Journal of Ovonic Research Vol. 17, No. 3, May - June 2021, p. 307 - 311

Effect of proton radiation on the performance ofInGaP/GaAs solar cell

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To understand the effect of radiation on the performance of tandem solar cells based on III-V materials in space and AM0 ; we exposed our solar cell InGaP/GaAs to proton ions radiation with different energy using SRIM simulation software(Stopping and Range of Ions in Matter) [1], and we investigate the effect of proton energy. The I-V characteristics and degradation of the electrical parameters (efficiency EFF; current schourt-circuit Jsc, voltage open-cicuit Vco and FF) are simulated by SILVACO TCAD [2] simulation software before and after irradiation.

(Received March 14, 2021; Accepted June 7, 2021)

Keywords: Proton, Irradiation, Solar cell,InGaP/GaAs, SRIM, SILVACO TCAD

1. Introduction

The advantages of III-V material for space applications are the efficiency of energy conversion more than on 32 % [4] ; the lifetime on orbits on 40-60% more than author material and the output power per square unit on 30% more at the same sun light exposition.

InGaP/GaAs solar cells have been widely used as power sources by space satellites because of their excellent properties such as high quantum efficiency and good irradiation tolerance [5]. As result the more mobile carriers - electrons - are better separated by the p-n junction field . While working in space solar cells are inevitably impaired by variety of irradiations, like electrons, protons and heavy ions, resulting in the degradation of their electrical properties [3]. In particular solar protons (hydrogen ions) cause heavy damage, which is represented in the occurrence of large vacancies in crystalline structure. After a period of time and under space radiation.

2. Simulations softwares

This work based on tow simulation software's, to simulate proton irradiation, we use SRIM(Stopping and range of ions in matter) which can represent the radioactive environment ofspace (protons radiation) then we use SILVACO TCAD to in vestigate the performance of the solar cell under the effect of proton irradiation, this lead to review how the charged particles (protons) irradiation will influence on solar cell proprieties, and how can were duce this influence that can we abbreviate it as crystalline structure damage.

3. Effect the proton Radiation on target InGaP/GaAs solar cell using SRIM simulation software

Stopping and Range of Ions in Matter (SRIM) is a group of computer programs thatcalculate interaction of ions with matter; the core of SRIM is a program Transport of ions in

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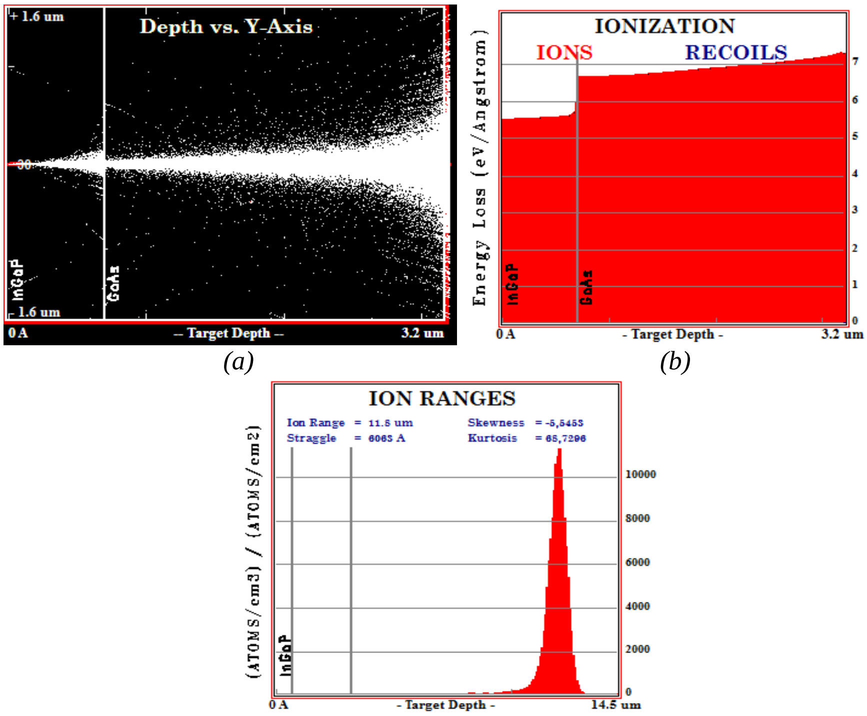
matter (TRIM), SRIM is popular in the ion implantation research and technology community and used widely in other branches of radiation material science.

SRIM is based on a method; as the input parameters, it needs the ion type and energy (inthe range 10 eV – 2 GeV) and the material of one or several target layers.

We exposed this sample solar cell InGaP /GaAs to protons irradiation with different energies 300,700 and 1000 keV of irradiation energy exposing, the proton flux was set as 1010 cm-2 and the sample has area of 10µm2 with AM0

3.1. Results and observations

The simulation results obtained for the 0.7 µm InGaP / 2.5 µm GaAs cell show that hydrogen ion path more than 3.2 µm from the top surface of the cell. the incident energy of the protons is 1Mev; energy lost 6.5 ev in the InGaP emitter and 7 ev in the GaAs base, the collision density created in this case is $42x10^{-5}$.



(a) *(b)*

(c)

Fig. 1.SRIM simulation of InGaP/GaAs solar cell irradiated by proton; (a) Target Depth, (b) Ionisation, (c) Ion Ranges.

Table 1. SRIM results of InGaP/GaAs.

Fluence	Energy	Ionisation	Collision	Depth
10^{10}	300 kev	19.7 ev/a	$5.1x10^{-4}$	2.3 um
10^{10}	700 kev	15.2 ev/a	$4.5x10^{-4}$	6.1 um
10^{10}	1 Mev	12.5 ev/a	$4.2x10^{-4}$	11.8 um

We can note that the depth is minimum for the proton energy of 300 kev and reach the maximum value of 11.8 µm for high energy irradiation. while ionization and energy loss is maximum for low energy. the collision phenomenon is inversely proportional to the irradiation energy.

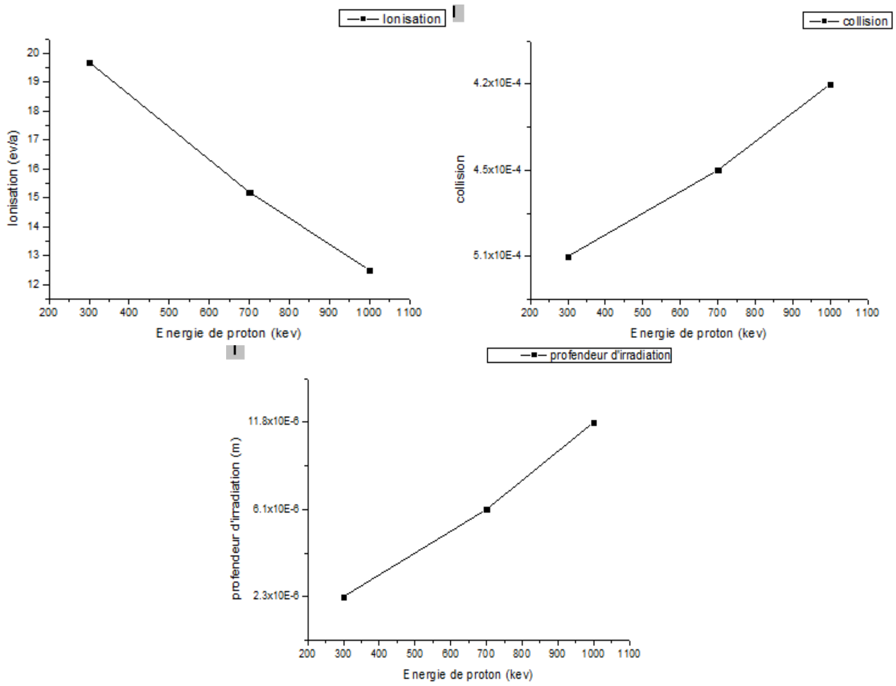


Fig. 2. Ionization, collision and irradiation depth of a 10^{10} proton fluence for several energies 300 kev, 700kev and 1Mev.

4. Effectof proton Radiation on the performances of InGaP/GaAs tandem solar cell using SILVACO TCADsimulation Software

Numerical simulations of solar cells represent important tools for research and development because they can allow investigation of a much wider parameter space at a fraction of the cost and time of experimental studies.

SILVACO, ATLAS used for simulation. BLAZE is a general-purpose 2-D device simulator for III-V, II-VI materials, and devices with position dependent band structure (i.e., heterojunction) [6][8]. The simulator works on mathematical models which consist of fundamental equations such as Poisson's equation, continuity equation, and transport equations. A simulation program for proposed p-InGaP/n-GaAs heterojunction solar cell structure has developed in ATLAS simulator from SILVACO international to obtain various electrical and optical characteristics.

4.2. Structure and simulation model

It consisted of two solar cells where the InGaP wide band gap top cell had a small thickness and a large band gap (Eg=1.74 eV) in contrast to the GaAs low band-gap bottom cell [8], which had a usual thickness for a GaAs cell and a band- gap value (Eg=1.42 eV) close to the optimal values of best cells [7]. This design is intends to convert a wider range of photons incident on the solar cell and generate therefore a maximum power output.

The InGaP top cell connected to the GaAs bottom cell by a tunnel hetero-junction (p+GaAs /n+ GaAs). The schematic diagram of the solar cell structure represented in Fig 3.

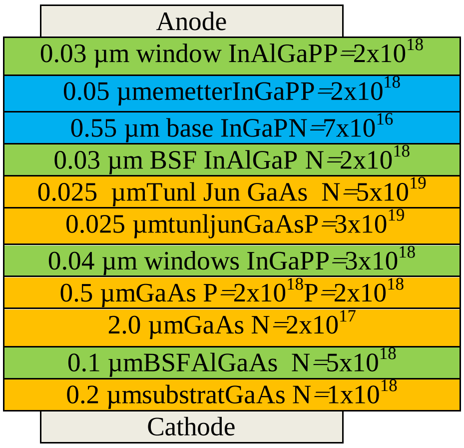


Fig.3. The schematic diagram of the solar cell structure

4.1. Results and observations

4.1.1. I-V parameter without defects

From our simulation, the following profile of The IV curves for GaInP/GaAsmultijunction solar cell without defectare formed by TonyPlot in Fig. 4.

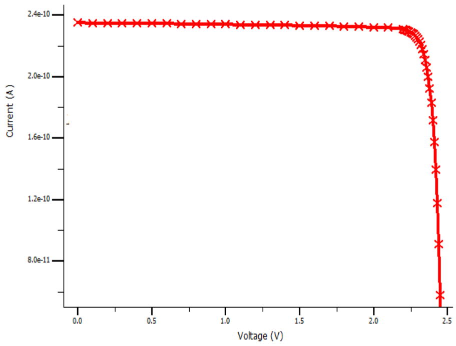


Fig. 4.I-V caracteristique of the InGaP/GaAs without defect.

Table1. Calculated parameter of InGaP/GaAs without defect.

Jsc: 23.5068 mAcm2	Voc:2.4636 v	FF:89.2541	EFF:37.4421%

4.1.2. I-V paramètrewith défects in the top cell InGaP/GaAs

This part present defect effect in the top cell InGaP, the simulationresults formed by tony plot given in the Fig. 5.

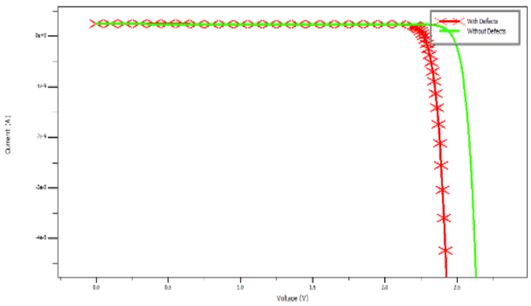


Fig. 5.Defect effect in the top cell InGaP

Table 5.Top cell Defect effect in the parameterofInGaP/GaAs.

	Jsc (mAcm^2)	**Voc (v)**	**FF**	**EFF (%)**
InGaP/GaAs Without defect	23.5068	2.4636	89.5241	37.4421
InGaP/GaAs With defect	23.5498	2.2695	90.6882	35.1114

4. Conclusions

Irradiation by proton in space degrade solar cell ; the proton low enrgy have minimum depth in cell but the proton with high energy have maximum depth in solar cell , the fluency of proton have effect in ionization and collision.

The I–V characteristics of the InGaP/GaAs solar cell simulated under AM0 before and afterproton irradiation , as we found, that the parameter of solar cell degraded after irradiation ; to understand that the relationship between protons radiation and the resulting parameter and damage is not always positive, we can define a defects parameter (NT,EGT,SIG,....) and a defect position (Top cell, tunnel cell,...) that should be presented as the most influential on the performance of certain solar cells.

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