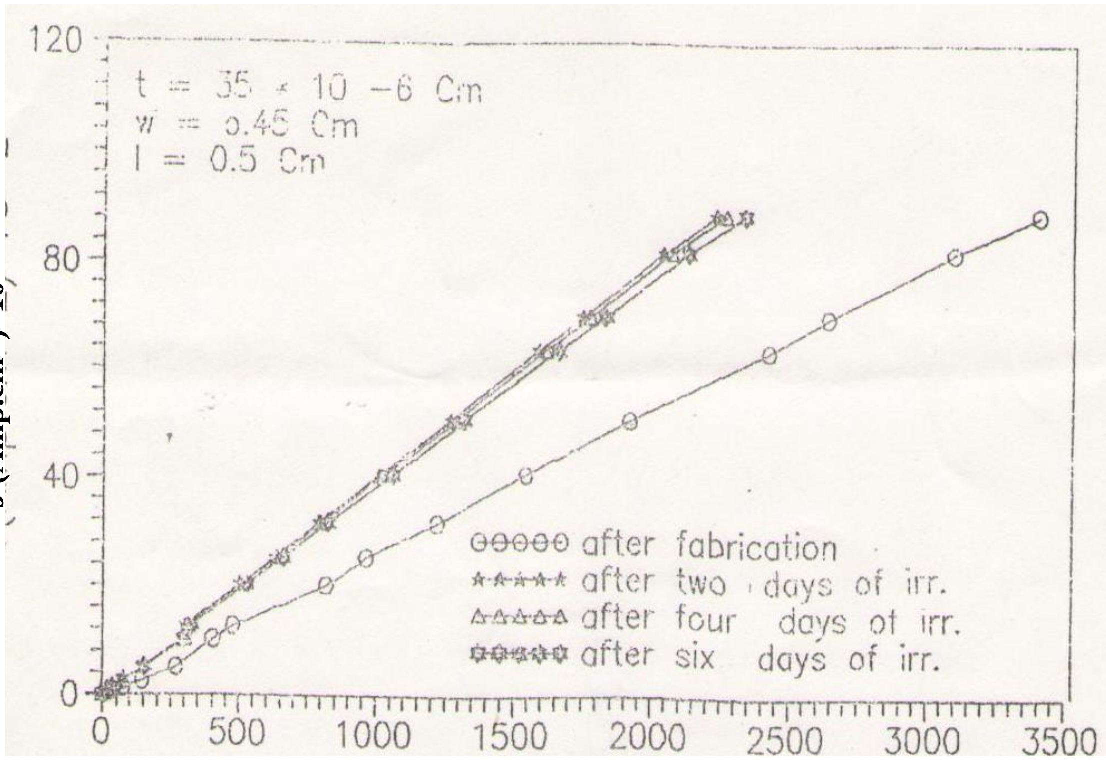
Table (1)

Exposure type	Exposure time (day)	Jo-J/J0%	ρ0-ρ/ρ0%	Damage coefficient (A, sec/m. particle)
Atmosphere	0	0	0	-
	2	5.32	9.26	-
	4	3.19	6.37	-
	6	0	0	-
Alpha	0	0	0	-
	2	53.55	31.69	4.106
	4	50.32	31.05	1.929
	6	46.54	28.46	1.187

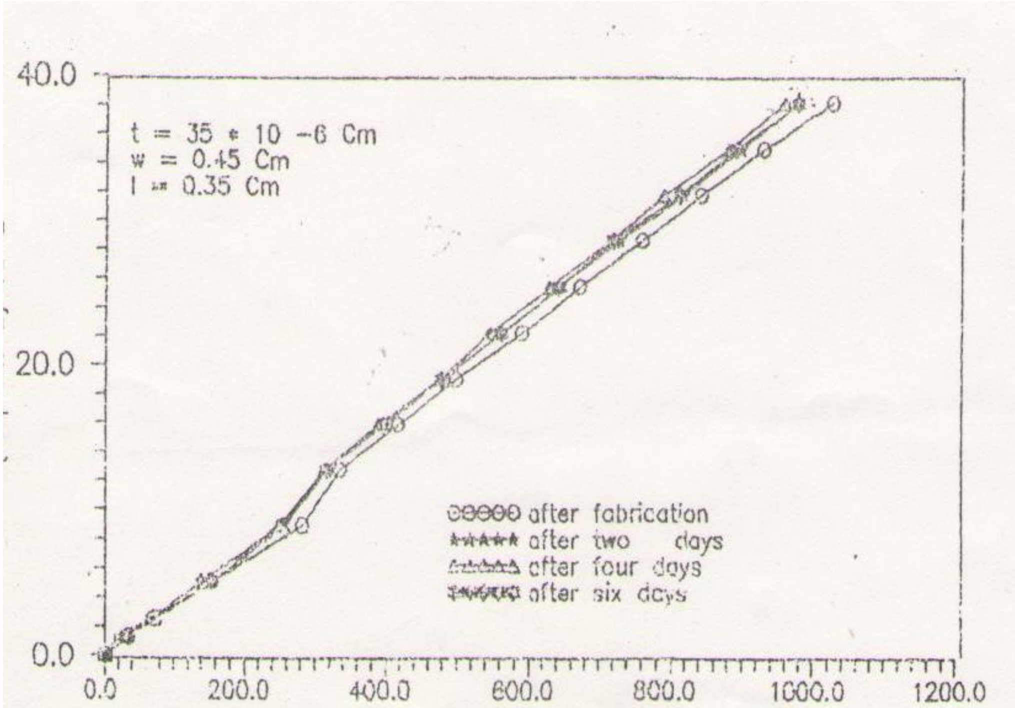
J (Amp.cm^{-2})*10^{-2}



V (Volt) *10^{-2}

Fig. (1) The current density as a function of voltage of GeAs (0.1As) thin film irradiation by α-particle

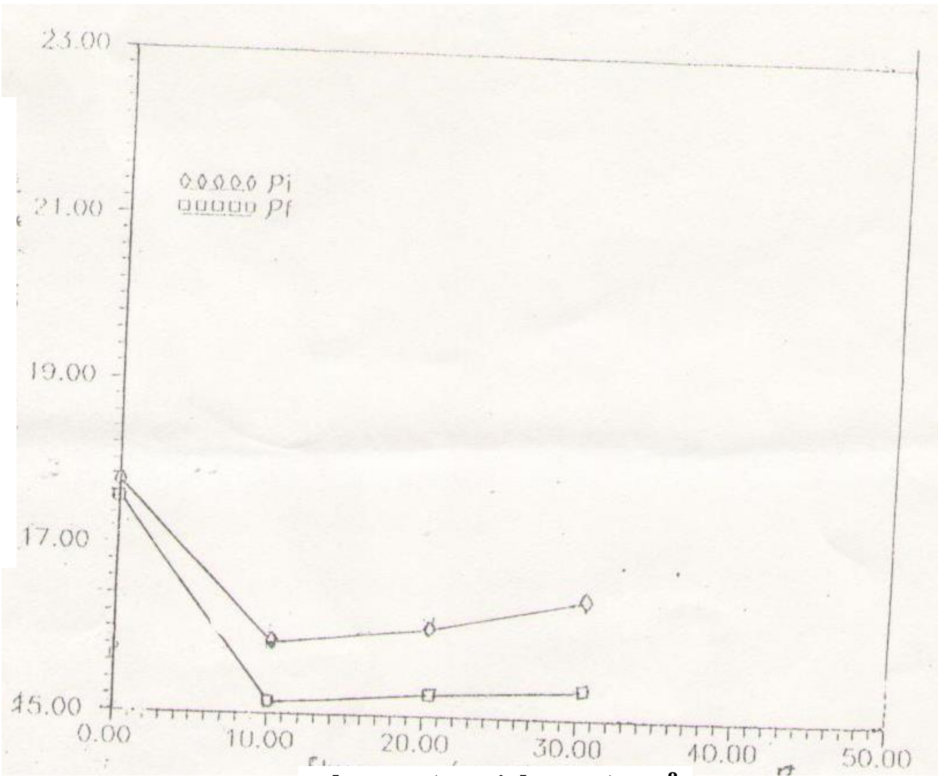
J (Amp.cm^{-2})*10^{-2}



V (Volt) *10^{-2}

Fig. (2) The current density as a function of voltage of film (0.1% n-type) atmosphere exposure

ρ(ohm.cm)*10



Fluence (particle/cm2)*10^8

Fig. (3) The initial & final resistivity as a function to the fluence α-particle

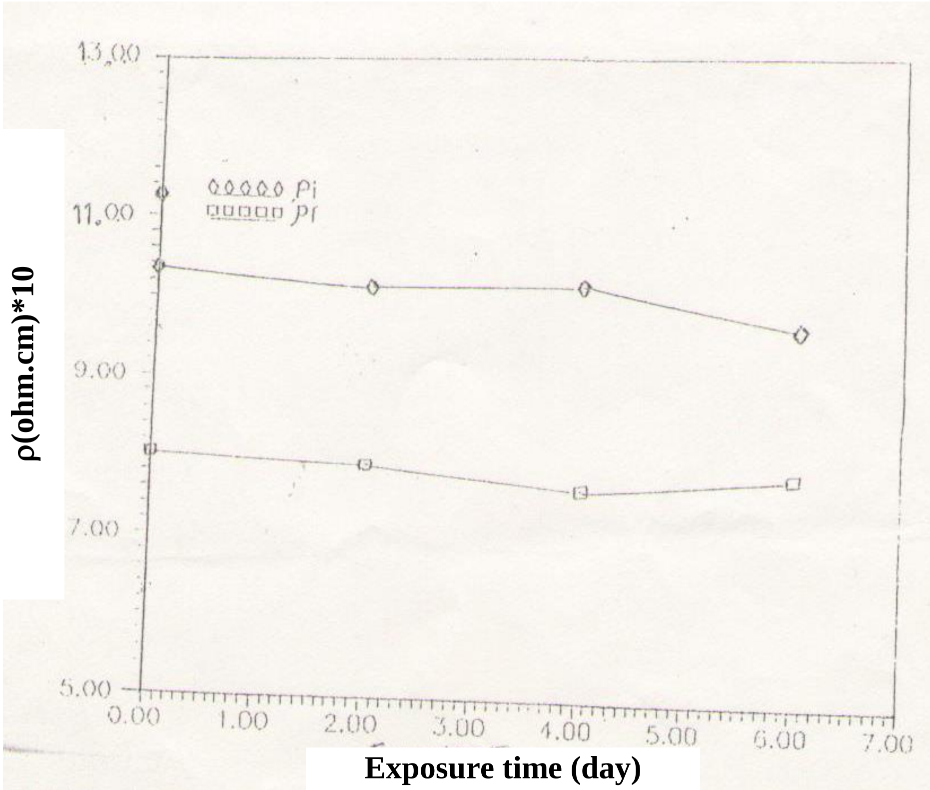


Fig. (4) The initial & final resistivity as a function to the atmosphere exposure

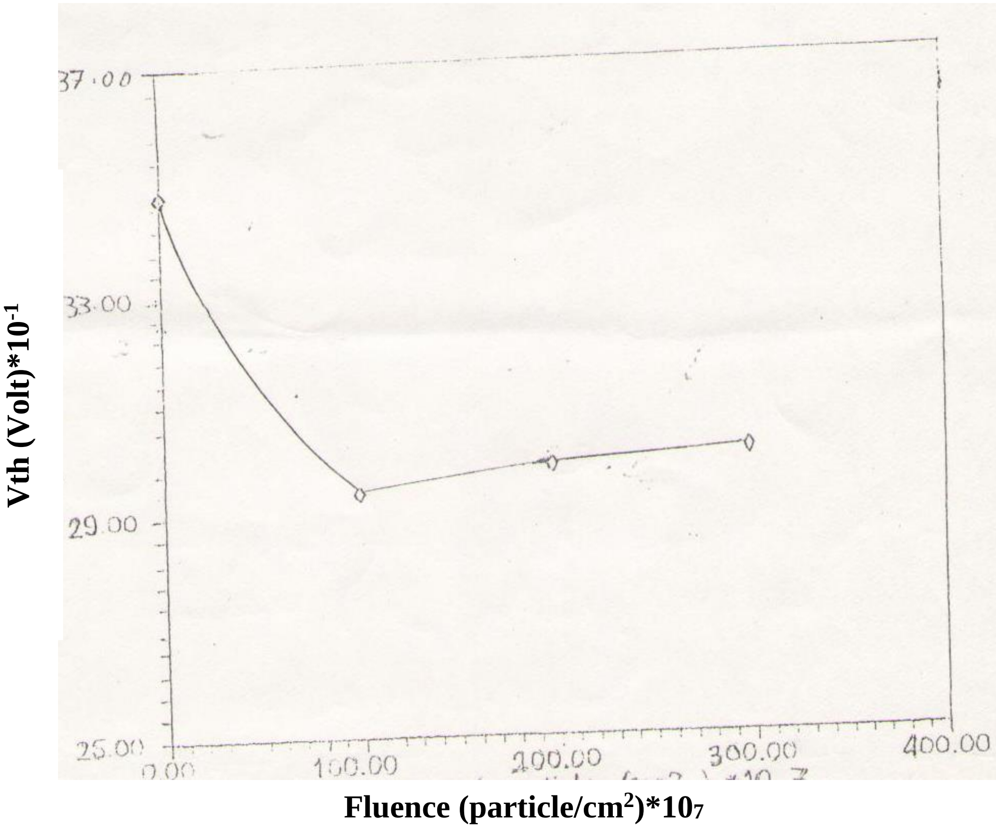
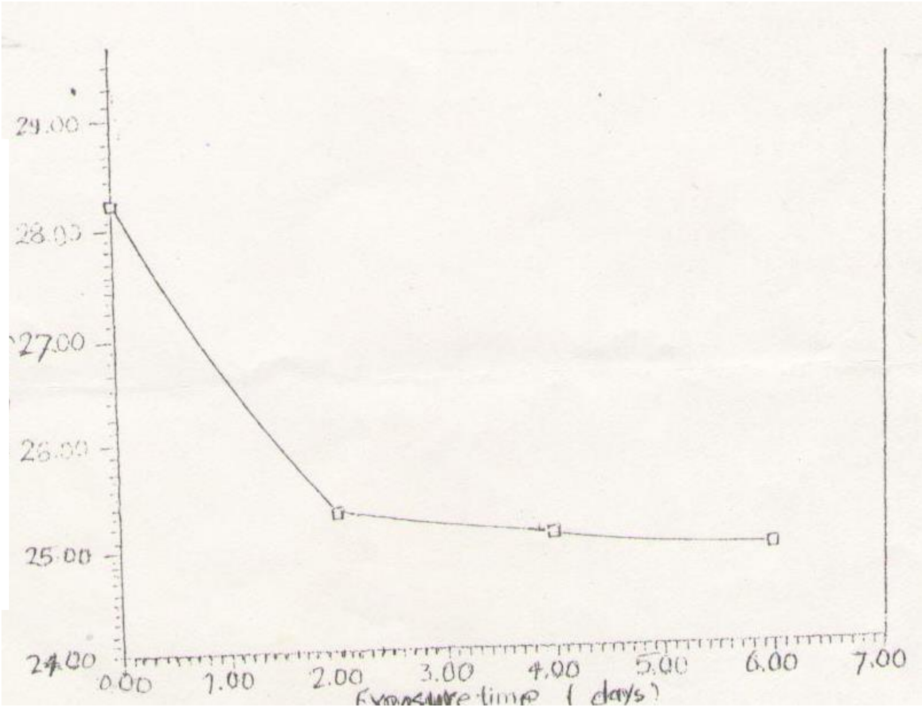


Fig. (5)The threshold voltage as a function of the fluence of α-particle

Vth (Volt)*10-1



Exposure time (days)

Fig. (6) The threshold voltage as a function to the atmosphere exposure