The Effect Of Environmental , Alpha And Beta Particles On Lightly Doped P-N Junction Germanium Filmsa

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Abstract

The lightly aluminum and arsenic doped germanium films were prepared using thermal co-evaporation techniques to deposit p-n film junctions with (0.1wt%) concentration. The prepared films were exposed to circumstance and natural radionuclide (Ra^{226}) emitted alpha and (Sr^{90}) emitted beta particles after heat treatment with various dosages .The J-V characteristics refer to shifting in both forward and reverse bias and lead to increase in resistivity, initial and final threshold voltages, resistivity variation percentage, but damage percentages decreases after every stages of exposure. Also the change of current per unit volume increase with environmental exposure and fluency.

Keywords: thin film, doping, semiconductors, environment, beta particle, alpha particle, thermal evaporation p-n junction.

الخلاصة

حضرت أغشية الجرمانيوم المطعمة بالألمنيوم والزرنيخ بسمك (٦٠٠±١٠) نانومتر لترسيب ألمفارق p–n باستعمال تقنية التبخير الحراري المشترك بتركيز واطئ (٠.١%) .عرضت بعض الأغشية للجو والبعض الآخر لدقائق ألفا المنبعثة من عنصر الراديوم (٢٢٦) والآخر إلى دقائق بيتا المنبعثة من عنصر السترونيوم (٩٠) بفيوض مختلفة بعد إجراء معاملة حرارية . أشارت مميزات (كثافة التيار – الفولتية) إلى وجود إزاحة في كلا الانحيازين الأمامي والعكسي والى حدوث زيادة في قيم المقاومية ،فولتيات العتبة الابتدائية والنهائية ونسبة التغير في المقاومية ،لكن نسب الضرر تقل بعد كل مرحلة من التعرض .كذلك لوحظ تغير التيار لوحدة الحجم مع التعرض الجوي والأشعاع الجسيمي.

1. Introduction

The germanium atom substitutes with an arsenic or aluminum atom by covalent bonds formed(Sze,1981).. The most fifth doping elements go to substitutional sites in networks of material, such that the displaced germanium transfers to the free surface (Nerbert,1971). Small quantity of impurities has large effect on electrical characteristic(Ravi,1981). (Hu, 1987) supposed clustering four arsenic atoms which formed tetragonal at interstitial natural position of silicon lattice(Von,et. al,1987). (Flangan & Klontz, 1978) studied effect of radiation in n-type more than p-type because of defect production at low temperature. The tracks result from radiation, lead to disturbing regions at thin specimen. The cross section of secondary defects is non-proportional to impurity concentration, the probability of this defect decrease with decreasing Fermi level, which describes in term of free migration of primary defect(Corbet,1979). The impurities with larger diameter occupy to extension regions, surrounded by dislocations. It was found that the data of doped Ge with As at range (150-240^{O}C) agreement in characteristic of some data taken from irradiated germanium by electron accomplish with (Brown)(Carton,et al.1976). (Mora *et al.*, 1972) studied the effect of neutrons on electrical properties of heavily doped ((1-8)× 10^{18}cm^{-3}) (p-type) of GaAs. They studied transition from semiconductor to metal. They were irradiated small rectangular wafers of heavily doped germanium with arsenic or antimony to form n-type by fast neutron of doses (2-5)× 10^{14} n/cm^{2}(Yoshikawa,et al,1977).

(Mch Hardy & Fitzgerald, 1985) presented research about the effect of different electronic irradiation intensities on the calcogenates (Si, Se, Te) films with As and Ge covered with silver(Adam,1978). (Srivastava *et al.*, 1986) prepared Ge film using thermal evaporation vacuum techniques on glass substrate at room temperature

(Fuknoka, Noboru *et al.*, 1992) measured the value of single crystal Ge resistivity after neutron irradiation. (Al-Bassam, 1996) prepared amorphous pure and doped germanium films by thermal co-evaporation process and irradiated with alpha and beta particles and observed shifting in (J-V) characteristics.

(Aleksandrov *et al.*, 1999) studied the influence of electrically inactive impurities such as carbon, oxygen, nitrogen and fluorine on the formation of donor centers in silicon layers implanted with erbium. (Shevchenk, 1999) indicated to influence of annealing on the dislocation-related electrical conductivity of Ge n-type single crystals with donor conc. of ($3*10^{12}cm^{-3}$) was formed at(760 ^{o}C) to strains.

(Oszwaldonski *et al.*, 2001) found the structural properties of InSbBi and InSbAsBi thin films prepared by flash-evaporation method using a mixture of powders. The electrical sheet conductivity and dominated the recombination current due to the generation and trapping center(Road,et al,2003). (Ashoor *et al.*, 2004) studied irradiated pure and doped amorphous germanium films with antimony. It showed that d.c. conductivity of n-type film increase with gamma radiation. (Al-Bassam, 2001) deposited p-GeAl (0.1wt%) films by thermal co-evaporation and irradiation with fluency alpha and beta up to 10^9 particle/cm^2, moreover to atmospheric exposure.

(Al-Bassam, 2004) prepared lightly As doped Ge films (0.1%wt) and irradiated with alpha particle emitted from (Ra^{226}). (Georgakakos,2010) studied the influence of alpha particle irradiation and temperature on ALGaAs/GaAs/AlGaAs hetrojunction structures on (I-V) and (C-V) characteristics with (180K-440K) and radiation of alpha particles (5MeV) at fluences changing from (4.9×10^{10} cm^{-2}) to (1.57×10^{12} cm^{-2}) by Al schottky contacts at test structures.(Yamazaki,2011) studied the diluted ferromagnetic semiconductor $Z_{1-x}Cr_xTe$ doped with iodine and nitrogen. It was concluded that the Cr ions in the undoped I-doped and lightly N-doped samples are divalent (Cr^{+2}),while trivalent (Cr^{+3}) coexist in the heavily N-doped sample.(Schrimpf et al,2011) studied radiation effect in new materials for nano-devices(Yamazaki,et al,2011). It was exposed to radiation posses significant challenges for electronic devices. The aim of the project is to know the effect of alpha and beta particles in addition to environment on (J-V) characteristics, and some electronic properties of p-n junction film devices using in nuclear laboratory systems, and other computerized devices.

2.Theoretical Calculations

When a particles have entered into thin films with certain solid angle, some electrical changes appear as result of defects, depending on the energy of particles and type of film. To compute the flux of radiation (particle/cm^2.sec), we used the equation (Nicholas,1976):

$$\phi = \frac{\text{no.of particles}}{\Omega A_s} \qquad (1)$$

where A_s (cm^2) is the source area, and Ω is the solid angle that can be calculated from the equation (Sasuki,1976) :

$$\Omega = \frac{1}{2}\left(1 - \frac{d}{\sqrt{d^2 + R_d{}^2}}\right) \qquad (2)$$

So R_d (cm) is the radius of the exposed area, d (cm) is the distance between the emitted source and exposed area.
For (J-V) characteristic, the function relation is J=f(V) or V=f^{-1}(J) or another function
$V = g(J)$ is used.
So, it could be find the resistivity $(\Omega \cdot cm)$ directly by using the equation (Nerbert,1971):

$$\rho = \frac{\Delta V}{\Delta J}\left(\frac{1}{l}\right) \qquad (3)$$

Such as l(cm) is the length of the film. To find of damage coefficient (D) (Amp/cm) is used the equation(Fertwarst,et al,1992):

$$\frac{\Delta I}{v} = D.\phi \qquad (4)$$

Where v (cm^3) is the volume of the exposed area, ΔI is the variation in current. The maximum range $R_{max.}$ (Material independent) of beta particle can be computed from
empirical formula given by Katz and Penfold(Cember,1996):

$$R_{\max}.\rho(gm/cm^2) = \begin{cases} 0.412E_\beta^{1.265-0.0954\ln E_\beta}, E_\beta \langle 2.5MeV \\ 0.530E_\beta - 0.106, E_\beta \rangle 2.5MeV \end{cases} \qquad (5)$$

Where E_β is the maximum beta energy in MeV. The thickness (t_d) of the material gives a generic quantifier which various absorbers can be compared(Nicholas,1983):

$$t_d(gm/cm^2) = \rho(gm/cm^3) \times t\ (cm) \qquad (6)$$

Also by Appling the Bragg-Kleeman rule for one material(Georgakakos,2010):

$$\frac{R_1}{R_2} = \frac{\rho_1}{\rho_2} \cdot \frac{\sqrt{A_1}}{\sqrt{A_2}} \qquad (7)$$

Where ρ_i and A_i are the density and atomic weight respectively and R_i is the distance of particle in material, then effective atomic weight was found from the equation(Georgakakos,2010):

$$A_{eff.} = \sum_{i=1}^{L} \frac{w_i}{\sqrt{A_i}} \qquad (8)$$

Where L is the no. of elements and w_i is the concentration of element.
The effective atomic number and atomic weight of alpha particle effect is given by(Georgakakos,2010):

$Z_{eff.} = \Sigma W_i Z_i$
(9)
From equation (3) and (4), it was introduce the another equation of damage coefficient:

$$D_V = \frac{|V_2 - V_1|}{\phi l^2 \rho}$$
(10)
Where $V=Al$, $\Delta J=\Delta I/A$
From Boltzmann equation(Sasuki,1976):

$$J = J_S (e^{\frac{V}{\eta V_T}} - 1)$$
(11)
Such that $V_T=kT/q$, $\eta=1$ for germanium:

$$\frac{J + J_S}{J_S} = e^{\frac{V}{V_T}}$$

$$V = V_T \ln(\frac{J}{J_S} + 1)$$
(12)
Derive eq.(2-11) with respect to V produce:

$$\frac{dJ}{dV} = \frac{J_S e^{\frac{V}{V_T}}}{V_T}$$

$$C = \frac{J + J_S}{V_T}$$
(13)

Where C represents the conductance of p-n junction also(Mill,Man-Halkiad,1972) :

$$\sigma_v = \left(\frac{J + J_S}{V_T}\right)\left(\frac{l}{wt}\right)$$
(14)
Where σ_v is the bulk conductivity of the film $(\Omega.cm^3)^{-1}$.
From eq. (11):

$$\Delta J = \Delta J_S \left(e^{\frac{V}{V_T}} - 1 \right) \quad (15)$$

Substitute eq. (4) in eq.(15) and if :

$V \rangle\rangle V_T$ and $e^{\frac{V}{v_T}} \rangle\rangle 1$

then

$$D_J = (J_{S2} - J_{S1}) \frac{e^{\frac{V}{V_T}}}{\phi l} \quad (16)$$

It can be produced the damage equation in terms of hyperbolic function(Havery,et al,1972):

$$\cosh v = \frac{e^{v} + e^{-v}}{2}$$
(17)
By analyzing produce:
$$e^{2v} - 2e^{v}\cosh v + 1 = 0$$

$$e^{v} = \cosh v \pm \sqrt{\cosh^{2} v - 1}$$
But
$$\cosh^{2} v - \sinh^{2} v = 1$$
So
$$e^{\frac{V}{V_T}} = \cosh(\frac{V}{V_T}) \pm \sinh(\frac{V}{V_T})$$
(18)
Equation (16) becomes:
$$D_J = (\frac{J_{S2} - J_{S1}}{\phi l})(\cosh(\frac{V}{V_T}) \pm \sinh(\frac{V}{V_T})$$
(19)

This equation represents the damage coefficient of lightly p-n junction films in the case of current density variation before and after exposure to nuclear radiation and environment.

In the case the current density and voltage are changed; equation (15) becomes:
$$\Delta J = J_{S2} e^{\frac{V_2}{V_T}} - J_{S1} e^{\frac{V_1}{V_T}}$$
(20)

Connect between equations (16) and (18) produce(Albassam,1997):
$$D_V = \frac{1}{l\phi}\{J_{S2}\left(\cosh(\frac{V_2}{V_T}) \pm \sinh(\frac{V_2}{V_T})\right) - J_{S1}\left(\cosh(\frac{V_1}{V_T}) \pm \sinh(\frac{V_1}{V_T})\right)\}$$
(21)

This equation represents the damage coefficient as result to the change in saturation current density and voltage variations of p-n junctions.

3. Experimental Details:

The films were deposited on hot glass substrate (100 ^{o} C) by means of (Edward's system) using thermal co-evaporation technique from two separate source(boats) for the host (Ge, 99.9wt%) and dopants (Al,0.1%wt,As,0.1% wt) materials under vacuum system around (10^{-5} -10^{-6} torr). The rate of deposition was about (6A/s). The heat treatment was about (393K) for (30min.) by using digital thermometer $(\pm 5K)$. The thickness of the film was $(600\pm 10)nm$ with aluminum ohmic contact on the film was made prior to exposure to radiation as electrodes.

The films were mounted on two sides at (0.2, 0.4 cm) distances and exposed to particle radiation at (300K) with(Ra^{226}) source emitted alpha particle its activity is (10^{-6}mCi) and (Sr^{90}) source emitted beta particle its activity(5×10^{-3}mCi) for four period times respectively . The other specimens of p-n junctions exposed to environment. Measurements of d.c. electrical resistivity were preformed on three thin film specimens of well-characterized homogeneity. The rate of count activity of the source was obtained by using silicon surface barrier-layer detector and scintillation (NaITI) detector. The samples were carefully kept in a glass chamber evacuated to (0.1) torr pressure.

The measurement of the film thickness can be estimated by equation (Carton,et al,1976):

$$t = \frac{m}{2\pi r^2 \rho} \tag{22}$$

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

4. Results and Discussion

For light concentration doping germanium with aluminum(0.1wt%) and arsenic (0.1wt %) to form p-n junctions respectively. It causes shifting in J-V characteristic as result of environment exposures , alpha and beta particles effects.

a- Effect of atmospheric exposure on lightly p-n film:

From Fig.1, it was observed that no saturation current density and no break down voltage values have appeared from (J-V) characteristics. There exist two threshold voltages in two forward and reverse bias as shown in Fig.2 ,the shifting are different in both forward and reverse biases. Also the resistivity of the film increase in both biases as increase the period exposure as shown in Fig.3. The shifting in (J-V) characteristic in the first stage is greater and almost so constant in the final. The resistivity variation percentage reach (20.69%) in forward and (23.16%) in reverse in the final stage of exposure as shown in table 1.

Table 1 also indicates the damage percentages with (9.83%) in forward and (9.53%) in reverse after 6 days of exposure. These variations occur because of atmospheric factor effects generate a perturbation in equilibrium of low donor and acceptor density carriers, permit to oxidation film and leads to increasing of oxygen contents in p and n sides. However the connections of (Ge-Al) and (Ge-As) contains oxygen atoms, lead to retard to passing current in the film.

The manners of (p-n) junction with (0.1%) are similar to intrinsic germanium films because the doping is low, so that the impurities are not enough to obtain the clear bias, or the potential barrier and saturation current density are lost.

The threshold voltages contain with the film because of unhomoginity of the film as result of precipitation.Fig.4 describes the change in current per unit volume with consecutive exposure to atmosphere.

The variation increases with increasing in days, leads to increase in resistivity because of generation of vacancies in the region occur the oxidation. The values for forward is less than for reverse bias.

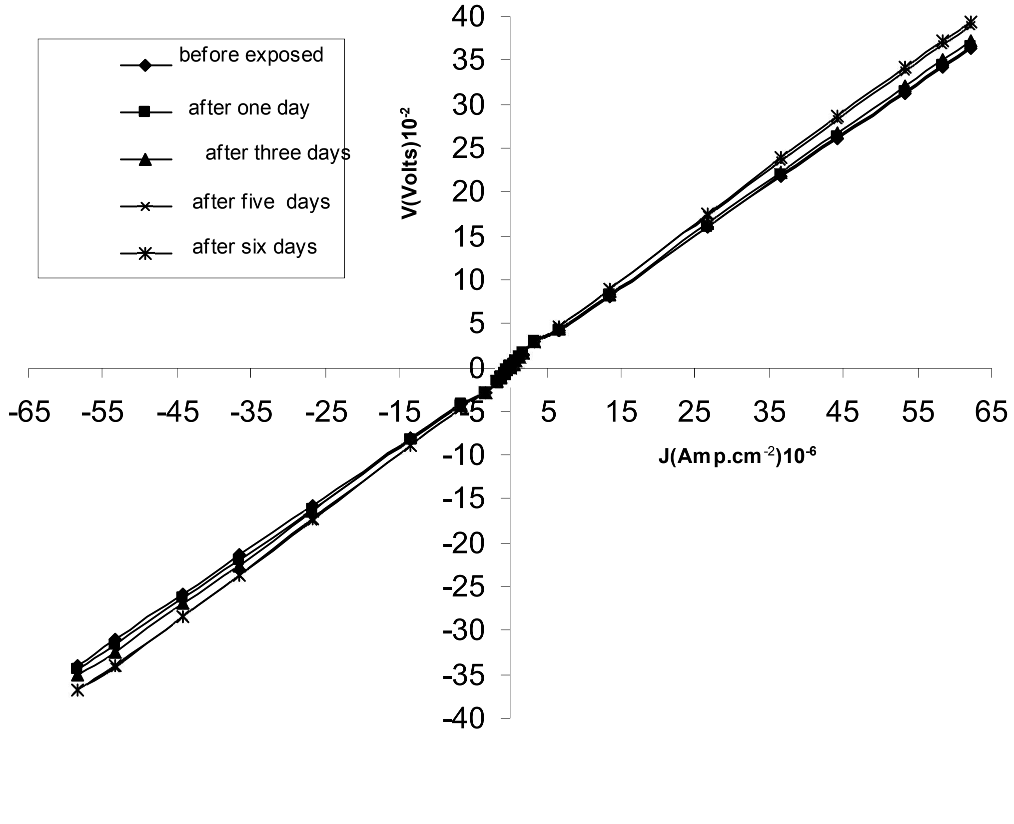

Fig.1 J-V charactristics of lightly (p-n) junction film before and after environmental exposure

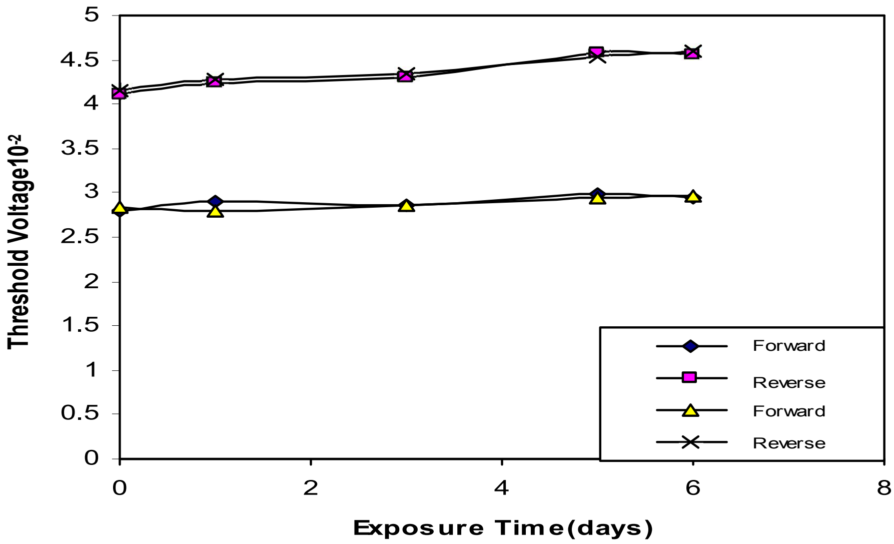

Fig.2 The environmental exposure time against initial and final threshold voltages of lightly p-n film junction

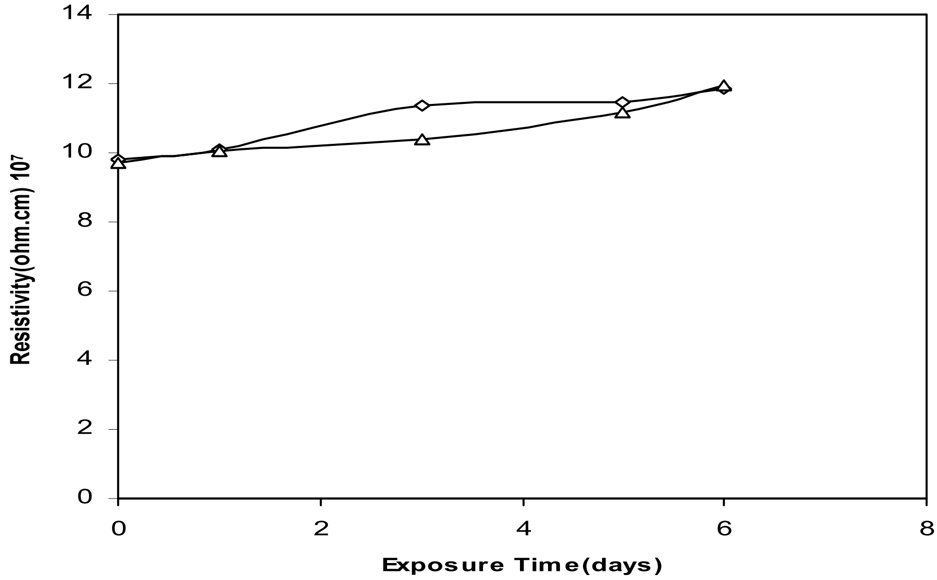

Fig.3 The environmental exposure time against resistivity of lightly p-n film junction in forward◇ and reverse △ bias

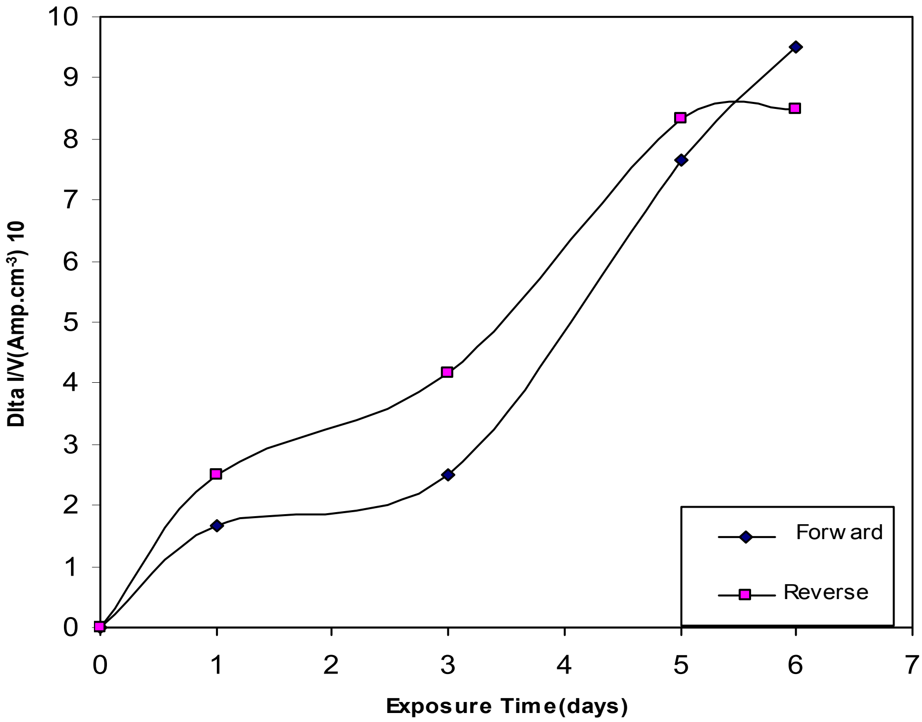

Fig.4 The environmental exposure time against variation in current per volume of lightly p-n nanofilm junction

b- Effect of alpha particles on p-n films:

Fig. 5 shows varying in (J-V) characteristic of exposure to alpha radiation with different doses. The shifting in curve is non-clear because the effect of alpha particle destroy the surface only, however the connections of germanium atoms in spite of containing the dangling bonds inter film, remain without destroy. Also the alpha particles prevent the oxidation the surface of the film. It was observed that the curve is not straight line because of amorphouization and nonhomogenous as result of preparation, however it was exists two threshold voltage values that increase after exposure to alpha particles as shown in Fig.6. Moreover the resistivity of the film was varied after every stage of exposure as shown in Fig.7. The resistivity and damage variation percentages in forward and reverse bias are shown in table 1. The saturation current densities are not appear because of light doping of Al and As in Ge. Point defects (vacancies) have generated continuously until reach saturation defect state, moreover to atmospheric exposure. The damage coefficient decreases after every stage of exposure, or the greatest is in the first stage of exposure. The non-linear of ohmic (J-V) characteristics is attributed to jumping the voltage values or raise resistance at these values. These produce a disordered zones and cascades of clusters. This means that the sites of host and impurity atoms are in dispersion positions due to preparation factors.Fig.8 represents the change of current per unit volume against fleunce ,it was increasing, the slope represents the value of damage coefficient as result to change in current density(D_J) and to change in voltage(D_V).

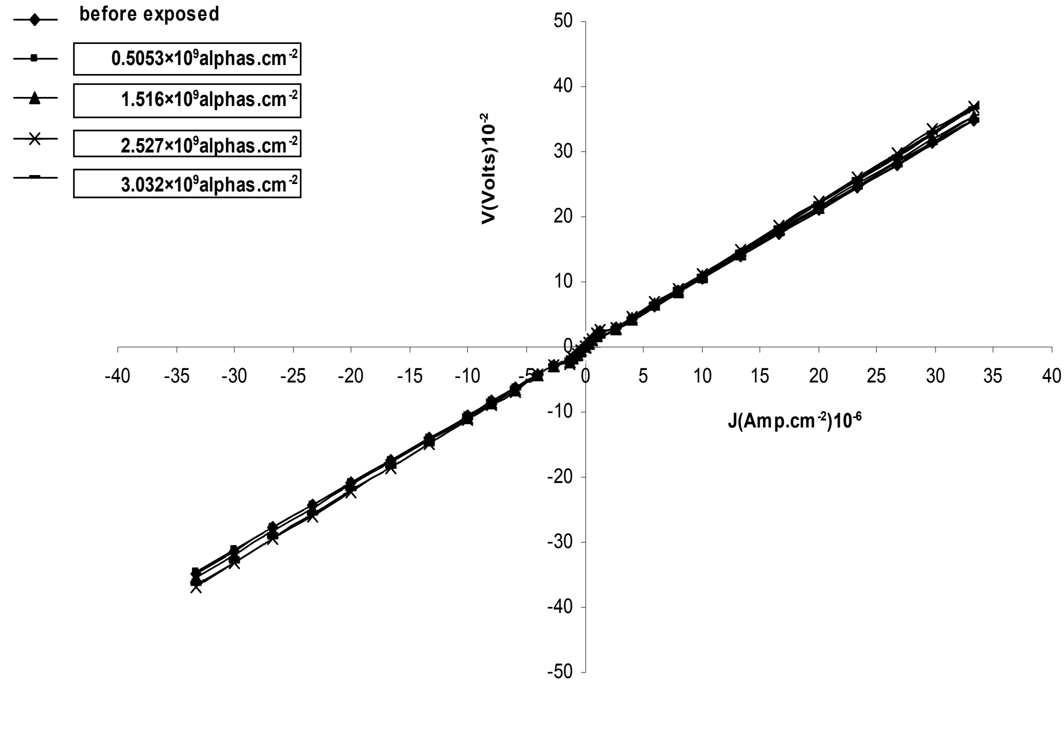

Fig.5 (J-V) charactristics of lightly (p-n) film junction before and after exposed to alpha particles in forward and reverse bias

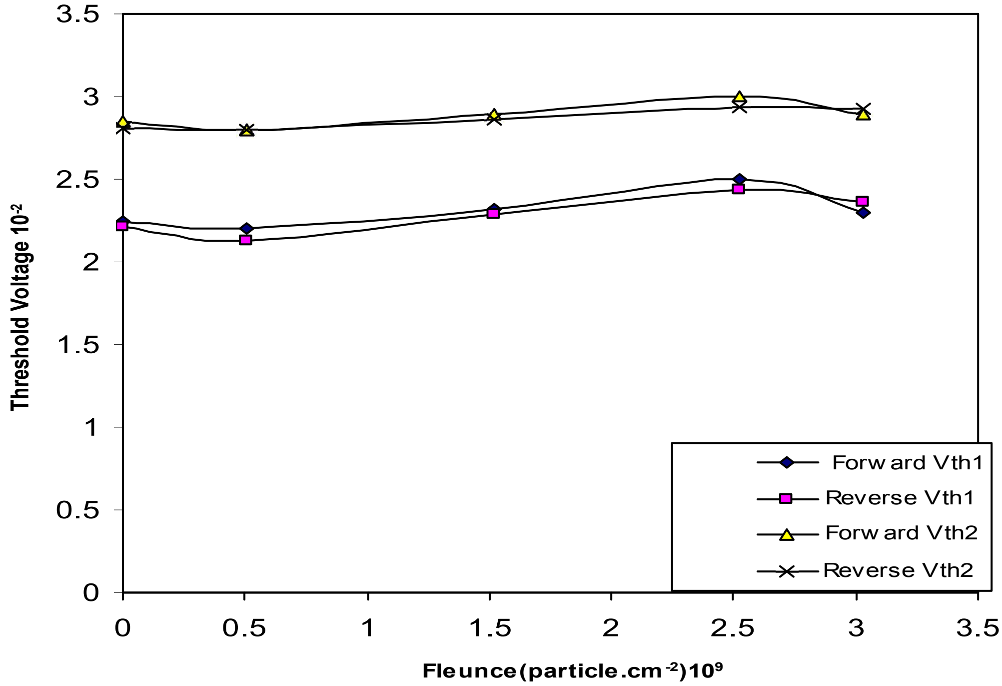

Fig.6 Fleunce of alpha particles against initial and final threshold voltages of lightly p-n film junction in forward and

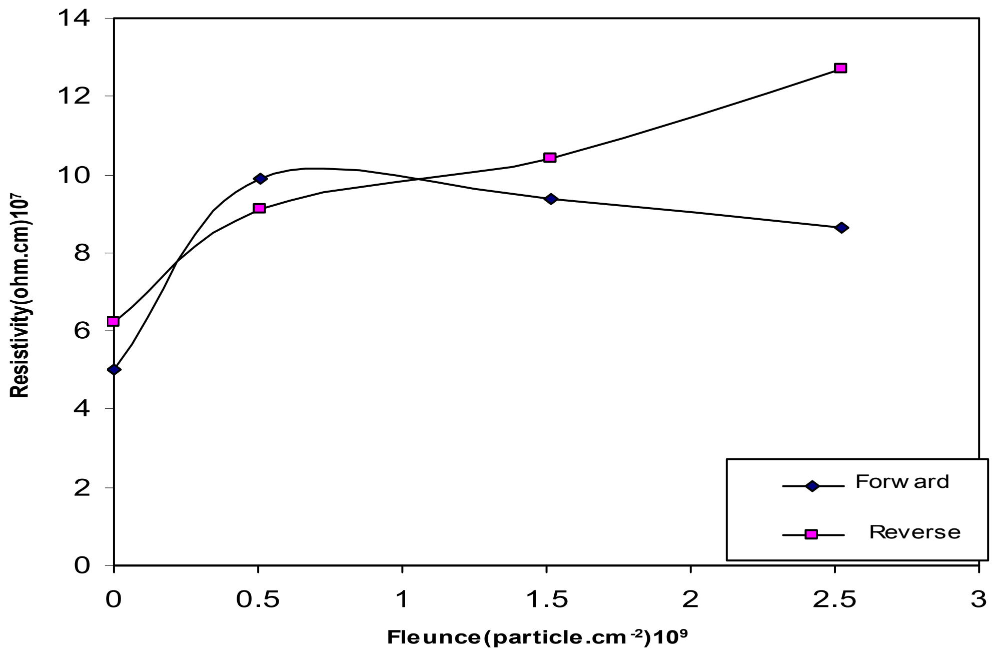

Fig.7 The fluence of alpha particles against resistivity of lightly p-n film junction in forward and reverse bais

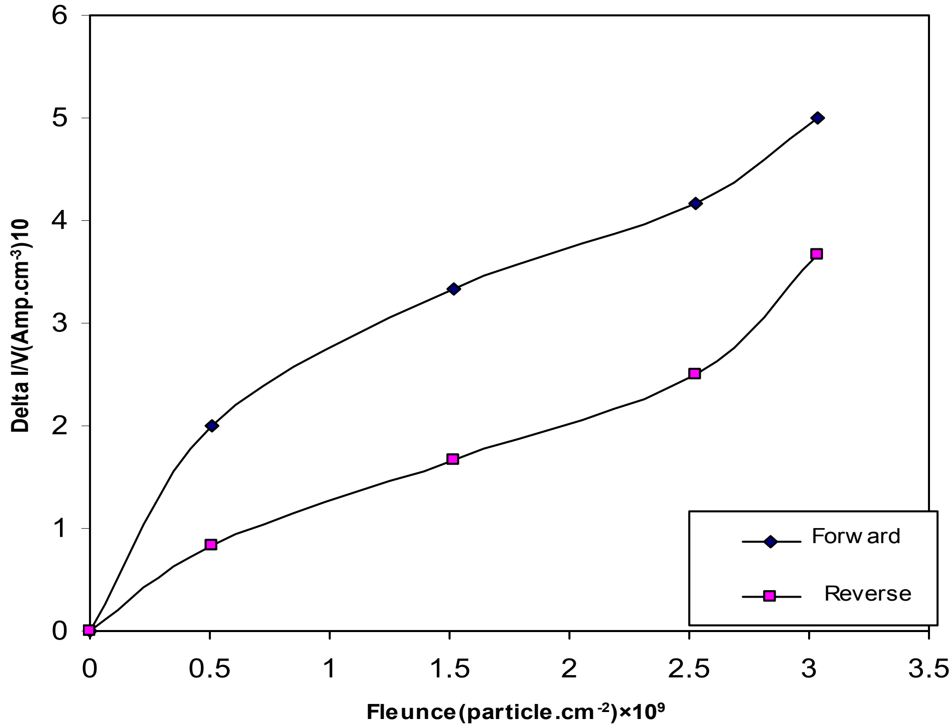

Fig.8 The fluence of alpha particles against variation current per volume of lightly p-n film junction in forward and reverse bais

c- Effect of beta particles on p-n films:

Fig. 9 indicates to (J-V) characteristics before and after different periods of exposure to beta particles. The shifting of the graph is low because of the energetic electrons were transmitted in the film generated point defects, and because of nonhomoginity, there are existing two threshold voltages (initial and final threshold voltages) as shown in Fig.10 , these lead to change in resistivity of the film. The increasing in resistivity as fleunce increase is shown in Fig.11. The resistivity of the film in forward is lower than reverse biases. The variation resistivity percentages increase as fleunce of beta particles increase reach (12.10%) in forward and (7.93%) in reverse bias after the final stage of exposure as shown in table 1.Fig.12 refers to the change in current per volume that increase as the exposed periods of beta increase, or the value of damage coefficient that produced in forward is greater than reverse. This describes from the values of damage percentages is greatest in forward as shown in table1. This is because of defect generation after exposure as result to displaced impurity atom or the host atom on two sides of junction. The partial destroy of potential barrier that is occurred lead to change in resistivity values at second and third stages and hence the film becomes stable for long duration time. The creation of vacancy defects in amorphous structure leads to decreasing donor levels, which trapped donor centers that means decreasing of carrier's contribution.

The occurrence irregular atomic displacements as result to beta particles increase dangling bonds and then more of the amorphouzation. The increasing dangling bonds is weaken the transitions the hole or electron between covalent band to conduction band in light of band model.

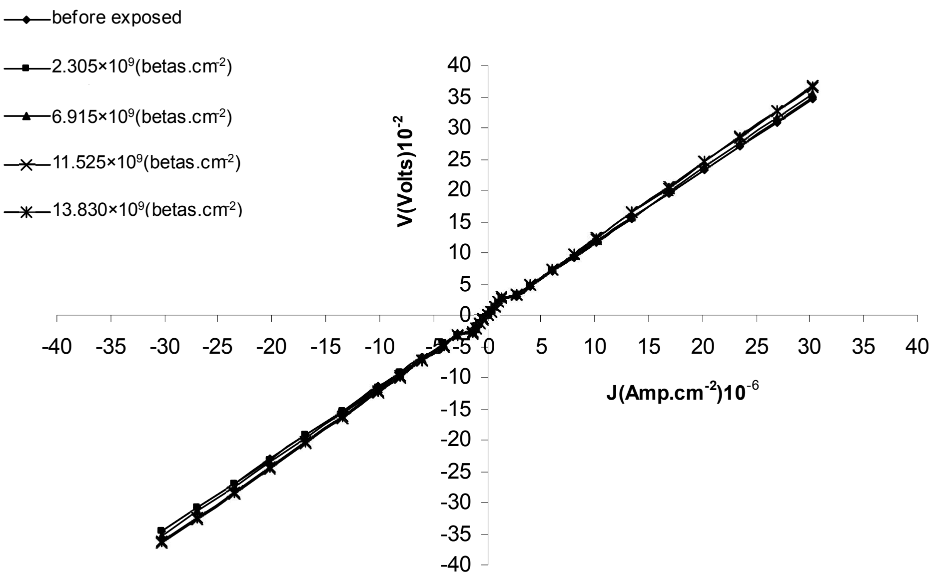

Fig.9 (J-V) charactristics of lightly (p-n) film junction before and after exposed to beta particles in forward and reverse bias

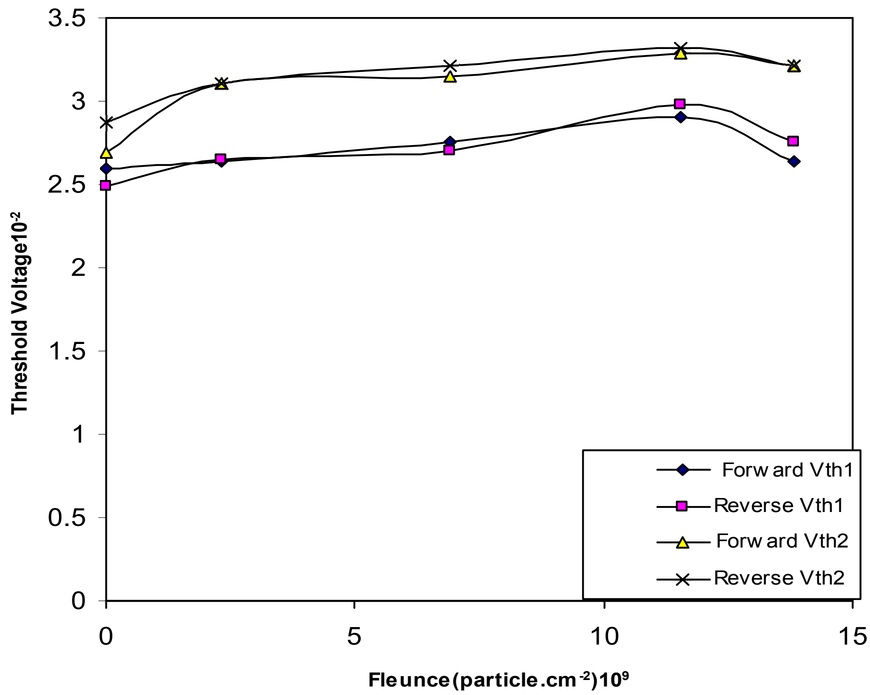

Fig.10 Fleunce of beta particles against initial and final threshold voltages of lightly p-n film junction in forward and

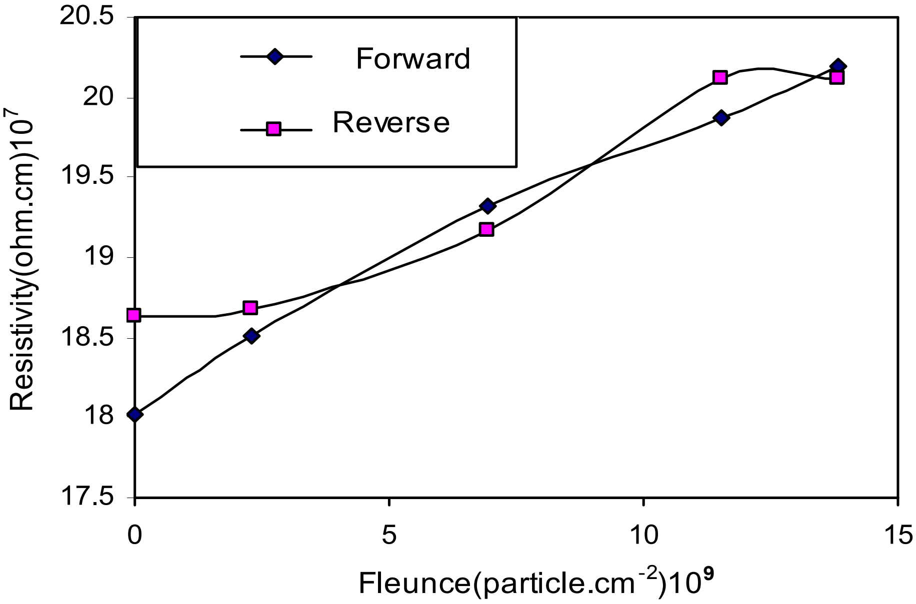

Fig.11 The fluence of beta particles against resistivity of lightly p-n film junction in forward and reverse bias

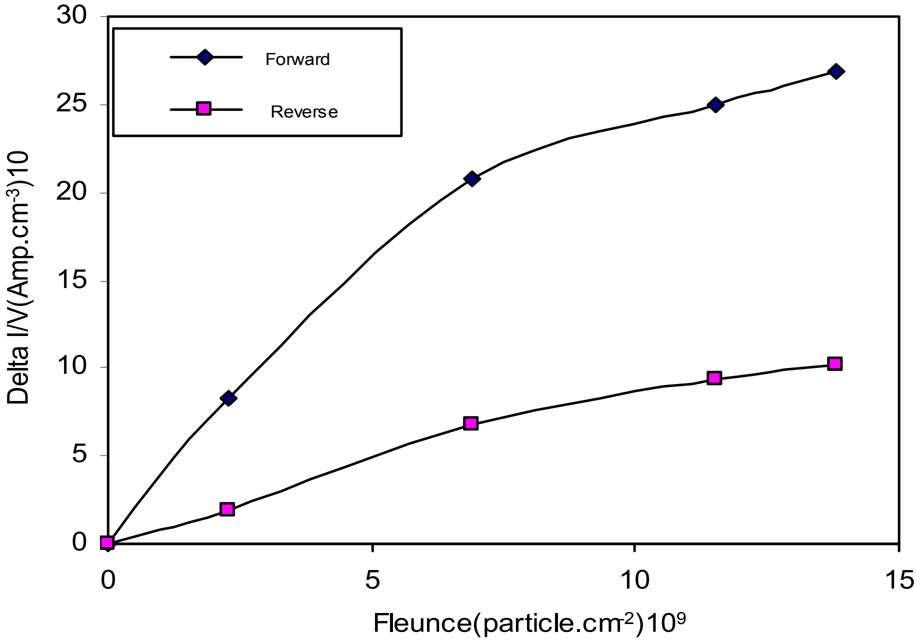

Fig.12 The fluence of beta particles against change in current per unit volume of lightly p-n film junction in forward and reverse bias

5.Conclusions

From the result of the project we can be produce:

1-It is observed that the lightly doped p-n junction film have affected on (J-V) characteristics before exposed to environment, alpha and beta radiation.

2-The shifting in forward bias is more than reverse bias in light p-n junction and effect of alpha is more than beta .

3-The p-n junction film is not have a clear bias, no saturation current and break down voltage in this p-n junction.

4-The resistivity and damage percentages decrease even the final stage of exposure Table1. shows a variation in resistivity ,damage percentages and damage coefficient as result to change in current density and voltage.

Exposure type	Fluency (days)	ρ_o-ρ/ρ_o%		J_o-J/J_o%		D_J 10^{-11} Amp.cm^{-1}		D_V 10^{-11} Amp.cm^{-1}		D_J/D_V	
		F	R	F	R	F	R	F	R	F	R
A.E	1	2.83	3.36	1.70	2.80	-	-	-	-	-	-
	3	15.73	7.03	2.59	4.67	-	-	-	-	-	-
	5	16.93	15.06	7.93	9.35	-	-	-	-	-	-
	6	20.69	23.16	9.83	9.53	-	-	-	-	-	-
Alpha	1	4.41	1.03	3.87	1.66	3.958	1.649	3.690	1.266	1.07	1.30
	3	9.43	5.21	6.45	3.33	2.198	1.099	1.949	1.099	1.13	1.00
	5	15.58	11.23	8.07	5.00	1.649	0.989	1.649	0.989	1.00	1.00
	6	16.22	12.95	9.68	7.30	1.649	1.209	1.649	1.209	1.00	1.00
Beta	1	2.72	2.19	1.75	0.41	0.361	0.0795	0.372	0.0795	0.97	1.00
	3	7.24	2.81	4.39	1.52	0.303	0.0987	0.301	0.0988	1.01	0.99
	5	10.29	7.95	5.26	2.08	0.217	0.0809	0.217	0.0809	1.00	1.00
	6	12.09	7.93	5.65	2.27	0.194	0.0735	0.194	0.7352	1.00	0.99

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