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Effects of Electron Irradiation on GaAs Solar Cells.

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Abstract

The solar cells used in orbit are exposed to radiation environment consists mainly of electrons, protons and neutron. These particles degrade the electrical performance of cells and varying characteristics (current-voltage, form factor, performance ... etc...) phenomenon created by the recombination of defects. The main purpose of this work is to characterize the effects of defects induced by electron irradiation on the IV characteristic of the solar cell and external to its parameters by numerical simulation of a pn solar cell based on GaAs.

Keywords: GaAs solar cell pn, irradiation, defects.

Introduction

The solar cells used in orbit are exposed to an environment radiation consists mainly of electrons, protons and neutrons. These particles degrade the electrical performance of cells and vary characteristics (current-voltage, form factor, performance ... etc.) by the phenomenon of creation of recombination centers. And different mechanisms are at work: the slow performance degradation as a result the ionization dose and dose integrated fault displacement and functional disturbances caused by cosmic rays and protons fast. These variations are disadvantageous; they reduce the current to open circuit and maximum power of the cell and consequently the solar cell efficiency. To predict the effects of deep defects created by electron irradiation, the current-voltage characteristics of a solar cell structure pn based on GaAs irradiated under AM0 illumination for a constant dose of electron irradiation are numerically calculated over the external parameters of the solar cell (density of short circuit current Jsc, open circuit voltage Voc, the factor Form FF and conversion efficiency η) are extracted.

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Nomenclature

Jn,p	Electron and hole conduction current densities
ρ	Space charge
ψ	Electrical potential
ε_0	Permittivity of free space
ε_r	Dielectric constant
E_R	Defect level
E_{fi}	Fermis Level
K_B	Boltzmann constant
T	Temprature
N_R	Defect density
$\mu_{n,p}$	Electron and hole mobilities

1. Nature and properties of defects created by electrons irradiation

The deep levels are due to the presence of impurities, substitutional or interstitial, or defects, or extended-time (dislocation) in the crystal lattice. These energy levels are close to the middle of the band prohibited, are associated with states that can be localized on the surface, volume or interfaces of the structure to be analyzed. These may enter the structure during the growth of the material during the implementation process of the component or even during operation of component (degradation of solar cells). Defects created by irradiation are usually deep levels [1]. A deep defect in a semiconductor can act as a trap, as a center of or as recombination center generation [2]. If a carrier is trapped on one level and if after a time it is retransmitted to capture the band from, the failure is considered a trap. If a carrier of opposite sign is captured before the first reissued, the level is a central recombination. Possible interactions of these deep levels with free carriers are capturing an electron, emitting an electron, and electron trap holes.

2. *Numerical model*

In this work, numerical modeling is used as a means of simulation mode of operation of a GaAs solar cell pn structure in the presence of trap levels. Indeed, the simulation two roles. First, it allows obtaining the external features of the solar cell (current, voltage, efficiency ... ..) to determine parameters (doping, geometry ....) for which the structure will be optimized. On the other hand, it allows obtaining the physical quantities (densities carriers, mobility ... ...) to better understand how internally of the solar cell. The electrical operation of a solar cell is described by three basic equations of physics of semiconductors: Poisson equation (1) and continuity equations of electrons (2) and holes (3). Resolution Digital these partial differential equations nonlinear and coupled their first requires discretization of the field in a simulation appropriate method. This discretization is to replace the problem physical continuous problem discrete digital suited to treatment with computer. We chose the finite difference method for discretization and we imposed boundary on additions. Several methods numerals are used to solve a non-algebraic system linear. Our choice is made on the Newton iterative method for steady. It is a method of solving coupled simultaneously the set of all the equations that define the system (Model) mathematics [3].

$$d^2\psi(x)/d^2x + \rho(x)/\varepsilon_0\varepsilon_r = 0 \quad (1)$$

$$- dJ_n(x)/dx - G(x) + U_R(x)=0 \quad (2)$$

$$- dJ_p(x)/dx - G(x) + U_R(x)=0 \quad (3)$$

With the density of mobile and fixed charges (related to deep defects).

In the case of generation-recombination on deep centers, the recombination rate is given by the SRH model (Schokley-Read-Hall) for single-level defects [4].

$$U_R=[N_R c_n c_p(np-n_i^2)]/[c_n n+c_p n_i \exp(E_{Fi}-E_R/k_B T)+c_p p+c_n n_i \exp(E_R-E_{Fi}/k_B T). \quad (4)$$

Our cell is exposed to the sunlight outside the atmosphere (AM0). So the generation of free carriers G (x) is an optical generation:

$$G(\lambda)=\Sigma_\lambda T\Phi_0(\lambda)\alpha(\lambda).\exp(-\alpha(\lambda)x))+R.\exp(-\alpha(\lambda)(2d-x)) \quad (5)$$

Where Φ_0 (λ) is the flux of incident photons, T is the transmittance of the transparent layer , R the reflectivity of the back contact , α (λ) the absorption coefficient varies with the wavelength of incident light.

3. Results and discussion

After one exposure time to radiations in space, the characteristics of the solar cell: the current of short-circuit, the tension has open circuit, the factor of form and the output, is severely affected.

The radiation is measured by the density of their fluence Φ. The latter is proportional to the density of defects (electron or hole).

We fix the defect density native to 10^{17} cm^{-3} .The defects are introduced one by one (electrons and holes). The energy level of each defect, the cross section and the rate of introduction are represented in Table 1.

Parameters of the traps induced in the solar cell.

Electron defects	**features**		
	Position (E_c-E_t)	***$K(cm^{-1})$***	***$\sigma_n(cm^2)$***
E1	0.14	1.50	1.2 10^{-13}
E2	0.30	0.40	6.2 10^{-15}
E3	0.76	0.08	3 10^{-14}
E4	0.96	0.10	1.9 10^{-12}
Holes Defects	***Position (E_v+E_t)***	***$K(cm^{-1})$***	***$\sigma_p(cm^2)$***
H1	0.29	0.1	5 10^{-15}
H2	0.41	0.1	2 10^{-16}
H3	0.71	0.2	1.2 10^{-14}

In Figure 1 we compare the effect of each defects on the characteristic I (V). In Table 2 presents the external parameters obtained.

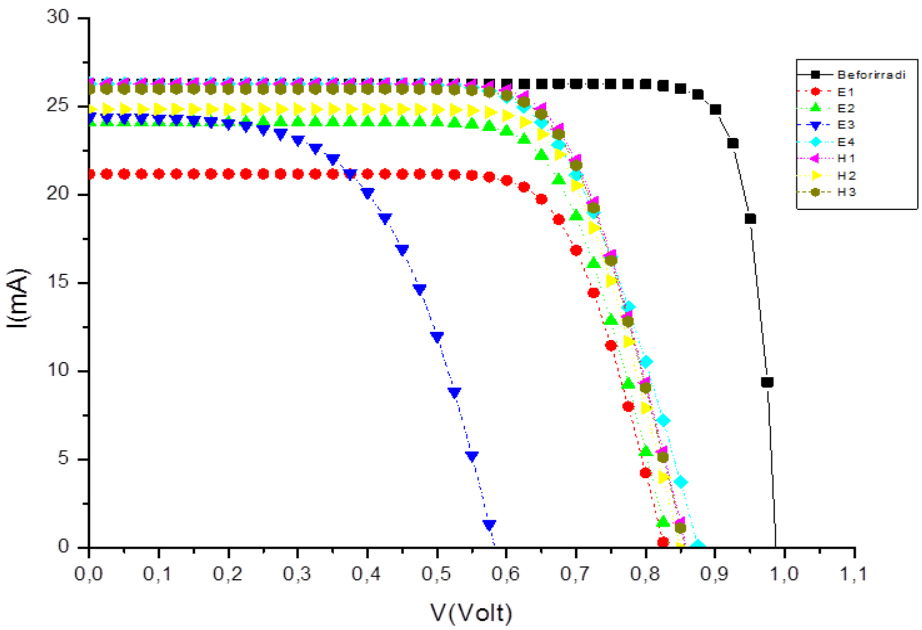

Fig .1 Effect of defects on the characteristic I (V).

Table 2
Effect of defects on the external parameters of the cell.

external parameters	***Jsc(mA)***	***Vco (V)***	***FF***
Before irradiation	26.2725	0.9862	0.8697
E1	21.1539	0.8400	0.6924
E2	24.0807	0.8301	0.7215
E3	24.3983	0.5820	0.5615
E4	26.2711	0.8560	0.7079
H1	26.2645	0. 8551	0.7166
H2	24.8289	0.8480	0.7155
H3	25.9744	0. 8531	0.7154

The deep defects are primarily responsible for the degradation of the solar cell.

4. Conclusion

The changes induced by electron irradiation in the external parameters of the solar cell pn GaAs are taken from the characteristic I (V) calculated by numerical simulation. Electron irradiation creates more defects that act as recombination centers (deep defects) or traps (defects shallower). The effect of each defect on the characteristic I (V) is estimated in order to know which of them are responsible for the degradation of external parameters. It was found that traps electrons affect all external parameters while the hole traps affect the short-circuit. Recombination centers (electrons and holes) primarily affect the open circuit voltage.

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